

2 CLIMATE VULNERABILITY MONITOR

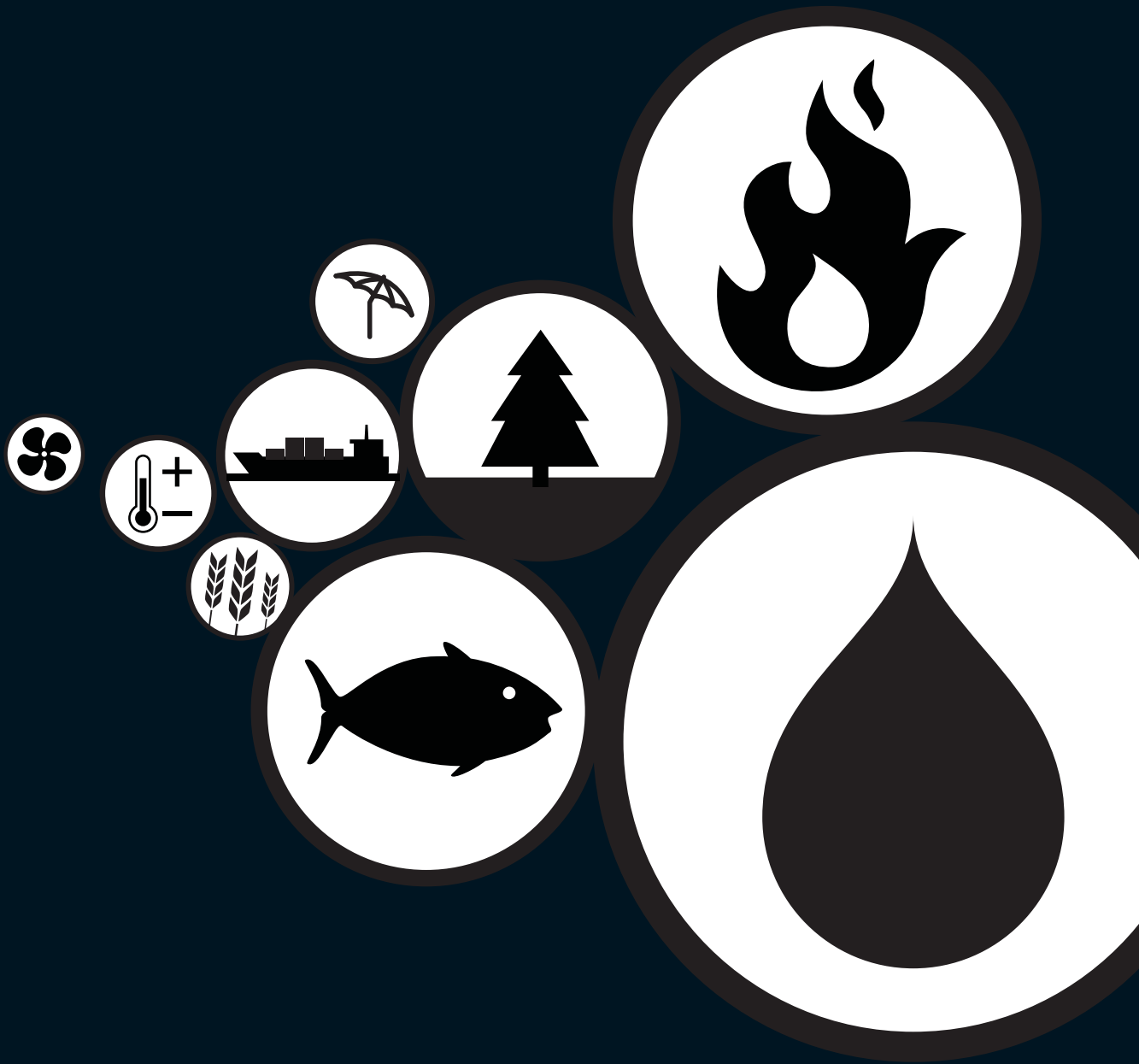
NO
EDITION

A GUIDE TO THE COLD CALCULUS OF A HOT PLANET



Climate Vulnerable Forum





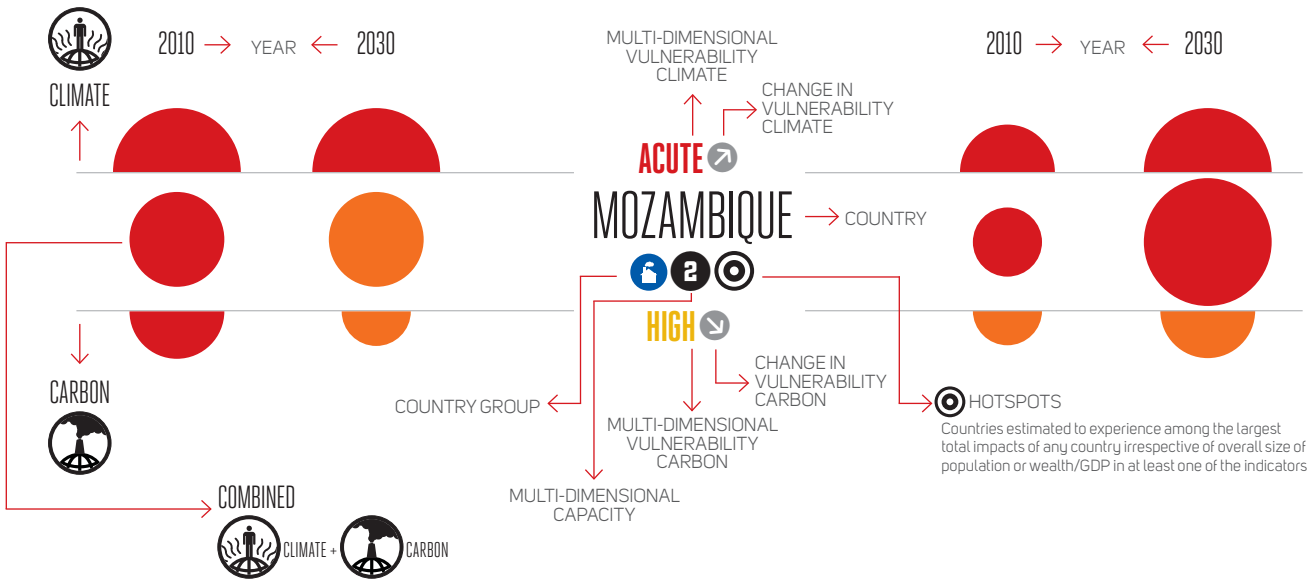
KEY TO THE MONITOR



DEATHS



ECONOMIC COST



VULNERABILITY

- ↗ INCREASING
- STABLE
- ↘ DECREASING
- ACUTE
- SEVERE
- HIGH
- MODERATE
- LOW

COUNTRY GROUPS

- 🏭 DEVELOPED
- 🏭 OTHER INDUSTRIALIZED
- 🌐 DEVELOPING COUNTRY HIGH EMITTERS
- 🌐 DEVELOPING COUNTRY LOW EMITTERS

MULTI-DIMENSIONAL CAPACITY

- 4 EXTENSIVE
- 3 INTERMEDIARY
- 2 RESTRICTED
- 1 HIGHLY RESTRICTED

ACUTE +

ACUTE -

SEVERE +

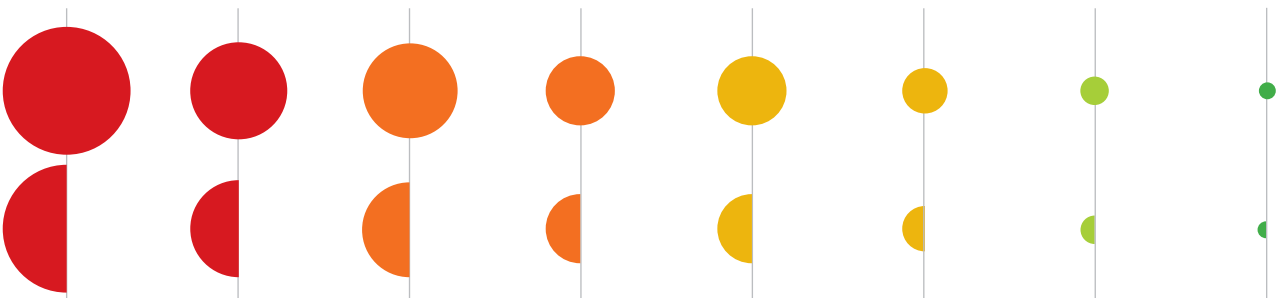
SEVERE -

HIGH +

HIGH -

MODERATE

LOW



COUNTRY GROUPS

List of countries by main Monitor country groups

DEVELOPED (ANNEX II)

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States

OTHER INDUSTRIALIZED (ANNEX I OUTSIDE OF ANNEX II)

Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Russia, Slovakia, Slovenia, Turkey, Ukraine

DEVELOPING COUNTRY HIGH EMITTERS (NON-ANNEX I ABOVE 4 TONS CO₂E 2005)

Algeria, Antigua and Barbuda, Argentina, Azerbaijan, Bahamas, Bahrain, Belize, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei, Bulgaria, Cambodia, Central African Republic, Chile, China, Congo, Cyprus, DR Congo, Equatorial Guinea, Gabon, Grenada, Guatemala, Guinea, Guyana, Indonesia, Iran, Iraq, Israel, Kazakhstan, Kuwait, Laos, Libya, Macedonia, Malaysia, Mexico, Mongolia, Myanmar, Namibia, North Korea, Oman, Papua New Guinea, Paraguay, Qatar, Saudi Arabia, Seychelles, Singapore, Solomon Islands, South Africa, South Korea, Suriname, Thailand, Trinidad and Tobago, Turkmenistan, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Zambia

DEVELOPING COUNTRY LOW EMITTERS (NON-ANNEX I BELOW 4 TONS CO₂E 2005)

Afghanistan, Albania, Angola, Armenia, Bangladesh, Barbados, Benin, Bhutan, Burkina Faso, Burundi, Cape Verde, Chad, Colombia, Comoros, Costa Rica, Cuba, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Fiji, Gambia, Georgia, Ghana, Guinea, Guinea-Bissau, Haiti, Honduras, India, Jamaica, Jordan, Kenya, Kiribati, Kyrgyzstan, Lebanon, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Micronesia, Moldova, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Palau, Panama, Peru, Philippines, Rwanda, Saint Lucia, Saint Vincent, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sri Lanka, Sudan/South Sudan, Swaziland, Syria, Tajikistan, Tanzania, Timor-Leste, Togo, Tonga, Tunisia, Tuvalu, Uganda, Vanuatu, Vietnam, Yemen, Zimbabwe

2 **CLIMATE VULNERABILITY MONITOR**

NO
EDITION

A GUIDE TO THE COLD CALCULUS OF A HOT PLANET

DARA and the Climate Vulnerable Forum
Climate Vulnerability Monitor 2nd Edition.
A Guide to the Cold Calculus of a Hot Planet

This book was set in Heroic Condensed, Franklin Gothic and Uni Sans

Graphic Design: wearebold.es

Icons inspired in The Noun Project collection

Photographs: Thinkstock/Getty Images

Includes bibliographical references

ISBN: 978-84-616-0567-5

(paper: offset 120 gr., interior; couché semimate 300 gr., cover)

LD: M-31813-2012

First published 2012

Copyright © Fundación DARA Internacional 2012

All rights reserved. No reproduction, copy or transmission
of this publication may be made without written permission.

Printed and bound in Spain by Estudios Gráficos Europeos, S.A.

HEADQUARTERS

Felipe IV, 9 – 3 Izquierda
28014 Madrid – Spain
Phone: +34 91 531 03 72
Fax: +34 91 522 0039
cvm@daraint.org
www.daraint.org

GENEVA OFFICE

International Environment House 2/MIE2
7-9 Chemin de Balexert
Châtelaine CH-1219 Geneva – Switzerland
Phone: +41 22 749 40 30
Fax: +41 22 797 40 31

DEDICATED TO THE INNOCENT VICTIMS OF CLIMATE CHANGE

“**A GREAT DEAL** has been written on the influence of the absorption of the atmosphere upon the climate.. Another side of the question that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? (..) If the quantity of carbonic acid [CO₂] decreases from 1 to 0.67, the fall of temperature is nearly the same as the increase in temperature if this quantity augments to 1.5. And to get a new increase of this order of magnitude (3-4°C), it will be necessary to alter the quantity of carbonic acid till it reaches a value nearly midway between 2 and 2.5.”

SVANTE AUGUST ARRHENIUS

April 1896

The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science

“**FEW OF THOSE** familiar with the natural heat exchanges of the atmosphere, which go into the making of our climates and weather, would be prepared to admit that the activities of man could have any influence upon phenomena of so vast a scale.. I hope to show that such influence is not only possible, but it is actually occurring at the present time.”

GUY STEWART CALLENDAR

April 1938

Quarterly Journal of the Royal Meteorological Society

“**IF AT THE END** of this century, measurements show that the carbon dioxide content of the atmosphere has risen appreciably and at the same time the temperature has continued to rise throughout the world, it will be firmly established that carbon dioxide is an important factor in causing climatic change.”

GILBERT NORMAN PLASS

May 1956

American Journal of Physics

“THE EARTH’S CLIMATE
system has demonstrably
changed on both global
and regional scales since
the pre-industrial era.. The
atmospheric concentrations
of key anthropogenic
greenhouse gases (i.e.,
carbon dioxide (CO₂)..)
reached their highest
recorded levels in the 1990s.”

THE INTERGOVERNMENTAL
PANEL ON CLIMATE CHANGE
September 2001

“A HUNDRED YEARS
from now, looking
back, the only question
that will appear
important about the
historical moment in
which we now live
is the question of
whether or not we
did anything to arrest
climate change.”

THE ECONOMIST
December 2011

COLLABORATORS

ADVISORY PANEL



MARY CHINERY-HESSE, Member of the Panel of the Wise of the African Union; Chief Advisor to the Former President of Ghana; Former Deputy Director-General of the International Labour Organization (ILO)

HELEN CLARK, Administrator, United Nations Development Programme (UNDP)

JOSÉ MARÍA FIGUERES, Former President of Costa Rica; Chairman of the Carbon War Room

ROBERT GLASSER, Secretary General, CARE International, Geneva

SALEEMUL HUQ, Director, International Institute for Environment and Development (IIED), Independent University, Dhaka

YOLANDA KAKABADSE, International President, WWF

ASHOK KHOSLA, President, International Union for Conservation of Nature (IUCN); Chairman of Development Alternatives, Co-Chair of the UN Resources Panel

RICARDO LAGOS, Former President of Chile; Former President of the Club of Madrid

LOREN LEGARDA, Senator of the Philippines; UN International Strategy for Disaster Reduction (ISDR) Regional Champion for Disaster Risk Reduction and Climate Change Adaptation for Asia and the Pacific

MICHAEL MARMOT, Director, International Institute for Society and Health, University College, London

SIMON MAXWELL, Executive Chair, Climate and Development Knowledge Network (CDKN)

DAVID NABARRO, Special Representative of the UN Secretary-General for Food Security and Nutrition

ATIQ RAHMAN, Executive Director, Bangladesh Centre for Advanced Studies (BCAS), Dhaka

TERESA RIBERA, Former Secretary of State for Climate Change of Spain

JOHAN ROCKSTRÖM, Executive Director, Stockholm Environment Institute (SEI) and Stockholm Resilience Centre

JEFFREY SACHS, Director, The Earth Institute, Columbia University, New York

HANS JOACHIM SCHELLNHUBER, Founding Director of the Potsdam Institute for Climate Impact Research (PIK)

JAVIER SOLANA, President, ESADE Center for Global Economy and Politics; Distinguished Senior Fellow, Brookings Institution; Chairman, Aspen Institute España

ANDREW STEER, President, World Resources Institute, Washington, D.C.

MARGARETA WAHLSTRÖM, United Nations Assistant Secretary-General for Disaster Risk Reduction

MICHAEL ZAMMIT CUTAJAR, Former Executive Secretary, United Nations Framework Convention on Climate Change (UNFCCC)

PEER REVIEW COMMITTEE



YASEMIN AYSAN, Former Under Secretary General, International Federation of Red Cross and Red Crescent Societies (IFRC)

SURUCHI BHADWAL, Associate Director, Earth Sciences and Climate Change Division, The Energy and Resources Institute (TERI), New Delhi

DIARMID CAMPBELL-LENDRUM, Senior Scientist, Public Health and Environment, World Health Organization (WHO)

MANUEL CARBALLO, Executive Director, International Centre for Migration, Health and Development (ICMHD), Geneva

IAN CHRISTOPLOS, Senior Project Researcher, Danish Institute for International Studies (DIIS), Copenhagen

JOSHUA COOPER, Director, Hawaii Institute for Human Rights

MARIANE DIOP KANE, Head of Forecasting, Agence Nationale de la Météorologie du Sénégal (ANAMS)

SEAN DOOLAN, Climate Change & Environmental Governance Advisor, United Kingdom Department for International Development (DfID), Ghana

PIERRE ENCONTRE, Chief, Special Programmes, Division for Africa, Least Developed Countries and Special Programmes, UN Conference on Trade and Investment (UNCTAD)

HANS-MARTIN FÜSSEL, Project Manager for Climate Impacts, Vulnerability, and Adaptation at the European Environment Agency (EEA)

TIM GORE, International Policy Advisor for Climate Change, Oxfam International Advocacy Office, New York

ANNE HAMMILL, Senior Researcher, Climate Change and Energy, International Institute for Sustainable Development (IISD), Geneva

RANDOLPH KENT, Director, Humanitarian Futures Programme, King's College, London

TORD KJELLSTROM, Senior Professor, Department of Public Health and Clinical Medicine, Umea University; Visiting Fellow, Honorary Professor, Australia National University, Canberra, and University College, London

ISABEL KREISLER, Climate Policy Specialist, Environment and Energy Group, Bureau for Development Policy, Bureau for Development Policy, United Nations Development Programme (UNDP)

JUERGEN KROPP, Head, North-South Research Group, Potsdam Institute for Climate Impact Research (PIK)

ALLAN LAVELL, Coordinator, Programme for Disaster Risk Management, Secretary General's Office, Latin America Social Science Faculty (FLASCO), San José

MARC LEVY, Deputy Director, Center for International Earth Science Information Network (CIESIN), Earth Institute at Columbia University, New York

FILIFE LÚCIO, Head of the Global Framework for Climate Services, World Meteorological (WMO)

URS LUTERBACHER, Chairman, Environmental Studies Unit, Graduate Institute of International and Development Studies, Geneva

STEERING GROUP



ANDREW MASKREY, Coordinator, Global Assessment Report (GAR), UN International Strategy for Disaster Reduction (UNISDR)

BENITO MÜLLER, Director Energy and Environment, Oxford Institute for Energy Studies

MICHELE DE NEVERS, Visiting Senior Associate, Center for Global Development, Washington, D.C.

MARTIN PARRY, Fellow, Grantham Institute for Climate Change, Imperial College, London

JAMES ROOP, Climate Change Advisor for Asia and Pacific, Climate Change Branch, AusAID

BEN RAMALINGAM, Visiting Fellow, Institute of Development Studies (IDS) and Research Associate, Overseas Development Institute (ODI), London

CARLO SCARAMELLA, Coordinator, Office for Climate Change, Environment and Disaster Risk Reduction, UN World Food Programme (WFP)

MATTHIAS SCHMALE, Under Secretary General, National Society and Knowledge Development, International Federation of Red Cross and Red Crescent Societies (IFRC)

HANSJOERG STROHMEYER, Chief, Policy Development and Studies Branch, UN Office for the Coordination of Humanitarian Affairs (OCHA)

FARHANA YAMIN, Research Fellow, Institute of Development Studies, Brighton

CO-CHAIRS

ROSS MOUNTAIN, Director General, DARA

SUFIUR RAHMAN, Director General, Economic Affairs, Ministry of Foreign Affairs, Bangladesh

MEMBERS

JAVIER DÍAZ CARMONA, Ambassador for Climate Change and Global Environmental Affairs, Costa Rica

SALAHUDDIN NOMAN CHOWDHURY, Director, Economic Affairs, Ministry of Foreign Affairs, Bangladesh

MATTHEW MCKINNON, Head of Climate Vulnerability Initiative, DARA

EDITORIAL AND RESEARCH TEAM



EDITOR

Matthew McKinnon

PROJECT COORDINATOR

Lucía Fernández Suárez

PRINCIPAL PROJECT ADVISOR

Søren Peter Andreasen

LEAD TECHNICAL RESEARCHERS

Beatriz Asensio (Coordination)
Cristian Conteduca (Modeling)
Dominik Hülse (Quantitative)

TECHNICAL ADVISOR

Peter Utzon Berg

SENIOR AID ADVISOR

Magda Ninaber van Eyben

FIELD STUDIES COORDINATOR

Belén Paley

COUNTRY STUDY RESEARCHERS

Nguyen Huong Tra
Nguyen Quang Thanh
Nguyen Thuy Hang
Emmanuel Tachie-Obeng
Tran Chung Chau

RESEARCH ASSISTANTS

Daniel Barnes (Coordination)
Johanna Barth
Rachel Clancy
Ana Chamberlain
Bosco Lliso
Abby Moran
Rachad Nassar
Jenena Oliver
Ana Rodríguez Seco
Emily Schuckert

PUBLICATION MANAGER

Rebecca B. Moy

COMMUNICATIONS AND VISUALS

Fiona Guy (Advisor)
Christina Samson
Nacho Wilhelm
Begoña Yagüe

GRAPHIC DESIGNERS

Mariano Sarmiento (Lead)
María Lasa
Ruth Otero
Marta San Marín


COPYEDITING

Morwenna Marshall
Tim Morris

The Advisory Panel and the Peer Review Committee members serve in their personal capacity, providing input to the Climate Vulnerability Initiative that informs the development of the Climate Vulnerability Monitor. DARA is solely responsible for the final content of this report.

PREFACE

THIS REPORT CHALLENGES A CONVENTIONAL VIEW: THAT GLOBAL ACTION ON CLIMATE CHANGE IS A COST TO SOCIETY. INSTEAD, IT ENLIGHTENS OUR UNDERSTANDING OF HOW TACKLING CLIMATE CHANGE THROUGH COORDINATED EFFORTS BETWEEN NATIONS WOULD ACTUALLY PRODUCE MUCH-NEEDED BENEFITS FOR ALL.



Climate change is already with us. It kills. It steals livelihoods. And it takes the most from those who have the least. But the costs are largely hidden from our understanding. Inaction on climate change actually takes from us all. Only together can we plot a different course: one of greater prosperity and well-being. Technical barriers no longer hold back our transition to a low-carbon world, and technological solutions exist to manage risks. We struggle instead with other barriers. There are political barriers: while some countries are committed to change and making progress, there is still a lack of conviction among the governments of too many industrialized and developing nations. Social and cultural barriers also exist: lack of understanding causes popular indifference or even hostility to sensible change. And financial barriers mean that only a fraction of the resources needed for low-carbon development and to support worst-hit communities are being made available. To tackle all these barriers, 20 countries highly vulnerable to climate change came together to form the Climate Vulnerable Forum. Our countries favour action on climate change. We are frustrated with the inadequacy of the global response and a world economy that continues to price carbon irresponsibly. We bear witness to the extremes at the climate frontlines of today. Despite having contributed the least to climate change, we are forced, almost unaided, to take costly measures to protect our people and our economies. We know the world is rapidly becoming more not less vulnerable, and that all our fates are tied.

"Many Forum governments are already embracing the call to action: Bangladesh has committed never to exceed the average per capita emissions of the developing countries. Costa Rica aims to be carbon neutral by 2021. But there are limits to what individual countries can achieve."

Farmers face more hot days as they set to work. Families are sleeping outside in mosquito-infested areas because their homes are unbearable in the heat of the night. Roads and buildings on permanently frozen land in the cooler regions are being damaged as melting sets in. Rivers are drying up, causing transport shocks, while unprecedented floods are devastating other areas. Salt from rising seas harms fertile land and fresh water supplies. Coastlines erode. Land is submerged. Populations fail to make a living. People move. Pollution also kills. It acidifies lakes and oceans, poisons plants and animal life, corrodes infrastructure and contaminates the air we breathe. We pay for each of these damages in lives, suffering and dollars. Yet the world has struggled to see how all these concerns are interlinked. That is why this report has sought to tackle our knowledge barriers. With a better understanding of the full array of issues and the causes behind them, nobody should remain indifferent or inactive.

The Climate Vulnerable Forum commissioned this second Climate Vulnerability Monitor at its Ministerial Meeting at Dhaka in November 2011. The report was again mandated to DARA for independent development and was reviewed by an external Advisory Panel and Peer Review Committee comprised of international authorities on this subject.

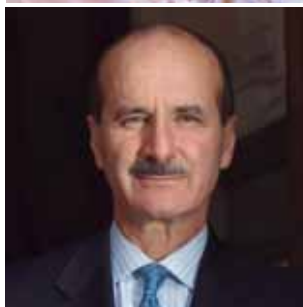
Against a struggling world economy, its main findings offer sobering news: climate change is already lowering economic output globally and will increasingly hold back growth – unless strong action is urgently taken. Its pages seek to move us to act by highlighting the

SHEIKH HASINA

Prime Minister of Bangladesh

JOSÉ MARÍA FIGUERES

Trustee of DARA, Former President of Costa Rica



human plight of an increasingly hotter and more polluted planet. Severe impacts on livelihoods, health and the world's poorest groups speak of fundamental injustices that simply cannot go unaddressed. The report relies on the incredible wealth of some of the most recently published research and scientific knowledge, assimilating literally hundreds of studies and bodies of data into a common framework that makes its collective meaning clear. More research is plainly needed and will continuously enrich our understanding, but improving knowledge should not be a premise to refrain from acting when so much is at stake.

In the past, humanity has prevailed against recognized threats to our security and prosperity. Today there are two wars we must win: the continued fight against poverty, and the new challenge of climate change. Both can be tackled simultaneously with the same policy framework that would shift our development path to a low-carbon footing. Taking action, we can lessen the social, economic and environmental damages of a carbon-intensive economy. We would create jobs, investment opportunities, new possibilities for international cooperation and technological deployment to the benefit of all.

Despite capacity constraints, many Forum governments are already embracing the call to action: Bangladesh has committed never to exceed the average per capita emissions of the developing countries. Costa Rica aims to be carbon neutral by 2021. But there are limits to what individual countries can achieve.

Solving the climate challenge requires broadest international cooperation. And yet countries still argue economic barriers to change. This report argues instead that strong measures on climate change would reap the most monetary benefits for society. Indeed, building global partnerships where all nations can fully participate in the transition to a low-carbon economy will lessen costs and heighten the social, environmental and economic dividends for all. Just as supporting vulnerable communities will ultimately improve the well-being of society as a whole. Divided, we face declining prosperity and immense suffering. Together, we have the chance to strengthen global welfare and safeguard the fate of the nations.

ACKNOWLEDGEMENTS

This report was a project that took on a life – almost – of its own. Unrivalled is a word that comes to mind when describing the energy, interest and dedication of our core partners: donors, advisors, researchers, reviewers, the team within DARA, experts at Commons Consultants, or the celebrated graphic designers – wearebold.es – who made the “measles” you generally love (and less often disprove of) as readers.

We set out to “improve” the 2010 report and ended up with something that struggles to bear a passing resemblance to what we thought was a useful contribution back in 2010. Somehow four maps turned into fifty-nine, a methodology note of twenty-five pages became a tome of well over one hundred that we ultimately couldn’t print in the book (the reader will find it online: www.daraint.org/cvm2). “Expert” workshops in Accra and Hanoi developed into fully-fledged policy exchanges, while delegates of the Climate Vulnerable Forum crowded Side Event rooms in Durban, Bonn and Rio. We hope you all appreciate the final result and cannot thank you enough for helping us to pull this unusual new work together.

Some much warranted apologies go to our close families and those of the core collaborators on this project. Thanks next to Lucía Fernández Suárez and the whole team and house in DARA, all of whom have helped make this report what it is – included of course are DARA’s Board of Trustees, in particular our key benefactor Diego Hidalgo, and our Trustee José María Figueres.

May we also extend our utmost gratitude to friends and colleagues at King’s College’s Humanitarian Futures Programme at the helm of the FOREWARN project, of which this report is one part: Randolph Kent, Hugh Macleman, Jonathan Paz, Emma Visman and Okey Uzoehina.

We would like to thank the members of our Advisory Panel for their generous insight and contributions to this effort over many, many months: Mary Chinery-Hesse, Helen Clark, José María Figueres, Robert Glasser, Saleemul Huq, Yolanda Kakabadse, Ashok Khosla, Ricardo Lagos, Loren Legarda, Michael Marmot, Simon Maxwell, David Nabarro, Atiq Rahman, Teresa Ribera, Johan Rockström, Jeffrey Sachs, Hans Joachim Schellnhuber, Javier Solana, Andrew Steer, Margareta Wahlström, and Michael Zammit Cutajar. And also to Jan Eliasson, even though you had to take up a new role part way through the endeavour, we were and will continue to be most grateful for your encouragement and support.

The Peer Review Committee continually challenged us and suggested innovations, adjustments and corrections we never would have thought of ourselves. We certainly hope the final report meets your high expectations of it: Yasemin Aysan, Suruchi Bhadwal, Diarmid Campbell-Lendrum, Manuel Carballo, Ian Christoplos, Joshua Cooper, Mariane Diop Kane, Sean Doolan, Pierre Encontre, Hans-Martin Füssel, Tim Gore, Anne Hammil, Randolph Kent, Tord Kjellstrom, Isabel Kreisler, Juergen Kropp, Allan Lavell, Marc Levy, Filipe Lúcio, Urs Luterbacher, Andrew Maskrey, Benito Müller, Michele de Nevers, Martin Parry, James Roop, Ben Ramalingam, Carlo Scaramella, Matthias Schmale, Hansjoerg Strohmeyer, and Farhana Yamin.

The Government of Bangladesh as Chair of the Climate Vulnerable Forum has not ceased to drive forward the climate cause with energy and dynamism in a truly international spirit. Thank you for your openness to the research team's fresh ideas on this topic, and your willingness to explore where they might lead. Thanks goes in particular to Dr. Dipu Moni, The Honorable Foreign Minister of Bangladesh; Dr. Hasan Mahmud, The Honorable Minister of Environment and Forests of Bangladesh; Ambassador Mohamed Mijarul Quayes, Foreign Secretary of Bangladesh; Mr. Mesbah ul Alam, Secretary of Ministry of Environment and Forests; Ambassador Abdul Hannan, Permanent Representative to the United Nations Office at Geneva; Dr. S.M. Munjurul Khan, Deputy Secretary of Ministry of Environment and Forests; Deputy Permanent Representative to the United Nations, Mr. Rahman Mustafizur; and Mr Faiyaz Murshid Kazi of the Bangladesh Foreign Ministry. Finally, thanks so much to two of the leading doyens of international macro-economic diplomacy in South Asia: Mr. Md. Sufiur Rahman, Director General and Mr. Salahuddin Noman Chowdhury, Director, each of Economic Affairs Wing of Ministry of Foreign Affairs of Bangladesh – may you continue to think and lead the way forward.

To our donors at AECID, AusAID and Fundación Biodiversidad: thank you for your many efforts to support this project and your helpful assistance in coordinating and realizing the wide-ranging activities involved. Thank you Juan Ovejero Dohn for looking after the team in Hanoi and Vietnam. To the Australian (and Italian) team in Accra, we hope you also enjoyed the experience of the country study: Sarah Willis and Azzurra Chiarini.

This report would not have been possible without the analytical expertise and dedicated work of Commons Consultants, the main research and production partner of DARA in this effort, a team led by Søren Peter Andreassen as Principal Advisor to the project

and Peter Utzon Berg as the primary Technical Advisor to the endeavour. Your honed creativity and technical precision allowed this project to achieve its close to outlandish aims.

Mariano Sarmiento, lead designer and his dedicated and talented team are responsible for all of the extremely helpful or too complex graphics in this report, depending on your viewpoint. However, the complexity is all our fault and not Mariano's nor his team's – what you see is much, much better than anything we would have subjected you to without their help. Morwenna Marshall, thanks once again for being there even at the most inconvenient moments, and to Tim Morris, our copy editors who each receive a special vote of thanks.

We particularly owe our thanks to additional scientists and experts who provided strong guidance and assistance with model selection of which there are simply too many to list here. You may have just thought you were just doing our chief modeller, Cristian Conteduca, a favour (you were) but your assistance in helping us to track down the knowledge which forms the foundation of this work was absolutely fundamental to helping this report make what we hope is a meaningful contribution to the debate. Antonia Praetorius, Sebastian Stempel, YiWei Ng, we thank you.

Many thanks also to the governments of Ghana and Vietnam and to the UNDP country offices there, as well as UNDP headquarters in New York, for your most helpful support. In Vietnam, Live&Learn, Hang Nguyen and colleagues were tremendous in supporting our country research, and in Ghana, the Environmental Protection Agency-Ghana with expert support from Emmanuel Tachie-Obeng did a highly effective job of facilitating our trip and national and community activities and for which credit is deserved. Mary Chinery-Hesse, thank you so much for welcoming us and taking part.

Finally, many thanks goes to Christer Elfverson, Magda Ninaber van Eyben, Marc Limon and Erik Keus, all of whom went out of their way to help see this project achieve its objectives. Thanks additionally to John Cuddy, Christiana Figueres, William Hare and Nicholas Stern for your sage advice, and to the Asia Society and friends at TckTckTck for your kind support behind the Monitor launch.

ROSS MOUNTAIN
DARA Director General

MATTHEW MCKINNON
Editor

CONTENTS

INTRODUCTION	14
EXECUTIVE SUMMARY	16
FINDINGS AND OBSERVATIONS	24
RECOMMENDATIONS	28
RESEARCH PROCESS	36
<hr/>	
KEY ISSUES	40
A VERY SHORT HISTORY OF CLIMATE SCIENCE	58
<hr/>	
THE MONITOR	60
<hr/>	
CLIMATE	104
ENVIRONMENTAL DISASTERS	106
HABITAT CHANGE	124
HEALTH IMPACT	154
INDUSTRY STRESS	176
<hr/>	
COUNTRY STUDIES	202
GHANA	204
VIETNAM	216
<hr/>	
CARBON	228
ENVIRONMENTAL DISASTERS	230
HABITAT CHANGE	240
HEALTH IMPACT	254
INDUSTRY STRESS	272
<hr/>	
METHODOLOGY	286
<hr/>	
MONITOR DATA TABLES	292
PARTNERS	302
ABBREVIATIONS	303
GLOSSARY	304
BIBLIOGRAPHY	308

A GUIDE TO THE COLD CALCULUS OF A HOT PLANET

INTRO- DUCTION

TWO DECADES OF FAILURE TO ACT DECISIVELY ON CLIMATE CHANGE HAVE MADE THE EARTH HOTTER AND MORE POLLUTED.

¹ There is still a window of opportunity, fast closing, to scale back pollution and tame the rising heat. But the world economy is locked onto a different course: fossil fuel consumption is expected to continue its rapid growth in the coming decades.² Major economies not committed to low-carbon development would need to enact policy changes to alter this fact. Current frontline stockpiles of hydrocarbons – of oil, coal, and gas – are multiples of what could possibly be consumed this century if the climate is to be kept under control, despite being valued as if all and more of these will be burnt.³ The cold calculus of a hot planet is that millions of people already suffer from the failure of the world economy to embark on a low-carbon transition. This report estimates that 5 million lives are lost each year today as a result of climate change and a carbon-based economy, with detailed explanations for why this is the case found in the relevant chapters that follow. In particular, effects are most severe for the world's poorest groups whose struggle against poverty is

worsened.⁴ Although no country is spared the impact: a depleted ozone layer for instance – also caused by potent greenhouse gases – has significantly increased the incidence of skin cancer, above all in the wealthiest of countries. The US will lose more than 2% of its GDP by 2030 according to this report's estimates.⁵

On the basis of this report's comprehensive reassessment of the incremental costs and benefits of a hotter, more polluted planet, a second cold calculus can also be made.

Climate change is found to have already set back global development by close to 1% of world GDP.

This impact is felt, but rarely counted, in the bottom lines of companies, industries and major economies, and is already playing a role in determining the wealth or poverty of nations. Inaction on climate change cost Least Developed Countries an average of 7% of their GDP for the year 2010 – with losses that will greatly increase in the years ahead. Indeed, the explosive increase in heat expected over the coming decades will only lead to a corresponding escalation in these costs, increasingly holding back growth as emissions go

unabated and efforts to support the worst-affected communities fail to meet the challenges at hand.

The losses incurred already exceed by a significant margin any costs of reducing emissions in line with a low-carbon transition.⁶ Action on climate change would therefore already reap monetary benefits for the world, both globally and for major economies like the US, China and India.

So the second cold, bottom-line calculus of a hot planet is that tackling climate change is already sensible in economic terms today. The step will also minimize widespread illness and mortality that inaction causes. And it would bolster the fight against poverty while helping to safeguard a natural world in steep decline.⁷

The findings of this report differ from previous studies that largely understand climate change as a net benefit or minimal cost to society today (or prior to mid-century), and which inform current economic decision-making on climate change, making it easier for governments to avoid serious action.⁸

While the methods of this study resemble previous research, three key distinctions in the approach have led to fundamentally different results.

First, this report draws on the most recent science and research into different climate-related impacts, taking advantage of the incredible growth in understanding on this issue since the 1990s era research that provides the basis of almost all other studies of this kind.⁹

Second, building on freshly available research, a number of new effects are considered here. Chief among these is the impact that increasing heat has on labour productivity, or the fact that workers (especially outdoors) produce less in a given hour when it is very hot. Fractional increases in global temperature can translate into tens of additional hot days with each passing decade.¹⁰ Labour productivity is estimated to result in the largest cost to the world economy of any effects analysed in this report. Other effects newly considered here include the thawing of permafrost in cold regions and the accelerated depreciation of infrastructure that results as frozen land shifts when it thaws.¹¹ Finally, this report also considers a full range of the closely inter-linked costs and benefits of the carbon economy, independent of any climate change impacts. When accounting for the large-scale costs imposed by carbon-intensive hazards to human health, the environment and economic sectors, such as the fisheries industry, the full costs of inaction are laid bare. Human society and the natural world, it turns out, are fundamentally susceptible to changes in ambient heat. Civilization itself emerged during an age subsequent to the last glacial era that was characterized by a uniquely stable and mild

THE CLIMATE VULNERABLE FORUM

The Climate Vulnerable Forum (CVF) is an international cooperation group for coordination, advocacy and knowledge-building among countries that face significant insecurity due to climate change. The Forum has distinguished itself through a determination to catalyze more effective and broad-based action for tackling the global climate challenge, internationally and nationally. Founded in 2009 by the Maldives, it now includes 20 governments and is a major foreign policy initiative of its current chair, Bangladesh. The Climate Vulnerability Monitor's second edition was commissioned at the November 2011 Ministerial Meeting of the Forum at Dhaka, Bangladesh.

climate. The balance is delicate: a few degrees cooler and much of the northern hemisphere freezes.¹² Several degrees hotter and parts of the planet exceed the thermal maximum at which human beings can exist outdoors.¹³

The world is just one degree Celsius (1.8° F) hotter than prior to industrialization – the principal cause of climate change.¹⁴ But small changes count: Ghana for instance, a focus country in this report, has warmed faster than others. In just 50 years, the number of very hot days in Ghana has increased by 50 in number.¹⁵ Inaction on climate change would see Ghana experience three to five times that increase in heat this century alone.¹⁶

It goes almost without saying that changes of this proportion have profound effects for human beings, the natural environment and the market economy. Releasing gigatonnes of carbon dioxide and other pollutants and gases into the atmosphere every year is neither a safe, sound nor healthy practice when cleaner, safer and more environmentally sound alternatives so readily exist. Low-carbon energy solutions – such as wind, solar, tidal or geothermal power – involve 10 to 100 times less negative externalities than carbon-intensive alternatives.¹⁷

Even for the sceptically minded, the argument for switching to safer, less damaging energy sources can be justified on account of the heavy costs of the prevailing carbon-intensive means.

The Climate Vulnerability Monitor (hereafter: “the Monitor”) was commissioned by the Climate Vulnerable Forum, an international cooperation group of climate-insecure countries, and mandated to DARA as an independent global study into precisely these effects. As its name indicates, the report serves to monitor the evolution of changes related to the climate as they are already being felt around

the world. Its role is to shed light on how society experiences inaction on the climate crisis today in order that the insight might assist in enhancing the contemporary global response to this most serious of societal concerns. The study has benefitted from the input of wide-ranging external advisory bodies and field research undertaken in Ghana and Vietnam.

Governments like those of the Climate Vulnerable Forum are already allocating significant taxpayer funds to deal with the local effects of climate change as they are taking hold. Governments worldwide are weighing macroeconomic energy and environmental policies, from infrastructure incentives to low-carbon regulation, nuclear energy reliance, or the exploitation of hazardous unconventional fuel reserves. In doing so, decisions are being made to allocate highly specific sums of money, human and intellectual capacities, and other resources of all kinds.

The Monitor helps to inform these decisions by presenting a snapshot of what current knowledge on climate change issues in their aggregate can reasonably be assumed to imply for the world. The analysis includes monetary, human and ecological estimations of the ramifications of inaction on climate change. These estimations are the result of this specific research effort and provide a reference of interest when considering what societal benefits might result from different policy strategies. The exercise enables the comparison of costs with benefits in order to judge the overall merits of different endeavours.

The report’s structure has three main parts. The front matter of the report provides an executive summary, context to and details of this study, as well as an overview of key findings and a series of detailed recommendations targeted at specific groups. The

Monitor itself is then presented, with the results of the assessment provided for every country and each of the different indicators used detailed one-by-one with key information provided each time at the country level, for different groups and overall. Finally, a number of special focus sections are also contained in this report, including independent chapters on the country-based research undertaken in Ghana and Vietnam. It is the hope that this report will spur debate and awareness of the double-sided cold calculus of action versus inaction on climate change with which the world now desperately struggles.

The choice for society is critical but hardly difficult if the externalities of inaction on climate change have indeed been underestimated by the world economy. Business-as-usual impacts would for this century be multiples of any costs associated with a transition to a low-carbon economy and imply unthinkable human suffering. All but the firmest responses leave the door wide open to catastrophic risks and threats to the planet’s ability to support life, none of which even enter into the Monitor’s assessment of costs. According to the International Energy Agency, just five years remain for the world’s major economies to enact structural economic transformations in order to break out of a dead end business-as-usual trap. If not, planned investments in high-carbon infrastructure would from 2017 rule out keeping the global temperature rise below the internationally agreed on level of 2° Celsius (3.6° F).¹⁸ Technological barriers no longer hold back the transition. Prolonging change only increases costs. Firm, urgent and internationally cooperative action heightens benefits for all. The best way forward is quite obviously clear.

DARA

Founded in 2003, DARA is an independent organisation headquartered in Madrid, Spain, committed to improving the quality and effectiveness of aid for vulnerable populations suffering from conflict, disasters and climate change. DARA was mandated by the Climate Vulnerable Forum as independent developer of the Climate Vulnerability Monitor in its first and second editions.

¹ The UN Framework Convention on Climate Change was signed in 1992 (UNFCCC, 1992)

² US EIA, 2011; IEA, 2011

³ BP, 2011; US EIA, 2011; CTI, 2011

⁴ UNDP, 2007

⁵ Martens, 1998; UNEP, 2002

⁶ For mitigation costs, see: Edenhofer et al., 2010 and IPCC, 2012b

⁷ Butchart et al., 2010; Crutzen, 2010

⁸ Tol, 2011; Nordhaus, 2011

⁹ Tol, 2011; Exceptions include: Nordhaus, 2006; Rehdanz and Maddison, 2005

¹⁰ Kjellstrom et al., 2009

¹¹ Nelson et al., 2002

¹² Petit et al., 1999

¹³ Sherwood and Huber, 2010

¹⁴ IPCC, 2007a

¹⁵ McSweeney et al., 2012: “A ‘Hot’ day or ‘hot’ night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region and season.”

¹⁶ Ibid

¹⁷ IPCC, 2012a

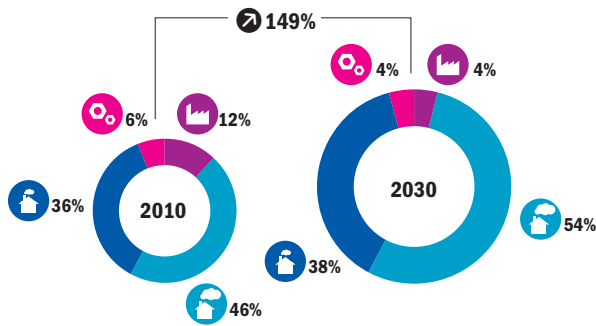
¹⁸ IAE, 2011

EXECUTIVE SUMMARY

This report provides a reassessment of the human and economic costs of the climate crisis. The reassessment is based on a wealth of the latest research and scientific work on climate change and the carbon economy, research that is assimilated as a part of this report.

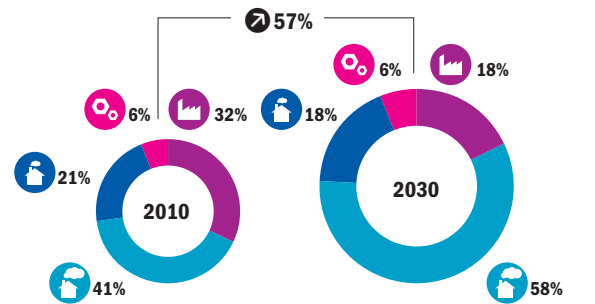
THE MAIN FINDING OF THIS REPORT IS THAT CLIMATE CHANGE HAS ALREADY HELD BACK GLOBAL DEVELOPMENT: IT IS ALREADY A SIGNIFICANT COST TO THE WORLD ECONOMY, WHILE INACTION ON CLIMATE CHANGE CAN BE CONSIDERED A LEADING GLOBAL CAUSE OF DEATH.

CLIMATE – TOTAL COSTS



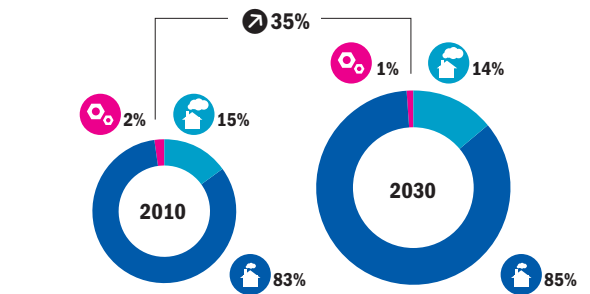
🏭 Developed
🏠 Developing Country Low Emitters
🏡 Developing Country High Emitters
⚙️ Other Industrialized

CARBON – TOTAL COSTS



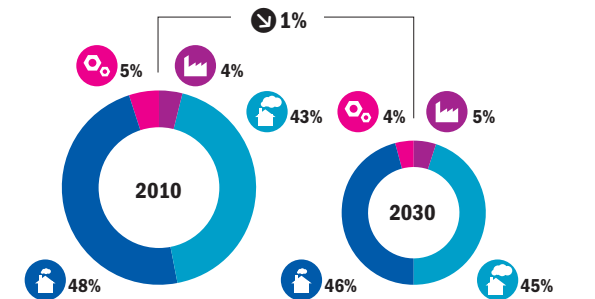
🏭 Developed
🏠 Developing Country Low Emitters
🏡 Developing Country High Emitters
⚙️ Other Industrialized

CLIMATE – TOTAL DEATHS



🏡 Developing Country High Emitters
🏠 Developing Country Low Emitters
⚙️ Other Industrialized

CARBON – TOTAL DEATHS



🏭 Developed
🏠 Developing Country Low Emitters
🏡 Developing Country High Emitters
⚙️ Other Industrialized

This report estimates that climate change causes 400,000 deaths on average each year today, mainly due to hunger and communicable diseases that affect above all children in developing countries. Our present carbon-intensive energy system and related activities cause an estimated 4.5 million deaths each year linked to air pollution, hazardous occupations and cancer.

the world's oceans, the slow response of the carbon cycle to reduced CO₂ emission and limitations on how fast emissions can actually be reduced.¹ The world economy therefore faces an increase in pressures that are estimated to lead to more than a doubling in the costs of climate change by 2030 to an estimated 2.5% of global GDP. Carbon economy costs also increase over this same period so that

TECHNICAL SUMMARY

The Monitor presents a new and original analysis, synthesizing the latest research and scientific information on the global impact – including benefits and losses – of climate change and the carbon economy in economic, environmental and health terms. Climate change already causes 400,000 deaths each year on average. The present carbon-intensive economy moreover is linked to 4.5 million deaths worldwide each year. Climate change to date and the present carbon economy are estimated to have already lowered global output by 1.6% of world GDP or by around 1.2 trillion dollars (2010 PPP). Losses are expected to increase rapidly, reaching 6 million deaths and 3.2% of GDP in net average global losses by 2030. If emissions continue to increase unabated in a business-as-usual fashion (similar to the new IPCC RCP8.5 scenario), yearly average global losses to world output could exceed 10% of global GDP before the end of the century, with damages accelerating throughout the century. The costs of climate change and the carbon economy are already significantly higher than the estimated costs of shifting the world economy to a low-carbon footing – around 0.5% of GDP for the current decade, although increasing for subsequent decades.¹ This report and scientific literature imply adaptation costs

OVERALL COSTS

	Losses 2010, Bln PPP corrected USD	Losses 2010, % of GDP	Net Losses, % of GDP 2010	Net Losses, % of GDP 2030
Climate	696	0.9%	0.8%	2.1%
Carbon	542	0.7%	0.7%	1.2%
World	1,238	1.7%	1.6%	3.2%

Climate change caused economic losses estimated close to 1% of global GDP for the year 2010, or 700 billion dollars (2010 PPP). The carbon-intensive economy cost the world another 0.7% of GDP in that year, independent of any climate change losses. Together, carbon economy- and climate change-related losses amounted to over 1.2 trillion dollars in 2010.

The world is already committed to a substantial increase in global temperatures – at least another 0.5° C (1° F) due to a combination of the inertia of

global GDP in 2030 is estimated to be well over 3% lower than it would have been in the absence of climate change and harmful carbon-intensive energy practices.

Continuing today's patterns of carbon-intensive energy use is estimated, together with climate change, to cause 6 million deaths per year by 2030, close to 700,000 of which would be due to climate change. This implies that a combined climate-carbon crisis is estimated to claim 100 million lives between now and the end of the next decade. A significant

NUMBER OF DEATHS

		2010	2030
Climate	Diarrheal Infections	85,000	150,000
	Heat & Cold Illnesses	35,000	35,000
	Hunger	225,000	380,000
	Malaria & Vector Borne Diseases	20,000	20,000
	Meningitis	30,000	40,000
	Environmental Disasters	5,000	7,000
Carbon	Air Pollution	1,400,000	2,100,000
	Indoor Smoke	3,100,000	3,100,000
	Occupational Hazards	55,000	80,000
	Skin Cancer	20,000	45,000
World		4,975,000	5,957,000

share of the global population would be directly affected by inaction on climate change.

Global figures mask enormous costs that will, in particular, hit developing countries and above all the world's poorest groups. Least Developed Countries (LDCs) faced *on average* in excess of 7% of forgone GDP in 2010 due to climate change and the carbon economy, as all faced inequitable access to energy and sustainable development.

Over 90% of mortality assessed in this report occurs in developing countries only – more than 98% in the case of climate change.

Of all these losses, it is the world's poorest communities within lower and middle-income countries that are most exposed. Losses of income among these groups is already extreme. The world's principal objectives for poverty reduction, the Millennium Development Goals (MDGs), are therefore under comprehensive pressures, in particular as a result of climate change.

The impact for rural and coastal communities in the lowest-income settings implies serious threats for food security and extreme poverty (goal 1 of 8), child health and the ability of children to attend school (goals 2 and 4), maternal health and women's development (goals 3 and 5), the prevalence of infectious diseases (goal 6) and, through water, fisheries and biodiversity impacts, environmental sustainability (goal 7). Furthermore, in a difficult fiscal environment, the advent of climate change has pressured governments to divert Official Development Assistance (ODA) funds from other development commitments and activities in an attempt to provide support for climate change concerns, including to a marginal degree, for helping vulnerable communities adapt to climate change. The Green Climate Fund, agreed upon in incrementally greater detail at the successive international climate talks at Copenhagen, Cancún and Durban, faces an economic environment of declining ODA tied to acute fiscal crises across a host of the world's wealthiest economies (see: climate finance). These developments have ultimately compromised the global partnership for development (goal 8). Lag areas towards MDG achievement also align very closely with the most

pronounced vulnerabilities resulting from climate change: sub-Saharan Africa, small island developing states, and South Asia in particular.

Poverty reduction efforts are in peril as the potential temperature increase the world is already committed to has only begun to be realized, and the world's major economies are in no way spared. The United States, China and India in particular are expected to incur enormous losses that in 2030 for these three countries alone will collectively total 2.5 trillion dollars in economic costs and over 3 million deaths per year, or half of all mortality – the majority in India and China.

The whole world is affected by these comprehensive concerns: 250 million people face the pressures of sea-level rise; 30 million people are affected by more extreme weather, especially flooding; 25 million people are affected by permafrost thawing; and 5 million people are pressured by desertification. The pressures that these combined stresses put on affected communities are immense and force or stimulate the movement of populations. As is highlighted in the Ghana country study in this report, they can also fuel violence and an erosion of the social and economic fabric of communities.

The impact of climate change on Labour Productivity is assessed here as the most substantial economic loss facing the world as a result of climate change. A large proportion of the global workforce is exposed to the incessant increase in heat, with the number of very hot days and nights increasing in many places by 10 days a decade.² Developing countries, and especially the lowest-income communities, are highly vulnerable to these effects because of geographical location – northern countries like Scandinavia, it is assumed, *benefit* from improved labour productivity due to warmer weather – but also because their labour forces have the highest proportion of non-climate controlled occupational environments.³ Global productivity in labour is surging due to technological advances and a shift of emphasis from agricultural activities to an industrial and service sector focus for most developing countries, among other key developments.⁴ Climate change, however, holds back the full extent of productivity gains the world would otherwise enjoy.⁵ In this way, the

to be at least 150 billion dollars per year today for developing countries, rising to a minimum of more than 1 trillion dollars per year by 2030. These costs are, however, considerably lower than costs of damages to developing countries estimated here, so adapting to climate change is very likely a cost-effective investment in almost all cases and should be central to any climate change policy. Beyond adaptation, this report also emphasizes the urgency of mitigating key risks: tackling food security, indoor fires/smoke, air pollution and other health issues such as diarrheal illnesses, malaria and meningitis that are all urgent priorities for lessening the extent of the human toll of this crisis. With costs due both to unabated climate change and the carbon economy expected to rise rapidly over the course of this century, tackling climate change by reducing emissions yields net benefits to the world economy in monetary terms – amounting to around a 1% higher GDP for the entirety of the 21st century (net present value at a 3% discount rate). World net benefits from action on climate change are insensitive to discount rates from 0.1% to 20% (the highest tested). Even the most ambitious reductions in emissions aimed at holding warming below 2°C (e.g. 400ppm CO₂e/IPCC AR5 RCP2.6 scenario) generates economic benefits for the

costs of climate change are hidden, which helps to explain in part how their full extent may have been missed. Even so, not all have benefitted from fast expanding labour productivity: labour productivity is a core indicator for MDG 1 (on extreme poverty and hunger), for instance, where little progress has been

registered in many developing regions of the world, in particular for sub-Saharan Africa and the Pacific.⁶ Not one country is *invulnerable* to the combined effects of climate change and the carbon economy. Inaction on climate change penalizes every country in the world, just as all are set to gain from action

world economy after accounting for the costs of reducing emissions (mitigation costs). Limiting warming to this level would limit human, territorial and ecological damage as well as other concerns, such as climate-induced forced movement of human populations.

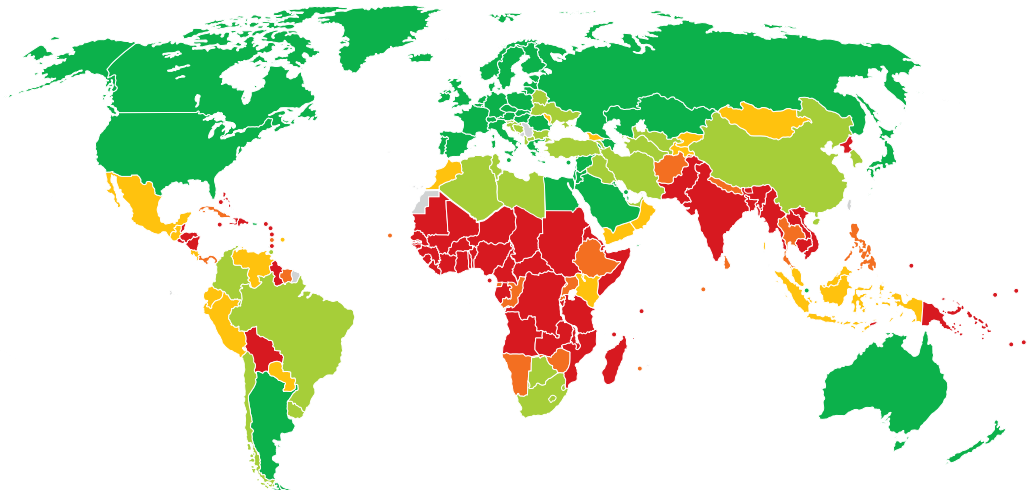
Over 98% of all climate change mortality and over 90% of all carbon economy related mortality is in developing countries; between 80% and 90% of all economic costs are projected to fall on developing countries. The most extreme effects of climate change are estimated to be felt by the Least Developed Countries, with average GDP losses of 8% in 2030. With respect to carbon economy effects, inequitable access to sustainable development sees Least Developed Countries again incurring the highest relative losses at over 3% of GDP, while between two thirds and three quarters of all carbon economy costs are borne by developing countries.

When the costs of climate change and the carbon economy estimated here are combined, not one country in the world is left unharmed. In terms of regional incentives to tackle climate change, every region is estimated to experience net economic benefits from action on climate change even for the highest levels of action.

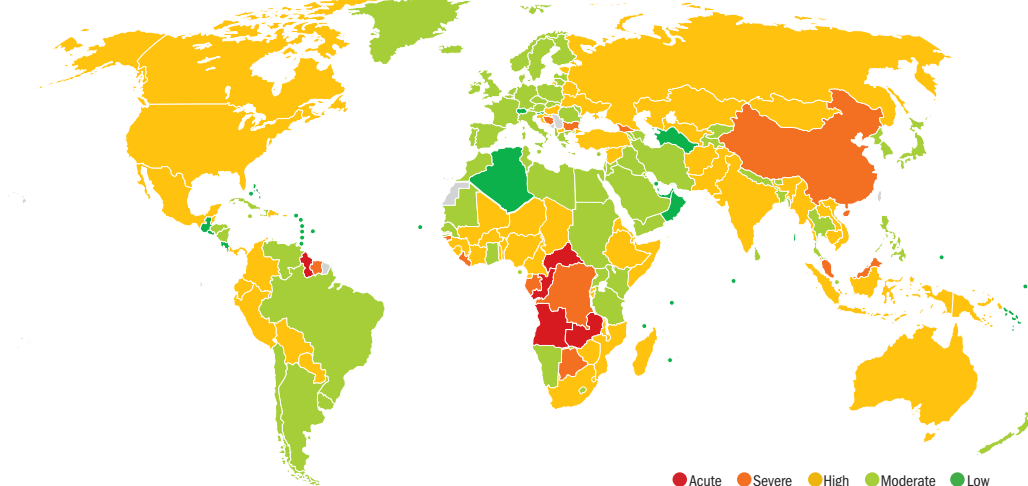
The Monitor only analyses incremental impacts as a result of climate change, or changes in the frequency of well-known stochastic events, such as floods and landslides. Not assessed here in any way are potential catastrophic impacts that could occur due to more rapid climate change fuelled

MULTI-DIMENSIONAL VULNERABILITY

CLIMATE



CARBON



● Acute ● Severe ● High ● Moderate ● Low

on climate change. Moreover, the vulnerability of the world is shifting with every passing decade. Countries once resilient to marginal weather effects increasingly realize susceptibilities to a changed climate as the increase in heat and associated effects continue to reach new extremes. Some quite serious damage is now unavoidable, but certain losses can still be reduced in the short term. In particular, human costs can be transferred to economic costs. This can be achieved through programmes aimed at reducing rural poverty – at the origin of hunger deaths and many communicable diseases afflicting the world’s poorest groups, with risks that worsen with climate change. Or it can be achieved by ensuring clean air regulations, safer working conditions and modern energy options for people at risk due to carbon-intensive forms of energy. All these measures will save lives but cost money. Economic losses themselves can also be lessened. A major recent review of humanitarian assistance work noted that Mozambique had requested 3 million dollars from the international community for flood preparations. That sum went unsecured, and 100 million dollars was subsequently spent on emergency flood response.⁷ Investment in agriculture might also be cost-effective if the costs of supporting upgraded farming were to generate more benefits (in productivity, output) than the initial outlay.⁸

There are, however, limits to the ability of populations to adapt. The oceans can hardly be refrigerated against marine stresses.⁹ Desert encroachment can be prevented but rarely reversed, and if so, generally at great expense.¹⁰ It might be possible to protect a beach, but concrete polders could well be to the detriment of an area’s authentic charm and so to the value of properties. A low-carbon, renewable economy – of hydro, wind, solar, geothermal, tidal and other innovative sources of energy – now competes with the most carbon-intensive forms of power generation in the open market, where they constitute around 10% of the global energy mix today.¹¹ Shifting the balance in favour of low-carbon energy has been estimated to cost approximately 0.5% or less of GDP for the current decade.¹² The carbon economy is largely responsible for the incredible growth in overall wealth society has amassed over the last 200 years, although, according to the World Bank, 1.3 billion people continue to remain trapped in dire poverty.¹³ Regardless, an economic system developed to support a global population of 1 or 2 billion people in the 19th century is ill suited to a global population in excess of 7 billion and growing.¹⁴ The climate challenge runs in parallel to other key global developments: a growing world population, a major propensity to urbanization, and structural

by feedbacks such as a release of Arctic methane deposits, more rapid sea-level rise that could result from the disintegration of the West Antarctic Ice Sheet or large-scale climatic disruptions such as the collapse of ocean circulation mechanisms, all of which are understood to pose significantly larger human, economic and ecological risks than anything portrayed here. The possibilities of these events are by no means ruled out, with risks increasing substantially with warming.² Other economists have therefore factored such risks into their economic analysis to a degree.³ Only with the deep and sustained emissions reductions spelled out in the lowest of the new IPCC RCP 2.6 scenario is there a reasonable chance (comfortably over 50%) of not exceeding the internationally accepted “safety” temperature threshold of 2°C global mean warming above preindustrial.⁴ Given the clear human, ecological and,

REGIONAL COST-BENEFIT ANALYSIS, 2010-2100**

PERCENTAGE OF GLOBAL GDP (NOMINAL), NET PRESENT VALUE AT 3% DISCOUNT RATE

Region	Climate + Carbon Costs				Highest Action		High Action		Moderate Action		Net Benefit		
	No Action	Highest action (400 ppm)	High action (450 ppm)	Moderate action (550 ppm)	Avoided costs*	Mitigation costs	Avoided costs*	Mitigation costs	Avoided costs*	Mitigation costs	Highest action	High Action	Moderate action
USA	3.0%	1.0%	1.0%	1.5%	2.0%	1.5%	2.0%	1.0%	1.5%	0.5%	0.5%	1.0%	1.0%
Japan	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.0%	0.0%	0.0%
Russia	4.5%	1.5%	1.5%	2.0%	3.0%	2.0%	3.0%	2.0%	2.5%	2.5%	1.0%	1.0%	0.0%
China	4.5%	2.0%	2.0%	2.5%	2.5%	2.0%	2.5%	1.5%	2.0%	1.0%	0.5%	1.0%	1.0%
India	11.0%	5.0%	5.5%	6.5%	6.0%	3.0%	5.5%	2.0%	4.5%	0.5%	3.0%	3.5%	4.0%
EU27	1.0%	0.5%	0.5%	0.5%	0.5%	1.0%	0.5%	0.5%	0.5%	0.5%	0.0%	0.0%	0.0%
ROW	8.5%	3.5%	3.5%	4.5%	5.5%	2.0%	5.0%	1.0%	4.5%	0.5%	3.5%	4.0%	3.5%
World***	4.0%	1.5%	1.5%	2.0%	2.5%	1.5%	2.0%	1.0%	2.0%	0.5%	1.0%	1.0%	1.0%

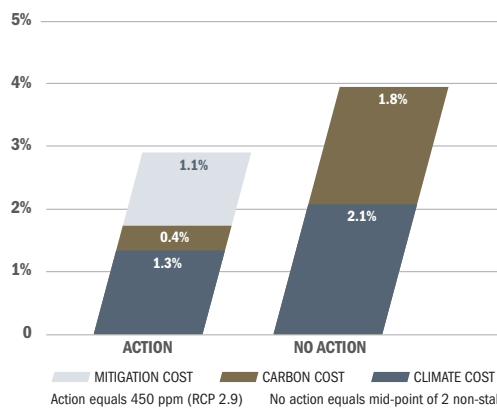
*Avoided costs: No action (A1B +8.5) minus reduced ppm scenario (400 ppm CO2e: RCP2.6; 450 ppm: RCP2.9; 550 ppm: SRES B1)

** Discounted (3%) sum of costs and GDP - mitigation costs from Edenhofer et al., 2010 (regional: Remind + Poles)

*** Median value of all 5 scenarios (Edenhofer et al., 2010)

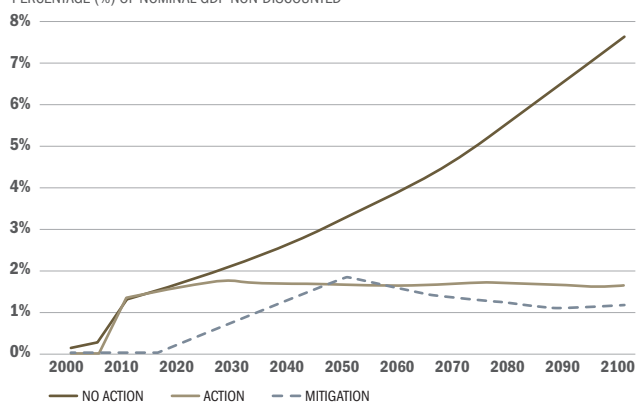
ACTION VERSUS INACTION OVER THE 21ST CENTURY

NPV OF GLOBAL CLIMATE/CARBON COSTS AND MITIGATION COSTS RELATIVE TO GDP (NOMINAL 2010-2100, 3% DISCOUNT RATE)



21ST CENTURY COSTS OF CLIMATE CHANGE ACTION, INACTION AND MITIGATION

PERCENTAGE (%) OF NOMINAL GDP NON-DISCOUNTED



shifts occurring in economies around the world. All of these tendencies – most pronounced in developing countries, in particular the process of industrialization now spreading more and more widely¹⁵ – can worsen or attenuate vulnerabilities to climate change or the carbon economy. In order to understand the fuller implications of this study and to make its findings comparable with previous works that take on longer-term perspectives, the costs of climate change and the carbon economy were also estimated for the period up until 2100. On this basis, business-as-usual development could see the costs of inaction exceeding 10% of global GDP in losses prior to 2100.

Reducing emissions results in net benefits for society in every case because the costs of a low-carbon transition are more than outweighed by averted losses due to climate change and the carbon economy. In the global context, the highest level of emission reductions results in similar global benefits to lower levels of action. However, the highest action sees fewer negative impacts on society – from human health to biodiversity and for the world's oceans – but requires slightly greater investments in low-emission forms of energy. Less ambitious action means accepting larger scales of human and ecological impacts.

The regional analysis of costs and benefits

differs little in fundamental terms from the global analysis: all regions benefit from climate action in economic terms. Most regions find optimal climate action in the high-action scenario. The highest action to reduce emissions also limits the risks of crossing tipping points leading to large-scale climate disruptions.¹⁶ Less ambitious action on climate change does not: moderate action on climate change has a high chance of exceeding the accepted international temperature goal of holding warming below 2° C (3.6° F) above pre-industrial levels.¹⁷ The most vulnerable countries have called for warming to be limited below 1.5° C above pre-industrial levels as they believe 2° C is far too damaging and a risk to their survival. Neither should the risks of catastrophic impacts be discarded as heresy: new research has highlighted great risks associated with heat, as opposed to ocean-related immersion of countries, with heat risks concerning far greater shares of the world economy and its population. In particular, at certain levels of high-end warming, large areas of the planet would progressively begin to exceed the thermal maximum at which human beings are able to survive outdoors.¹⁸ The possibilities of very rapid climate change are not implausible or ruled out by climate change models, especially as the planet warms beyond the 2 degrees Celsius temperature threshold

ultimately, economic advantages of aiming for a highest-action scenario, this report's findings imply that the highest action targets would reap the most benefits for the world. Therefore, the highest-action scenario is recommended to policy makers as the preferred target for enhancing and safeguarding global prosperity. Mainstream economic modelling shows that this transition is technologically and economically feasible but that action is needed now to get onto this pathway.⁵ International cooperation will clearly be central to ensuring that the costs of the transition are maintained at the lowest most efficient level and that the transition yields the highest co-benefits.⁶

¹ See: Edenhofer et al., 2010; IPCC, 2012a

² Weitzman, 2007; Hare in Mastny, 2009

³ For example: Hope, 2006; Stern, 2006

⁴ Pope et al., 2010

⁵ For an overview of some leading mitigation scenarios, see: Edenhofer et al., 2010; UNEP, 2011; IPCC, 2012a

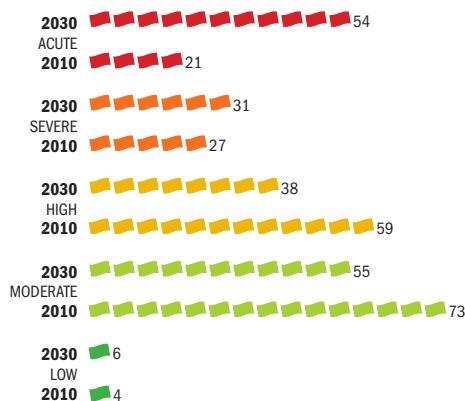
⁶ For example the economic benefits of cross-border emission reduction cooperation: De Cian and Tavoni, 2010

the international community has set for itself.¹⁹ Of particular long-term concern are 1500 gigatonnes of CO₂ (GtCO₂) of methane stored in frozen sediments in the East-Siberian Sea at depths of less than 40 to 50 metres.²⁰ This represents three times the amount of CO₂ that could be released over much of this century if the 2 degrees target is to be kept.²¹ As the Arctic sea warms due to climate change, these sediments are thawing and methane is already being visibly released at rates that currently exceed the total amount of methane emitted through natural processes over the entirety of the world's oceans.²² While all policy pathways for reducing emissions have similar net benefits in economic terms, the highest-action route would clearly reap the greatest human, societal, economic and environmental benefits, since it would ensure the greatest chances of avoiding climate-triggered catastrophe and would minimize the human, social and environmental impacts of a hotter planet. Therefore, the cold calculus of a hot planet implies the most ambitious

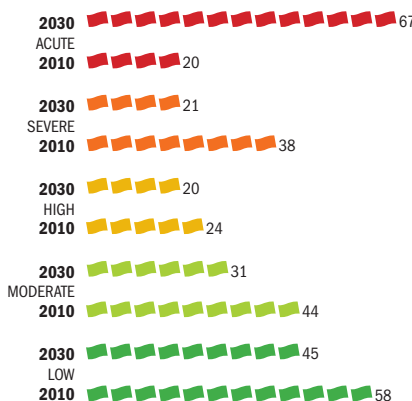
action on climate change is the savviest choice both in monetary, humanitarian and environmental terms. The highest-action approach is the pathway that the analysis in this report most supports. The world risks carbon lock-in due to high-intensity carbon infrastructure plans still moving forward in the near term, so the shift in focus to a low-carbon transition should likely occur prior to 2017 and continue aggressively thereafter.²³ Several major economies will need to adjust and enact important domestic policy and legislative initiatives in order to make this a reality. Whatever the case, action on climate change that seeks out international partnership is most likely to further lessen the costs of a low-carbon transition and expand the benefits of this transition for all concerned. This report documents in part the potential benefits of avoided impacts of climate change in addition to the potential co-benefits of emission reductions that are targeted at key economic, health and environmental concerns.²⁴

¹ Hansen et al., 2005
² Kjellstrom et al., 2009a; McSweeney et al., 2012
³ ILO LABORSTA, 2012
⁴ Storm and Naastepad, 2009; Wacker et al., 2006; Restuccia, et al., 2004; Storm and Naastepad, 2009; McMillan and Rodrik, 2012
⁵ Kjellstrom et al., 2009a-b
⁶ UN, 2012
⁷ Ashdown et al., 2011
⁸ Parry et al., 2009; EACC, 2010
⁹ Cheung et al., 2010
¹⁰ Puigdefabregas, 1998
¹¹ US EIA, 2011
¹² Edenhofer et al., 2010; IPCC, 2012b
¹³ Chen and Ravallion, 2012
¹⁴ World Population Prospects/UN DESA, 2011
¹⁵ OECD, 2012; IMF WEO, 2012; World Population Prospects/UN DESA, 2011
¹⁶ Pope et al., 2010
¹⁷ UNFCCC, 2009
¹⁸ Sherwood and Huber, 2010
¹⁹ Wietzman, 2007
²⁰ Shakhova et al., 2008
²¹ Meinshausen et al., 2009
²² Shakhova et al., 2008 and 2010
²³ IAE, 2011; UNEP, 2011
²⁴ De Cian and Tavoni, 2010

CLIMATE+CARBON




































CLIMATE



■ = 5 countries (rounded)

SUMMARY OF ECONOMIC IMPACT

	NET 2030	NET 2010	LOSSES 2010	GAINS 2010	2010				2030				
													
CLIMATE	 DROUGHT	18	4	4	*	*	2	1	*	4	11	3	1
	 FLOODS & LANDSLIDES	94	10	10	*	2	6	1	*	21	66	5	3
	 STORMS	100	15	15	*	2	3	7	*	16	64	20	*
	 WILDFIRES	*	*	*	*	*	*	*	*	*	*	*	*
	TOTAL	213	29	29	*	5	14	10	1	40	142	28	4
	 BIODIVERSITY	389	78	78	*	8	26	36	9	56	299	80	54
	 DESERTIFICATION	20	4	5	*	*	*	2	1	5	4	6	6
	 HEATING & COOLING	-77	-33	5	-38	1	2	24	-8	30	7	-65	-49
	 LABOUR PRODUCTIVITY	2,400	311	314	-3	135	162	16	-1	1,035	1,364	49	-12
	 PERMAFROST	153	31	31	*	1	10	3	17	5	68	5	75
CARBON	 SEA-LEVEL RISE	526	86	86	*	23	42	15	5	166	310	29	22
	 WATER	13	14	44	-30	3	-3	13	7	-21	45	39	39
	TOTAL	3,461	491	563	-71	166	235	60	30	1,276	1,908	144	135
	TOTAL	106	23	23	*	17	5	*	0.5	84	21	*	1
	 AGRICULTURE	367	50	51	*	27	17	3	2	208	144	8	10
	 FISHERIES	168	13	16	-3	7	7	1	-1	97	80	-3	-6
	 FORESTRY	44	6	7	-1	*	4	*	*	9	34	1	1
	 HYDRO ENERGY	-24	-4	*	-4	*	-3	*	*	3	-20	-1	*
	 TOURISM	*	*	5	-5	2	*	-1	*	19	-16	-2	-1
	 TRANSPORT	7	1	1	*	*	*	1	*	*	1	6	*
TOTAL	565	66	80	-13	37	25	2	2	329	223	8	5	
TOTAL GLOBAL RESULTS	4,345	609	695	-84	225	279	72	33	1,730	2,294	179	144	
CARBON	 OIL SANDS	24	7	7	*	*	*	7	*	2	1	20	0.5
	 OIL SPILLS	38	13	13	*	1	6	6	0.5	3	24	9	2
	TOTAL	61	20	20	*	1	6	13	0.5	5	25	29	3
	 BIODIVERSITY	1,734	291	291	*	32	128	114	17	236	1,034	349	115
	 CORROSION	5	1.5	1.5	*	*	0.5	0.5	*	1	4	0.5	0.5
	 WATER	10	4	4	*	*	*	3	1	*	2	4	4
	TOTAL	1,749	296	296	*	32	129	117	18	238	1,038	353	120
	TOTAL	630	172	172	*	74	67	21	10	226	341	37	26
	 AGRICULTURE	-171	15	17	-2	1	2	9	4	-58	-121	4	4
	 FISHERIES	77	9	9	*	1	7	0.5	*	5	70	2	0.5
 FORESTRY	83	28	28	*	3	9	14	1	13	48	18	4	
TOTAL	-11	52	54	-2	4	18	24	5	-40	-3	24	8	
TOTAL GLOBAL RESULTS	2,429	540	542	*	112	220	174	34	429	1,401	444	156	

* Less than one billion dollars

Billions of dollars (2010 PPP)
non-discounted. Totals do not
correspond exactly due to rounding. Environmental disasters Developing Country Low Emitters Habitat change Developing Country High Emitters Health impact Developed Industry stress Other Industrialized

FINDINGS AND OBSERVATIONS

1.

THE MOST AMBITIOUS RESPONSE TO CLIMATE CHANGE IS THE MOST ADVANTAGEOUS POLICY IN HUMAN, ECONOMIC AND ENVIRONMENTAL TERMS

- Tackling climate change reaps significant net benefits for society in monetary terms, with monetary gains resulting from even the strongest action and far outweighing any associated expenses
- Climate change is estimated to have already cost the world close to 1% of GDP, the negative effects of the carbon economy add a further 0.7% of GDP to today's losses
- Both climate change and carbon economy costs grow as emissions expand and are lessened as they are cut
- Combined costs could double by 2030, lowering world GDP by well over 3% in absence of concerted action to reduce emissions and vulnerabilities globally
- This major revision of climate-related costs is based on an original research aggregation exercise of third-party scientific studies and data with more comprehensive and updated analysis than previously available including the full breadth of effects linked to the carbon economy, with overall conclusions notably unaffected by a differing of the discount rate applied
- The analysis excludes the willingness to pay to avoid long-term non-marginal catastrophic risks, often factored in by economists, which would further increase the costs of inaction and raise the benefits of ambitious responses, only strengthening the conclusion drawn here
- All collective actions aimed at stabilizing GHGs in the Earth's atmosphere generate net benefits to society: on the basis of available information the 400ppm CO₂ equivalent (RCP2.6) target results in the least human and environmental damages in addition to its monetary benefits
- Inaction would see a continuing escalation of the costs of the climate crisis and a diminishing ability for any policy action to bring it under control as humanity would be increasingly placed at the most extreme of risks

2.

THE HUMAN TOLL OF INACTION COULD EXCEED 100 MILLION DEATHS BETWEEN NOW AND 2030 ALONE

- Climate change and the carbon economy as estimated here are responsible for 5 million deaths each year today and cause illness in tens of million people globally comparable to the third leading cause of preventable death with a similar societal impact as tobacco use (see: Health Impact Climate/Carbon)
- The carbon economy claims the largest share of this impact, in particular

- due to toxic air pollution, at over 4.5 million deaths a year today
- Climate change is estimated to be responsible for 400,000 deaths each year, particularly due to hunger and communicable diseases in the lowest-income countries
- By 2030, the annual death toll is estimated to rise to 6 million, including close to 5.5 million deaths due to the carbon economy, and over 600,000 as a result of climate change
- Inaction on climate change could claim well over 100 million lives in the twenty year period to 2030
- Reducing emissions will rapidly diffuse risks to populations due to the carbon economy and generate co-benefits for human health, although the effect on the burden of disease will persist for decades
- Constraining climate change will have less of a beneficial effect on its near-term health impacts given that an additional half a degree of warming is now virtually inevitable in the decades immediately ahead
- Climate change linked health concerns are therefore an urgent priority for policies aimed at adapting to climate change, since the accelerating rate of change is outpacing the ability of expected large-scale gains in socio-economic development to lessen key health vulnerabilities in lower-income countries

3.

CLIMATE ACTION IS GOOD VALUE, BUT THE COST OF ADAPTING TO CLIMATE CHANGE HAS LIKELY BEEN UNDERESTIMATED

- Tackling the carbon economy alone is in many cases a sound proposition without even consideration of climate change – reducing the scale of future damages due to climate change are an added bonus to what can be a set of financially and environmentally sound policy measures in their own right
- Given the extent of near-future warming that decades of insufficient regulatory action have now unavoidably forced the world to experience, reducing emissions remains just half of the picture: parallel efforts to adapt to climate change are now essential to a safe and prosperous world
- While a full reassessment of the costs of adaptation is beyond the scope of this report, this Monitor's findings imply that it is very unlikely that the adaptation costs currently facing developing countries could be less than 150 billion US dollars per year today – double the highest of previous published estimates of around 75 billion US dollars per year – simply because a number of key climate change impacts assessed here, such as Heating and Cooling, or Water represent quasi adaptation costs by virtue of how they have been calculated – autonomous adaptation at cost (or gain) being assumed
- Moreover, provided the costs of adaptation rise at similar rates as the

costs of climate change, developing countries could be facing a minimum of over 1 trillion dollars of annual adaptation costs a year by 2030 (in 2010 dollars PPP) – an order of magnitude higher than any previous estimate

- While those figures represent minimum amounts, it is unlikely that the margin of error exceeds much more than double the minimums estimated here, whereas the impact of climate change is estimated to incur several times greater losses for developing countries: 500 billion dollars for 2010 and 4 trillion dollars for 2030 (2010 dollars PPP non-discounted)
- On the basis of existing literature on the subject, adaptation costs are therefore very likely to be less than the costs of the impacts of climate change – as a result adaptation represents a cost-effective investment across a broad range of sectors, meaning resources spent on adaptation are almost certain to reap net benefits for affected countries and for society as a whole
- An important qualification to any estimations of the costs of adaptation however is that climate-related uncertainty significantly increases costs, since planning is ideally robust to the full (or nearly) range of potential outcomes which may include opposites, such as more water, and inundation, or less water but drought

4.

CLIMATE INJUSTICE IS EXTREME

- Climate change takes the most from those who have the least: Least Developed Countries faced in excess of 10% GDP losses due to climate change and the carbon economy in 2010
- The Monitor uses four different country groups as broad geopolitical markers covering developed and industrialized countries as well as developing countries split between “high” and “low” emission categories – the latter group consists of 85 countries with less than 4 tons of CO₂e of GHG emissions (in 2005) or well below the safe per capita emissions level necessary for ensuring stabilized climate conditions in the near-term
- Low-emission countries have essentially contributed nothing to climate change – if all countries were polluting only to those levels, climate change would be marginal – although with a global carbon budget now all but exhausted even the lowest emitting countries can contribute or detract from the world’s ability to rise to the climate challenge
- Lacking any responsibility for climate change, the low-emission country group nevertheless experiences approximately 40% of all its economic losses, and over 80% of all climate change-related mortality
- In an intergenerational perspective, more than half of all climate change-related deaths are solely among young children in lower or middle income countries who have virtually no responsibility whatsoever for the problem

– which adds further insult to the also serious implications of today’s inaction for the welfare of future generations

5.

CLIMATE INACTION COMPROMISES GLOBAL DEVELOPMENT AND POVERTY REDUCTION EFFORTS

- With serious ramifications for agricultural and coastal communities in both economic, health and productivity terms, climate change almost surgically targets global poverty reduction efforts, in particular towards the eight internationally agreed Millennium Development Goals (MDGs), directly and manifestly compromising above all the targets for extreme poverty and hunger (goal 1), child health (goal 4) and environmental sustainability (goal 7), but with important repercussions also for gender equality (goal 3), maternal health (goal 5) and infectious disease (goal 6)
- Effects are most extreme for countries understood to have the lowest levels of capacity, where local efforts are less able to be relied upon for making headway in responding to these additional and growing pressures
- Regional lag towards the MDGs, particularly for Least Developed Countries, small island developing states and African countries also corresponds very precisely to those geographic groups worst affected by the impacts of climate change, where the relative scale of losses reach their most extreme values as assessed by the Monitor
- The net impact of climate change doubles as a share of global GDP between 2010 and 2030 with the growth in losses increasing rather than slowing over time regardless of an expected tripling of global wealth during this 20-year period
- So despite an extremely strong link between wealth and a capacity to withstand climate change, impacts still outstrip the ability of economic development to rid developing countries of heightened vulnerabilities to climate change – contrary therefore to the assertions of previous studies, investment in development is not a sufficient response to limit the impacts of climate change and should not be considered a substitute for a dual policy strategy on climate change encompassing early and strong reductions of emissions together with adaptation

6.

INTERNATIONAL CLIMATE FINANCE: A CLEAR DEFAULT ON COPENHAGEN/CANCUN COMMITMENTS

- Two important goals on “new and additional” finance for climate change were agreed in 2009 in Copenhagen at the major UN climate conference there (COP15) and adopted in more official form at subsequent talks

a year later in Cancún (COP16): 1) “Fast Start Finance” of 30 billion US dollars balanced between adaptation and mitigation to flow from developed to developing countries between 2010 and 2012; and, 2) a similar collective goal to mobilize 100 billion dollars a year of climate finance in support of developing countries

- Several possible definitions of “new” and “additional” are left open to interpretation, and include: a) resources that are over and above pre-existing (2009) flows of climate change finance; b) resources additional to commitments to deliver foreign aid of 0.7% GNI as Official Development Assistance (ODA) – a commitment widely unmet since it was adopted by the UN in the 1970s; c) additional to commitments or intentions for progressively increasing ODA to meet the 0.7% target as communicated by governments well prior to the new climate finance pledges; and d), additional to 2009 levels of ODA
- Climate change finance fails to meet any of the above criteria except the first: climate change finance has increased significantly, especially finance for mitigation of climate change
- Because the other definitions do not qualify however, it is clear that “Fast Start” climate change finance has been withdrawn from earlier parallel commitments to sustainable development and poverty reduction efforts – the annual new and additional share of climate change finance is actually in the realm of just 2-3 billion US dollars for 2010, and not 10 billion a year, which raises further serious concerns that long-term financial goals could result in still more and greater diversions
- Numerous developed countries did however face in precisely this period the most extreme of financial pressures of the recent historical era, with a number among them facing fiscal collapse as a result of serious domestic and transnational economic and credit crises during the years of 2008-2012
- The recently agreed Green Climate Fund faces a difficult initiation environment as a result, endangering effective and cost-efficient climate action, in particular there is still no clarity on the scale and sources of generation of funding above all for the interim period from 2013-2020
- Given that ODA fell in real terms in 2011 versus 2010, the new and additional proportion of climate finance for the second year of the three year commitment period can only be lower still, meaning around 20 billion dollars of new and additional climate change finance should flow in 2012 if Copenhagen/Cancún commitments are to be met
- The finance provided is also imbalanced: adaptation makes up a mere 14% of the committed 14 billion dollars of overall climate change finance in 2010, or around 2 billion dollars – indications of change since then are unclear due to delayed reporting cycles – the need for enhance Monitoring, Reporting and Verification (MRV) is critical, in particular because there are serious risks of double or inaccurate accounting for resources under current reporting regimes
- Worse still, “Fast Start” finance is very slow: disbursement rates for

conventional ODA are much faster than for climate finance – 76% versus 48% – mainly due to the complex array of funding instruments involved, slowing the rate at which climate-related funds reach beneficiaries

- Adaptation finance is not responding to vulnerabilities: with just over 2 billion dollars of adaptation finance flowing annually from developed to developing countries, wholesale gaps remain for even the most severely affected front-line nations – these are often complicated by conditionalities and other barriers that lock-out some of the world’s most vulnerable countries from support
- The Clean Development Mechanism – albeit under severe pressure since several developed countries discontinued forward association – is currently leveraging tens of billion dollars of annual investment in low-carbon initiatives in developing countries and has emerged as one of the most meaningful de facto technology transfer instruments currently operational with around half of all projects resulting in a technology transfer of one form or another – coverage however is extremely limited with almost 90% of all investment benefitting either China or India alone

7.

NOBODY IS SPARED THE GLOBAL CLIMATE CRISIS

- In one respect or another, every country is experiencing negative impacts either resulting from the effects of climate change or as brought about by the carbon economy – not one country has Low vulnerability to the combined effects of climate change and the carbon economy, and just seven of the 184 assessed have Moderate vulnerability
- Even the largest and most advanced of the world’s economies face serious losses, such as the United States, which is estimated to incur a 2.1% reduction in GDP by 2030
- That many wealthy countries exhibit low general vulnerability to climate change is more an indication of the extremity of effects taking hold on the climate frontlines, than of how inconsequential the effects of climate change are for the affluent
- Wealthy countries may have much lower thresholds of tolerance for climate-related impacts since wealth to a large extent insulates communities from suffering extreme societal risks: for example, the 75,000 additional deaths estimated to have been caused by the 2003 European Heat Wave that leading experts believe would almost certainly not have occurred in the absence of global warming is a major anomaly and point of concern for Europeans
- Advanced economies can also afford to part with much less of their economic growth than their developing counterparts – according to the International Monetary Fund, developing countries are growing more than four times as fast in real terms than advanced economies for whom

any marginal loss will have a disproportionate effect on what has been an average of just 1.5% in collective real economic growth over the last decade

- Furthermore, in the increasingly globalized world economy of the 21st century, the fortunes of all nations are more intimately tied, especially for highly networked developed countries that rely on foreign investments both domestically and abroad to sustain even marginal growth and retain high levels of prosperity – an unrestrained climate crisis can only become a major impediment to that prosperity whether or not its effects are felt locally or elsewhere
- The Monitor examines marginal short-term impacts and the implied evolution of these beyond the 2010-2030 scope of much of this report, but in the longer-term climate change implies rapidly growing risks of non-marginal and truly catastrophic impacts, such as a collapse in ocean circulation or of major ice sheets, or the breaching of thermal tolerance levels for humans – all of which would generate large-scale losses for any income group and none of which are accounted for in the Monitor

8.

OUTDATED ESTIMATES OF THE NEGATIVE EXTERNALITIES OF CLIMATE INACTION GUIDE TODAY'S REGULATORY DECISIONS

- Previous global estimates of the impact of climate change reveal less than 20 original studies developed by a much smaller range of authors, and with the exception of three, all are based on third-party research or data from the 1990s or earlier
- Previous studies routinely include the positive effects of carbon fertilization due to high levels of CO₂ without controlling for negative effects of an expanding carbon economy, such as ground-level ozone toxicity, ocean acidification, acid rain or the health hazards of pollution, among others
- No single study includes the impact of climate change on labour productivity, which the Monitor estimates as the most significant near-term impact of climate change in monetary terms
- Hundreds of estimates of the social cost of carbon are based on just nine studies of the negative externalities of climate change, all grounded in 1990s research and data, and which are actually integrated into and continue to guide the regulatory decisions of major countries
- In many cases these studies feed policy recommendations on emission reductions that would allow the rise in global temperatures to exceed the internationally agreed 2° Celsius (3.6° Fahrenheit) safety limit, since a common conclusion is that the costs of firm mitigation exceed any marginal benefits from reduced damages

RECOMMENDATIONS

FOR ALL NATIONAL POLICY MAKERS

COMMIT FIRMLY TO LOW-CARBON PROSPERITY

- Breaking free from the climate crisis will save lives, improve health and extend the lifespan and well-being of entire populations
- Tackling climate change results in net economic benefits and can reduce instability and system-level market volatility, restore domestic energy independence and jobs, while boosting business productivity and enhancing trade balances and economic competitiveness among major economies
- A low-carbon economy *will* reduce the stunning rate of contemporary environmental degradation, deforestation and irreversible biodiversity loss that is crippling the world's ecosystems with serious economic repercussions
- A global commitment to a low-carbon economy could strand half or more of all hydrocarbon reserves, rendering them unmarketable and potentially creating space for regulatory actions with very low costs not yet factored into economic modelling on low-carbon transition costing

PRIORITIZE PARALLEL MEASURES TO ADAPT TO CLIMATE CHANGE

- Adaptation cannot be a stand alone response to the climate challenge: treating only the symptoms but not the cause of the climate crisis would result in spectacular economic losses for the world economy – not all the effects of climate change can be adapted to; some come at a pure sunken cost, while uncertainty in many cases doubles the costs of adaptation since the possibility of random outcomes (e.g. more or less rain) require parallel measures in opposing directions
- Adapting to climate change is expensive, but not doing so is even more costly – on the whole, adaptation is cost effective and, if strategically programmed, may result in productivity boosts that more than compensate for any investment made –

governments are accordingly advised to close the adaptation gap

- Not investing in convincing adaptation responses will increasingly hold back country-level business and investor confidence, especially for highly vulnerable countries where climate change is already one of the most significant economic challenges
- Climate change is radically more dangerous and damaging for the world's poorest populations than for any other groups. Not empowering marginalized communities to overcome the daunting new challenges only multiplies economic, social and political risks and instability, and will guarantee a steady erosion of longstanding poverty-reduction investments
- International funding and resources of all kinds need to be anchored both in the best possible understanding of the probable distribution and severity of vulnerabilities and impacts attributable to climate change and the highest co-benefits of supported mitigation actions in terms of human health and the environment

UNITE STRENGTHS IN INTERNATIONAL PARTNERSHIP

- A new international partnership is called for based not only on essential mutual trust and reassurances but also on pure common interest and shared economic, environmental and social benefits
- The climate crisis has emerged as one of the greatest common challenges of humankind: in a planet at risk, with death and damages in pandemic proportions and humanity and justice tested to the limits, not even half of the world's powers are capable of solving the problem alone
- Working in partnership, any costs associated with a low-carbon transition are minimized as the global comparative advantages of emission reduction and removal are fully leveraged, while the dividends of climate action for sustainable human development can be maximized in greater fulfillment of human rights

- That partnership can build on the significant energy already invested by the international community over the course of nearly two decades and 17 major UN climate conferences dealing with every conceivable technical aspect of the climate problematic in great detail and to the steady improvement of complex but vital institutional instruments such as the Clean Development Mechanism

FOR GOVERNMENT GROUPS

DEVELOPED COUNTRIES

1.1 Support the vulnerable *effectively*:

Decades of investment in poverty-reduction efforts largely on the basis of public taxpayer resources have been seriously undermined by climate change and environmentally unsound development. Explosive climate stress and what are often termed its “risk multiplier” ramifications for health, social and political security, migration and global prosperity are also likely to indirectly endanger the already slow growth prospects of many developed countries. Act effectively by ensuring efforts are aligned with an evidence-based prioritization that places vulnerability up front, support promising local government initiatives, and reach for the last mile of impact.

1.2 Deliver fully on Copenhagen/Cancún

commitments: Full delivery of climate finance is an essential component for meeting ambitious emission-reduction objectives. The prevailing financial climate is unfavourable, but climate finance has been largely transposed from parallel planned increases in Official Development Assistance committed or announced prior to and separately from international climate change agreements. Current flows are heavily imbalanced, with only marginal support for vulnerable countries to adapt to escalating damages. While mitigation actions can have very substantial benefits for sustainable human development, diverting resources intended for urgent poverty

reduction priorities penalizes the world's poorest groups as more than one billion people are still living with hunger on a daily basis. The global response to climate change cannot be taken out of the international community's commitment to eradicate extreme forms of poverty, a project now seriously endangered in large part precisely as a result of climate change. Despite the prevailing macro-economic difficulties, developed countries are urged to convene an extraordinary session of OECD Development Assistance Committee and to subsequently communicate a joint and time-bound action plan for delivering on the full set of collective climate finance and sustainable development commitments, much of which would otherwise go unmet by the end of 2012 and thereafter.

1.3 Rescue the MDGs: The Millennium Development Goals (MDGs) would have had significantly greater chances of being met globally in the absence of the climate crisis. The MDGs may not now be fully attained unless additional resources are devoted to the cause, targeting in particular progress specifically jeopardized by climate change impacts not accounted for when the MDGs were developed. With only a few years remaining before the foreseen conclusion timeframe, substantial emergency resources should be put into efforts to achieve the MDGs on the basis of goal specific, geographic and income-group lag. The evidence for seriously compromising effects for key MDGs and progress in priority regions as a result of climate change underscores the critical importance of mainstreaming climate change considerations into national-, provincial- and even town- or village-level development policies. An MDG rescue fund could constitute an early thematic funding window for the newly established Green Climate Fund set to be established within the framework of the UN Climate Change Convention (UNFCCC). While the international community is now

busy designing the successor "Sustainable Development Goals" that will take over from the MDGs after 2015, this important process should nevertheless not detract from the vital importance of first ensuring success by 2015 on the original MDGs.

DEVELOPING COUNTRIES

2.1 Prioritize climate policy with highest co-benefits: Faced with limited capacities and resources, policy makers should deliberately target high-impact actions with multiple societal benefits in human, economic and environmental terms. One example is the promotion of efficient and clean-burning cooking stoves, which addresses indoor smoke-linked disease and deforestation, as well as supporting gender development and labour productivity. Promoting clean-burning stoves also limits potent particulate emissions which could help slow the aggressive short-term increase in temperatures. Dozens of other high-impact policy options abound. Pursuing low-carbon development strategies across the sectors of construction, forestry, water and agriculture in addition to the electricity-generation industry will broaden the possible development dividends yielded.

2.2 Pledge strong national action: Strong leadership can pay dividends. Above all, it is in the firm interests of developing countries to create a domestic environment of predictability as to the direction and intent of national climate change policies. More ambitious climate change policies will reassure foreign investors that climate risks are under control and that steps are being taken to ensure economic competitiveness and risk diversification with respect to energy usage and forward planning. With climate change already firmly embedded in the contemporary economic system, strong national action plans are an assertive starting point for reassuring key stakeholders in the economic and social prospects of an economy in the near term.

2.3 Invest in national risk analysis:

Developing countries are overwhelmingly more vulnerable to climate-related impacts than industrialized nations. This is not only due to income inequalities and poverty but is also a product of heightened environmental vulnerabilities since the majority of developing countries are tropical or sub-tropical, where the implications of climate change are most severe. The high carbon intensity of economic activities common to many developing countries is a further disadvantage. As such, climate-related concerns are an important emerging factor for macroeconomic planning and the pursuit of optimal economic competitiveness. Effectively addressing climate-related risks requires sustained investment in local expertise, educational programmes, civil society groups and specialist technical networks. Ideally, reference climate change and emission scenarios, the backbone of climate change response planning, would be updated every 2-3 years and involve wide-ranging stakeholder groups in the development of each new iteration. National governments are best placed to foster the development of the most sophisticated country-specific climate-related analysis possible. Solid reference scenarios and analysis supports more accurate and efficient national policies and solidifies support for its implementation, including among development partners.

HIGHLY VULNERABLE COUNTRIES

3.1 Prioritize adaptation: Climate change is already a major determinant of the prosperity of economies most vulnerable to its effects. A highly robust climate change adaptation strategy and implementation plan is an essential safeguard for national development progress and economic growth prospects. As the knowledge base expands, country risk will increasingly factor in the diverse negative and positive effects of climate change to the economic prospects of nations, with direct

financial implications for investor confidence and foreign investment. Vulnerable countries need to learn from each other's successes and reassure the global economy that climate-related risks are well under control. Regional and localized knowledge tools, such as focused climate models, warrant serious investment in order to improve localized analysis as best as possible.

3.2 Boost domestic capacity:

Considerable institutional competences are required to manage costly adaptation programmes necessary to limit damages and productivity losses due to climate change. If institutional arrangements are not in place, serious opportunities for participation in the global low-carbon transition may be foregone. Just one example relates to the Clean Development Mechanism (CDM). National authorities responsible for the registration of projects that could enable local environmentally sound energy-related projects to access financial resources from international carbon markets are still absent in a number of highly vulnerable countries. Capacity goes beyond the public sector too: no point in establishing a national CDM authority in the absence of any local entrepreneurial activity for developing low-carbon projects in the first place. Moreover, making the most of vibrant civil society interest on climate change will only add value and legitimacy to the climate change policy development process and is a valuable asset to governments that should be cultivated and strongly promoted.

3.3 Strengthen climate governance:

The diffuse nature of climate change means its varied effects cut across the institutional divisions of policy both vertically, from national to provincial and district or municipal levels, as well as horizontally, encompassing government departments ranging from environment agencies to foreign, finance or planning ministries, resource management, civil defence, labour relations, agriculture, forestry, fisheries, commerce, science and education, health and safety, national meteorological services, to name just a few. Implementing meaningful policy requires extraordinary levels of coordination and stewardship. The most successful examples, such as the Philippines, thrive because of a deliberate high-level consolidation of national responsibility on climate issues in legislatively-mandated central authorities backed by direct executive involvement. The success of countries like the Philippines in implementing effective domestic climate change policies shows that improved climate change governance is a more significant determinant of climate policy success than the level of national domestic resources committed to climate policies.

FOR CIVIL SOCIETY AND THE PRIVATE SECTOR

COMMUNICATORS AND THE MEDIA

4.1 Question received wisdom: It has often been argued that green policies “curb economic growth”, “increase gasoline prices” or “destroy jobs”. Taxes on carbon do increase certain costs, namely by putting more of the burden of the negative effects of pollution back onto its sources. For most economies,

an ambitious response to climate change would only attenuate dependency on costly and insecure imported fuel supplies in favour of locally developed energy solutions, such as energy efficiency upgrades to buildings. If the US was able to cut its trade deficit in half purely by shifting to domestic solutions for meeting and reducing energy requirements, would that not increase domestic prosperity, rather than curtail it? If half or more of the world's existing stocks of hydrocarbons, such as oil, were rendered obsolete, might not their market price just as well plummet not rise? If climate policy is only another ruse in support of “big” executive government, why in the US are individual states taking the legislative initiative and not the capital? When the local building and automobile industries actively lobby in favour of national legislation on climate change while hydrocarbon businesses would do the opposite, to what extent are policy outcomes being determined by vested influences as opposed to domestic economic interests?

4.2 Promote awareness on risks as opportunities: Risks are opportunities.

Serious environmental and health impacts of the carbon economy will abate as low carbon development progressively dominates economic activities. The same for climate change impacts. In almost every case, taking measures to limit damages due to the warming the world is already committed to will improve competitiveness and minimize any losses. The Monitor emphasizes that it is no longer credible that mitigation of climate change will lead to reduced economic growth. Indeed, the benefits of reducing the

carbon intensity of growth far outweigh any small and artificial premium in profit margins associated with carbon-based development strategies. The dividend of mitigation furthermore is most pronounced in fast-growing, newly industrialized developing countries.

4.3 Take a stand: Time is running out, and the stakes are tremendous, if not incalculable. If a low-carbon transition is not engineered within the decade, the consequences will be dire regardless of the ultimate magnitude, since they involve irreversible damage: the extinction of whole species, and thousands upon thousands of human lives lost. In worst cases, not solving climate change could render large areas of the planet unsuitable for human existence outdoors. The injustices, environmental irresponsibility and inhumanity involved are simply staggering. A nearly unparalleled body of scientific and observational evidence now amassed and plain for all to see with the steady disappearance of Arctic sea ice and glaciers. The dramatic weather-related adjustments and extremes repeated around the world are difficult to ignore. Despite the complexity of the topic, ignorance is no excuse for inaction, and indifference can be tied to complicity. With this report, there is now a comprehensive current-day economic justification for action in addition to the human, ethical, environmental and rights-based arguments already in wide circulation. Civil society groups, communicators and people of all kinds in positions of public influence or authority within their communities, whether in faith-based groups, municipal or educational establishments, should find no further obstacles to taking a stand in tackling climate change.

INVESTORS

5.1 Perform comprehensive risk

analysis: Corporations reliant on business models based on carbon assets, such as reserves of oil, are taking a daily gamble that a low-carbon economy will never prevail and those assets will never be stranded unable to reach markets due to regulation. Certainly, the structural features of the global economy and every mainstream energy outlook analysis back the narrative of the low-carbon economy as a pipe dream. But only a very narrow window of legislative action in favour of a firm response to climate change would strand half or more of the world's existing stockpiles of carbon-based fuels as unmarketable. To what extent are investment portfolios exposed or not to that possibly marginal but phenomenal risk? Are those risks worth bearing? How might they be minimized?

5.2 Encourage diversification

strategies: Hydrocarbon companies should be capable of presenting comprehensive diversification strategies into low-carbon alternatives. If no convincing diversification strategies have been developed, it is clear that corporate leadership are carrying investor resources along a risky political gamble. Detailed economic modelling by major pension funds has demonstrated that a diversified portfolio should reap more benefits for investors in the case of a low-carbon transition than under business-as-usual conditions. Few companies in the energy sector rival the omnipotence of hydrocarbon businesses, mainly state-owned as they are. Therefore, whether or not the future energy requirements of the planet are met through renewable sources or via point-supplied carbon

intensive fuels, the leading global energy corporations of today are still the best equipped to service the world's energy requirements of a low-carbon economy. Not preparing the ground for a potential low-carbon transition only builds up risks that need not exist. Coal businesses, for instance, with strong investments in carbon capture and storage (CCS) and employee and environmental safety research and development, would most likely benefit from a low-carbon transition rather than suffer.

5.3 Foster transition stability:

Legislative steps that entail irreversible change to the landscape of the world's energy industry are a systemic risk embedded in global markets, just like climate change is already an inescapable and growing determinant of market prosperity itself. The energy sector constitutes the primary or at least a major share of virtually every major stock exchange. Abrupt policy action that results in a stranding of a majority of carbon assets could cause serious instability. And yet changes are very specifically a contingent necessity to the constraining of climate change, which in spite of current business trends is nevertheless a widely ratified international priority. In a globalized economy, it is a sovereign regulatory concern for any party to the UNFCCC. Equity market regulators across the 194 parties involved should be monitoring and publicly reporting on the extent to which systemic carbon-linked risks might jeopardize national and global prosperity. This would enhance investor visibility to the risk profiles of entire indexes and encourage better carbon risk management. Regardless of the motivations, regulators unwilling to

publicize relevant information on such hazards might be suspected of purposely concealing inordinate risks, which may only compound exchange-specific risks and compromise investor confidence here.

RESEARCH COMMUNITY

6.1 Encourage attribution research: Imperfect data sets, confounding parallel effects, basic empirical limitations and otherwise, thwart the identification of climate change's role (or lack thereof) in any socio-economic or environmental phenomena. Yet the exercise is highly relevant and significant. Hundreds of billions of dollars of taxpayer resources virtually everywhere are already being diverted each year, consciously or not, to address the sprawling repercussions of a hotter planet. Knowing where these resources should or should not be deployed is of prime concern. Just one example serves to illustrate why. If climate change is assumed solely responsible for localized coastal degradation in a river delta due to a subjective rise in sea levels, a concrete wall along the foreshore might conceivably be built. However, equal or greater blame may well be attributable to upstream dams, hydro stations, irrigation, or localized ground-water pumping that would continue to cause land to sink further behind a prohibitively expensive, infrastructure-heavy coastal fortress aimed at containing sea-level rise. Furthermore, coastal defences in one area often accelerate degradation in adjacent coastal zones by inhibiting the natural dissipation qualities of tidal energy, spreading inadvertent losses further still.

6.2 Expand global analysis: Global estimates and models of the impact of climate change are so complex and subject to such a wide array of assumptions and proxies by the experts or research teams involved in their development as to be almost irreproducible by third parties, even when full transparency is provided on the methodological steps involved. And yet understanding the costs and benefits involved in addressing any serious policy concern is ordinarily an unavoidable imperative. Climate change proposes nonetheless perhaps the most ambitious policy agenda the modern world has had to decide on. The dearth of recent analysis on the question has no doubt lessened confidence in global policies capable of enabling a major macroeconomic restructuring crucial to the initiation of a low-carbon transition. The Monitor's reassessment of the costs of climate change would best be judged through comparison with other similarly updated studies. Where future studies include also carbon economy side effects, such as carbon fertilization, they should also include the full range of carbon economy side effects, including ozone toxicity, acid rain, pollution issues relating to health and other relevant impacts such as those assessed by the Monitor.

6.3 Avoid misrepresentation of risks: The level of confidence and agreement among academic specialists and their models is less important for vulnerable communities than the potential risks implied by science. Understating risks by stressing instead the uncertainties associated with attributional association to climate change is irresponsible because the implication

is to displace concern, entailing potentially deadly and economically debilitating ramifications if policy makers fail to act on risks. While many risks cannot be affirmed as stemming from climate change with a high degree of confidence, neither can their causal association to climate change be discounted with any better degree of confidence. Future reference reports should aim to highlight first the range of risks, then the levels of confidence and uncertainty associated with them, and not the other way around. It is safer to risk being over prepared than under.

FOR THE INTERNATIONAL DEVELOPMENT AND HUMANITARIAN COMMUNITY

DEVELOPMENT ACTORS

7.1 Focus on economic development, education and environmental governance: Any strategy that boosts economic and human development will almost certainly also reduce climate vulnerability by some degree. This is highlighted by the very low levels of climate impacts assessed for the few high-income tropical countries that share environmental vulnerabilities with lower-income neighbours, such as Brunei, Saudi Arabia or Singapore. Education is also critical so that communities experiencing a growth of income are equally equipped with high degrees of awareness of the risks faced and the means available to mitigate these. Educating children, especially girls, may be the most cost-effective method to spread awareness, since the school system, as well as informal educational avenues, is a sustainable conduit to invest in, and children are

more likely to further pass on their knowledge to other groups, namely adults. Environmental governance is equally key, since the unsustainable exploitation of natural resources, above all fisheries, forests and water, might occur regardless of the level of education and may even intensify as incomes rise. But environmental governance should look beyond simple protection towards actually enhancing the public goods natural resources have to offer. This might include the construction of dams to trap water from heavy downpours for irrigation during drier spells, or the expansion of natural reserves or wetlands for pollination, waste water treatment or wind protection.

7.2 Raise the disposable income of farmers and fishermen: Support national efforts to establish appropriate national government policies and investments that yield for the lowest income groups. The groups most consistently and heavily exposed to climate-related impacts are small-scale or subsistence farmers and fishermen, and especially their children. The greatest challenge faced by the lowest income bracket of these groups is to reverse the vicious cycle of decline that climate-related risks are constantly feeding. In order to break out of decline, farmers and fishermen need to expand their incomes and profitability. If not, even the most cost-effective of opportunities to protect against damages may remain out of reach on purely financial grounds, such as higher quality seeds, clean burning stoves, irrigation equipment or crop insurance. Education and rural extension training has a role to play in helping farmers

to boost productivity so that more can be achieved with the same resources available. Expanding market access for the raw or finished goods produced by this group is another option of growing interest as the world's markets continue to globalize. Providing financial stimulus and training to local entrepreneurs or cooperatives to establish light agro-fishery industries capable of packaging these goods for admission to global supply chains would allow local producers to appropriate a greater share of the value chain and maximize the commercial value of their goods.

7.3 Integrate climate strategies to revitalize development: Access to carbon markets via the reformed CDM, which allows the pooling of micro-level activities into one larger and therefore collectively financeable project, and the possibility of a global carbon market for forests, represent new sources of long-term income streams that could enable a host of fresh sustainable development initiatives to take hold in developing countries. Simple large-scale energy projects like hydro dams or extensive concrete sea defences may be attractive climate-related initiatives for administrative or other reasons, but energy-efficient cooking stoves and mangrove plantations would likely accomplish the same objectives – reduce emissions, protect against coastal degradation – but bring much higher co-benefits – for health, biodiversity, forests, carbon sinks, or wind protection, to name just some key advantages. Several successes in payment for ecosystem services systems, Costa Rica's scheme being a prime example, also provide templates for governments to regulate and incentivize the protection and growth

of valuable environmental assets in an integrated and self-sustaining way. International policy makers should prioritize high co-benefit initiatives and integrated programmes that deal simultaneously with multiple issues in order to maximize the scarce resources available for tackling climate vulnerability while making the most out of the transition to a low-carbon economy in terms of sustainable human development at a global level. With far fewer resources available for adapting to climate change, prioritizing mitigation projects that also boost local adaptive capacity or directly result in adaptation dividends could double or more the possible extent of adaptation efforts. As an example, retrofitting buildings with thermal insulation would reduce cooling energy loads, and therefore emissions, but also safeguard health and labour productivity from rising temperatures.

THE HUMANITARIAN SYSTEM

8.1 Brace for change: Change is already underway. That change is also significant: as heat rises, parts of the world will experience climates with no analogue in human history. It is still extremely difficult to confidently attribute a specific extreme weather event in part or entirely to climate change, especially not close to the time of its occurrence. Certain types of events, such as extreme heat leading to drought or flooding triggered by heavy rains, nevertheless carry the classic hallmarks of disasters suspected to have been caused or aggravated by climate change. On the basis of the classical laws of physics, moreover, it is nearly impossible that, for example, more abundant, frequent and concentrated heavy rainfall or severe hot and dry spells would not result in a

general increase in flooding or drought. As such, the humanitarian sector needs to be capable not just of preparing for but also responding to weather-related emergencies on larger scales and at more frequent intervals. Likewise, all development and humanitarian partners should increasingly realize the value of building, together, the resilience of communities to avoid simply racing to respond to emergencies and maximize the effectiveness of development investments.

8.2 Establish a thematic funding window for climate-linked emergency response:

The damage caused by the general increase in the extremity of certain types of weather already accounts for a significant and growing share of human and economic disaster losses. The concern falls squarely within the competence of the UNFCCC and is a legitimate target for climate change finance, especially for developing countries with marginal capacity that are penalized by current finance flows, which seek out strong “absorptive capacity”. Persistent Horn of Africa and Sahel food security crises highlight the extent to which the international humanitarian community is not sufficiently equipped to cope with climate-related disasters. As climate stresses continue to mount, that capability will only be further eroded if action is not taken to ensure it is reinforced. The track record of humanitarian sector resource mobilization makes it unlikely that standard sources of funding will keep pace with costly additional burdens to emergency response. A climate finance-replenished thematic funding window should be established to finance a share of all emergency relief and rehabilitation costs associated with any extreme

weather events, especially floods and drought – since such events can neither be attributed nor *dis-attributed* to climate change. The same window could also finance emergency preparedness activities in known high-risk hotspots. The UN’s Central Emergency Response Fund (CERF) could establish a dedicated window for this purpose in conjunction (or not) with the Green Climate Fund.

8.3 Evolve thinking and partnerships:

Even without today’s clear resource constraints, it will take more than just additional financial resources to cope with the increases in risks expected as a result of heavier rain and more extreme heat. Strategic planning should question whether the past is an accurate basis for future situations given the highly dynamic conditions the world now finds itself dealing with as a result of climate change, economic and population growth, globalization, and otherwise. Extreme droughts are breaking new records today, but those records will only be re-broken again and again in the years to come. Organizations and institutional response structures will need to become more accustomed to dealing with highly uncertain and speculative information, find efficient ways to prepare for a range of different possible outcomes, including unprecedented multi-country crises that could be triggered by repeated extremes, such as heavy flooding followed by extreme and prolonged drought, and compounded by additional risks, such as energy price spikes. The interactions between climate change and other wide-ranging crises merits more focused examination: just as climate change outcomes are affected by wide-ranging issues, so too climate change will affect critical determinants of tomorrow’s humanitarian crises, if not

already, today’s. Breaching conventional comfort zones in order to work more widely and effectively with non-traditional humanitarian actors like the private sector or the military, would also help to expand reach and impact.



RESEARCH PROCESS

INCEPTION AND DEVELOPMENT

The first edition of the Monitor was meant to serve as a departure point for discussions to refine understanding of climate vulnerability. As stated in that 2010 report, the goal has been to improve both the methodology and the accuracy of this tool going forward. A number of considerations raised during the development of the first report by external review bodies could not be adequately addressed at that time, but instead have fed into development of the second edition. So while this new report was only formally commissioned in November 2011, the second Monitor nevertheless has its origins well rooted in the first.

The original Monitor approached the problem of climate change in a non-technical but policy-relevant way. It established a conceptual framework that assessed vulnerability at the national level. But it allowed for an understanding of vulnerability as internationally fluid not static, with today's isolated vulnerabilities rapidly becoming tomorrow's shared vulnerabilities. Separating out some of the different components of vulnerability helped to show that nearly every country in the world faces some aspect of the problem to a high degree. Much of the architecture of the original report is retained in this Monitor.

Not unsurprisingly, a number of headline conclusions from the 2010 report still hold, such as an insufficient focus on the human health impacts affecting most vulnerable communities or the highly significant links between a country's

level of vulnerability to climate change and its human development status. However, it became evident that not all original country-level results were satisfactory and that certain sections of the original report oversimplified the socio-economic effects of climate change. Nor did the original format provide sufficient granularity for sector-level effects (economic impacts were limited to "land" and "marine") or convey key nuances between different levels of certainty. Much of the difficulty stemmed from a heavy reliance on third-party global or regional macro models that pooled information at those levels, leading to a certain degree of inaccuracy in the results for some countries, since the information wasn't designed for the Monitor's nation-by-nation analysis. This second edition continued to draw on other studies; however, it still did not solve the challenge of providing accurate national-level outputs. The difficulties of re-running climate impacts models developed by others is a recognised issue for the field (Nordhaus, 2011). The second Monitor's now greatly expanded set of indicators is therefore primarily anchored in individual bodies of recent research pertaining to discrete effect areas, such as distinct economic sectors (agriculture, fisheries, forestry, etc.) and specific resource, health or environmental impacts (e.g. water, heat and cold illnesses and biodiversity). DARA has also worked with additional external advisory bodies in order to further the range of inputs. The new Monitor also includes a new thematic pillar.

While the original edition focused on the effect of “Climate”, this edition focuses on both “Climate” and “Carbon”. The new section on the socio-economic impacts of the carbon economy came from recognition that there is a distinct, symbiotic relationship between climate change concerns and the carbon economy. Viewing climate policy more holistically will help decision makers form parallel or combined responses to both the consequences of global warming and its root causes. Another major adjustment to the second Monitor is the inclusion of in-depth country-level input, including field research and exchanges with local specialists. This input was viewed as a must for the effective development of an improved Monitor report, and the governments and experts of Ghana and Vietnam fully embraced and engaged with that process.

CONSULTATION & COUNTRY RESEARCH

EXTERNAL ADVISORY BODIES

Two external advisory bodies have provided critical input at various intervals during the course of the Monitor’s development. A senior Advisory Panel provides strategic guidance on the Monitor’s framing, analysis and recommendations. An open format Peer Review Committee provides specialist and technical input in particular on methodological and theoretical issues. Participants in these two bodies serve in a non-remunerated

personal capacity and represent a broad spectrum of expertise and viewpoints on the topic as well as a variety of stakeholder groups whose perspectives and involvement have helped enrich the Monitor’s development, analysis and presentation. The research team responds to every question and critique from these groups and endeavours to reflect all input within the limitations of the overall project. The expectations for the second Monitor were presented to the report advisory bodies at the beginning of 2012 in the form of an Inception Report to which DARA received a first round of substantive feedback. The second Monitor then underwent two separate methodological and quantitative reviews by its Peer Review Committee, including a full-day workshop in Geneva in April 2012. A dialogue between Committee members and the Research Team was also organised with representatives of the Climate Vulnerable Forum on that occasion. A draft report was submitted for review to both bodies in August 2012 and adjusted prior to public release. Individual members of the advisory bodies comment only on certain aspects of the project, not on its entirety, based on their expertise, availability and other considerations. While the Monitor benefits from external advisory bodies and open peer review, the system and approach of this project is to be distinguished from academic

peer-reviewed scientific literature. This report is designed primarily as a policy and communication tool that strives for technical accuracy in encapsulating the scientific work of third parties together with other forms of qualitative and quantitative information, including field-based research.

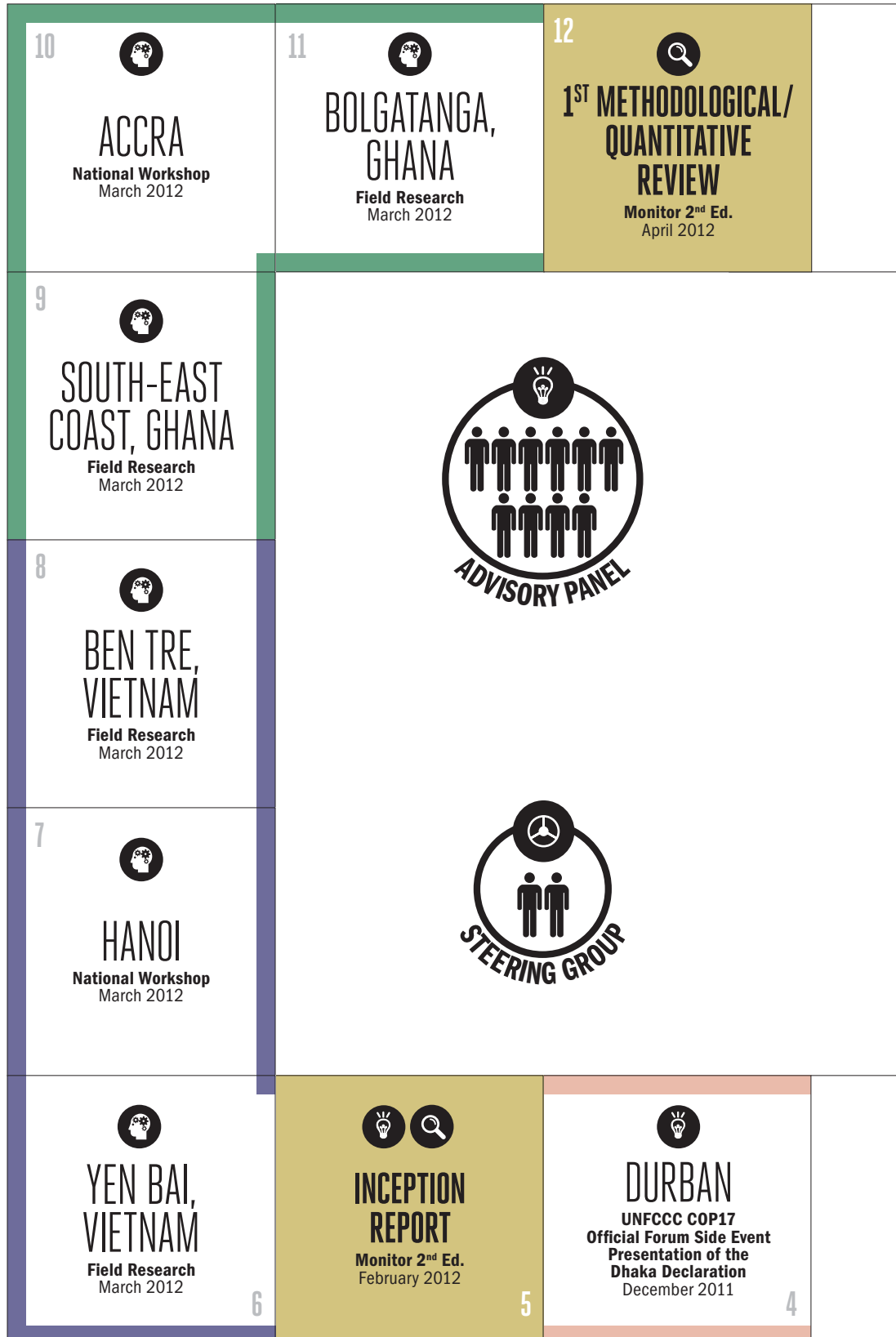
COUNTRY STUDIES

Country studies were undertaken in Vietnam and Ghana in March 2012. In each case, a half-day national workshop was convened to present conclusions of desk research conducted by DARA and to seek substantive input from key stakeholders and policy makers across public, private and civil society groups. Two representative territorial units were also identified in each country for field research, and dozens of extended interviews were conducted there with senior representatives of local government, civil society and business groups.

ADDITIONAL CONSULTATIONS

Climate Vulnerable Forum delegates were briefed on the Monitor’s progress at an official open session of the group at the UN climate change talks in Bonn, Germany in May 2012. Additionally, some early results from the Monitor project were presented and discussed publicly at an official Climate Vulnerable Forum Side Event to the UN Conference on Sustainable Development (Rio+20) in Rio de Janeiro in June 2012.

RESEARCH PROCESS



13



GENEVA
Peer Review
Committee Workshop
April 2012

14




BONN
UNFCCC Intercessional
Negotiations
Official Forum Side Event
May 2012

15



RIO DE JANEIRO
UN Conference on
Sustainable Development
Official Forum Side Event
June 2012

16



**2ND METHODOLOGICAL /
QUANTITATIVE REVIEW**
Monitor 2nd Ed.
July 2012

17




**DRAFT REPORT
REVIEW**
Monitor 2nd Ed.
August 2012

18





NEW YORK
Launch of Monitor 2nd Ed.
September 2012

19



WASHINGTON, D.C.
Expert Discussion
October 2012

2
NO EDITION




3




DHAKA
Climate Vulnerable Forum
Ministerial Meeting
November 2011

2



CANCÚN
UNFCCC COP16
Launch of Monitor 1st Ed.
December 2010

1

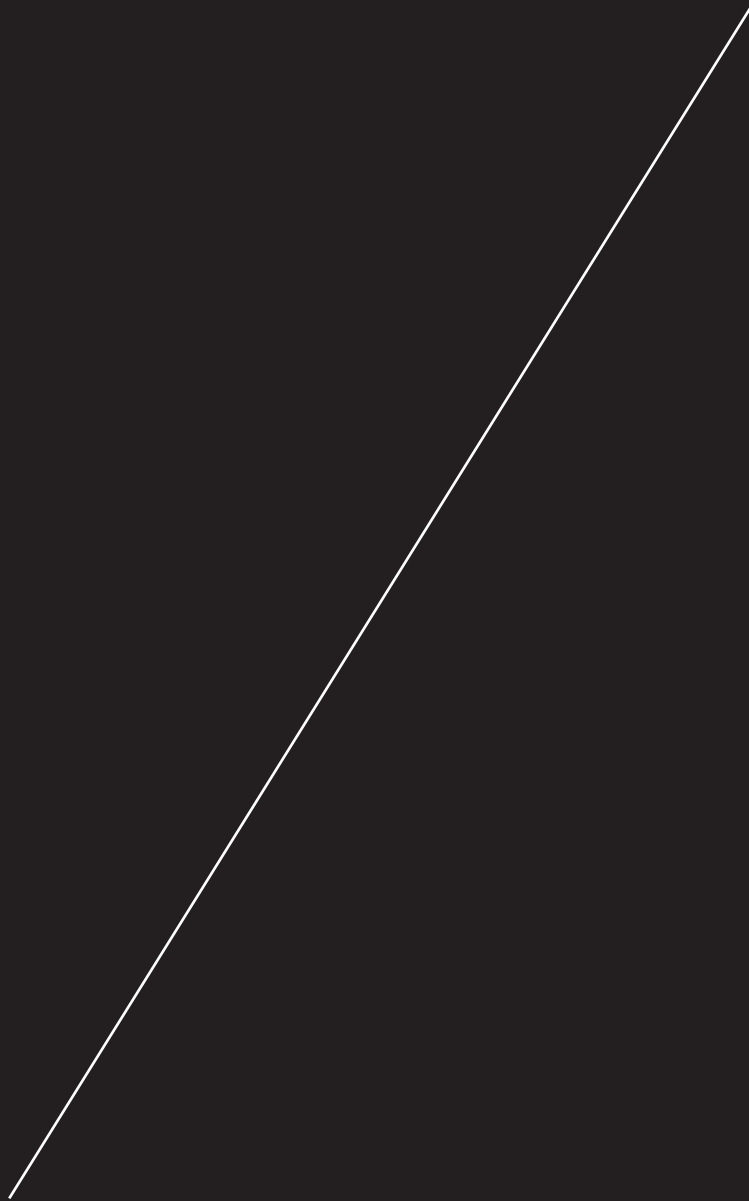
LONDON
Launch of Monitor 1st Ed.
December 2010

20

DOHA
UNFCCC COP18
Official Forum Side Event
November 2012

CLIMATE VULNERABILITY MONITOR

KEY ISSUES



ADDITIONAL DEATHS



2010 · 20,000
2030 · 45,000



2010 · 2,750
2030 · 3,500



2010 · 2,500
2030 · 3,500



2010 · 55,000
2030 · 80,000



2010 · 85,000
2030 · 150,000



2010 · 3.1 MILLION
2030 · 3.1 MILLION



2010 · 35,000
2030 · 35,000



2010 · 1.4 MILLION
2030 · 2.1 MILLION



2010 · 30,000
2030 · 40,000



2010 · 20,000
2030 · 20,000



2010 · 225,000
2030 · 380,000

ADDITIONAL COSTS



2010 · 29
2030 · 213



2010 · 20
2030 · 61



2010 · 66
2030 · 565



2010 · 52
2030 · -11



2010 · 491
2030 · 3,461



2010 · 296
2030 · 1,749



2010 · 23
2030 · 106



2010 · 172
2030 · 630



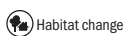
Climate



Carbon



Environmental disasters



Habitat change



Health



Industry stress





\$ = Billion USD PPP (2010 non-discounted) - negative values show gains

AFFECTED GROUPS

 ARID REGIONS 

 FARMERS     

 CYCLONE BELT COUNTRIES 

 SIDS 

 ARID FORESTED ZONES 

 DEFORESTATION ZONES 

 INDIGENOUS GROUPS   

 DRYLAND COMMUNITIES 

 AFRICA  

 HUMID TROPICAL COUNTRIES  

 PREGNANT WOMEN   

 SMALL CHILDREN  

 ELDERLY      

 ARCTIC COMMUNITIES 

 MOUNTAINOUS COMMUNITIES  

 SMALL ISLANDS    

 LOW-ELEVATION COASTAL COMMUNITIES 

 COASTAL CITIES 

 SUBSISTENCE FARMERS    

 WATER-INTENSIVE INDUSTRIES 

 CHILDREN    

 INFANTS   

 LOWER-INCOME COMMUNITIES/GROUPS  

 CHRONIC DISEASE SUFFERERS 

 OUTDOOR WORKERS 

 CITIES  

 SUBSISTENCE FISHERFOLK  

 REMOTE COMMUNITIES  

 SAHEL MENINGITIS BELT 

 YOUNG ADULTS 

 TROPICAL COUNTRIES 

 LIVELIHOODS DERIVED FROM FISHING 

 ENERGY COMPANIES 

 BEACH RESORTS 

 LOW-ELEVATION WINTER RESORTS 

 DENSELY POPULATED RIVER WAYS 

 OIL SAND HOST COMMUNITIES 

 COASTAL COMMUNITIES 

 TROPICAL FOREST COMMUNITIES/ZONES  

 NEWLY-INDUSTRIALIZED COUNTRIES 

 TRANSITION ECONOMIES  

 INDUSTRIALIZED COUNTRIES  

 WOMEN 

 RURAL POPULATIONS WITH POOR ENERGY ACCESS 

 COAL MINERS 

 VEHICLE DRIVERS 

 COAL AND GAS POWER PLANT WORKERS 

 FAIR SKINNED 

 DEVELOPED COUNTRIES 

 CHINA 

 RIVER BASINS 

 OUTDOOR OCCUPATIONS 

 MIDDLE INCOME COUNTRIES 

 HEAVILY LABOURING WORKERS 

 LOWER INCOME COMMUNITIES  

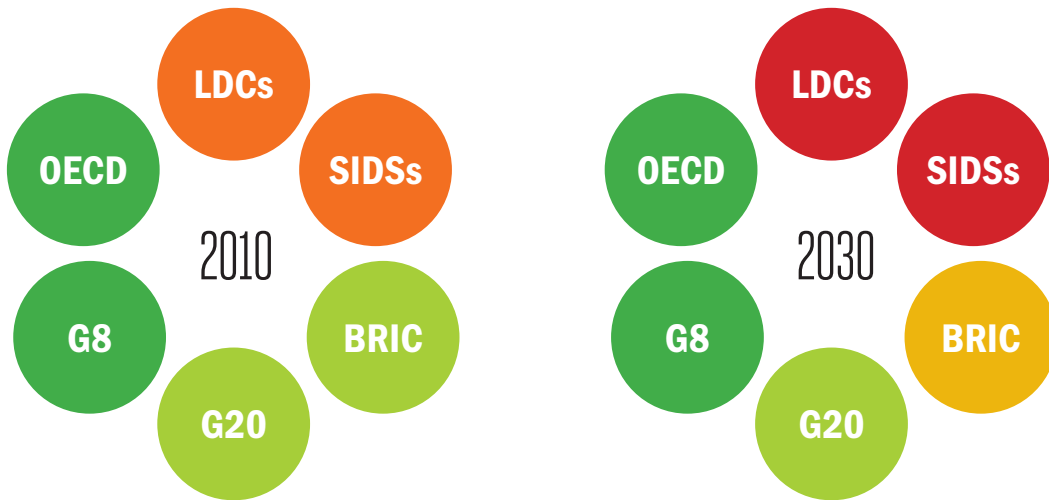
 FISHERMEN 

-  Drought
-  Floods & landslides
-  Storms
-  Wildfires
-  Biodiversity
-  Diarrheal infections
-  Heat & cold illnesses
-  Hunger
-  Malaria & vector-borne
-  Meningitis
-  Desertification
-  Heating and Cooling
-  Labour productivity
-  Sea level rise
-  Agriculture
-  Fisheries
-  Tourism
-  Water
-  Forestry
-  Hydro Energy
-  Transport
-  Permafrost
-  Biodiversity
-  Fisheries
-  Oil sands
-  Air pollution
-  Indoor smoke
-  OIL Spills
-  Water
-  Skin cancer
-  Agriculture
-  Forestry
-  Corrosion
-  Occupational hazards

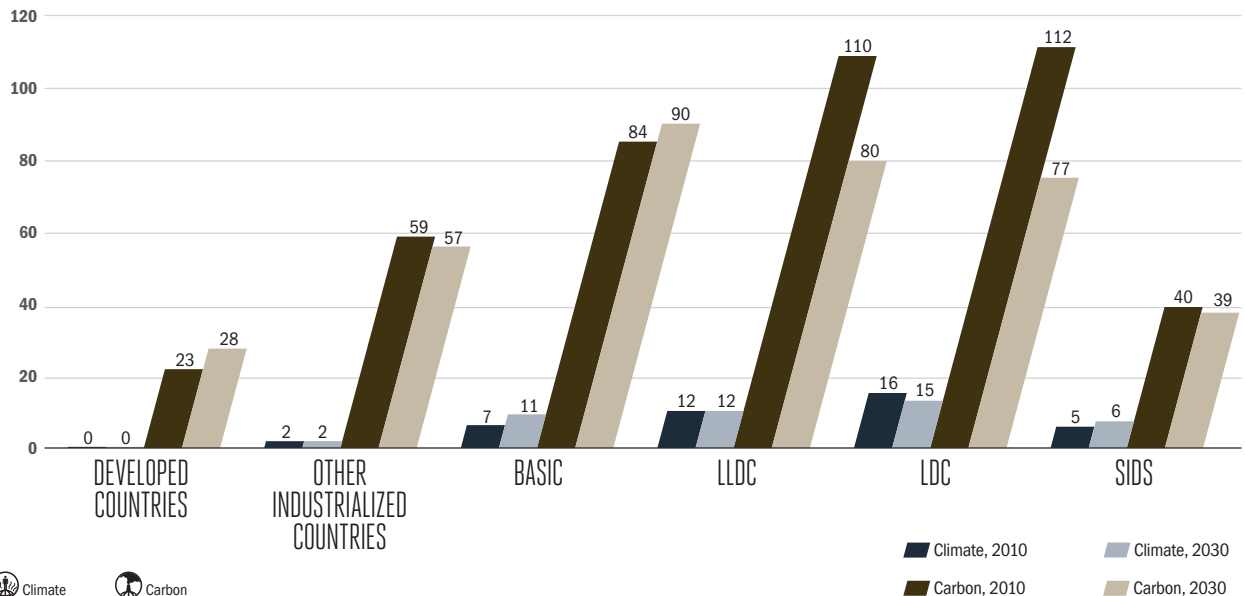
GEOPOLITICS



CLIMATE



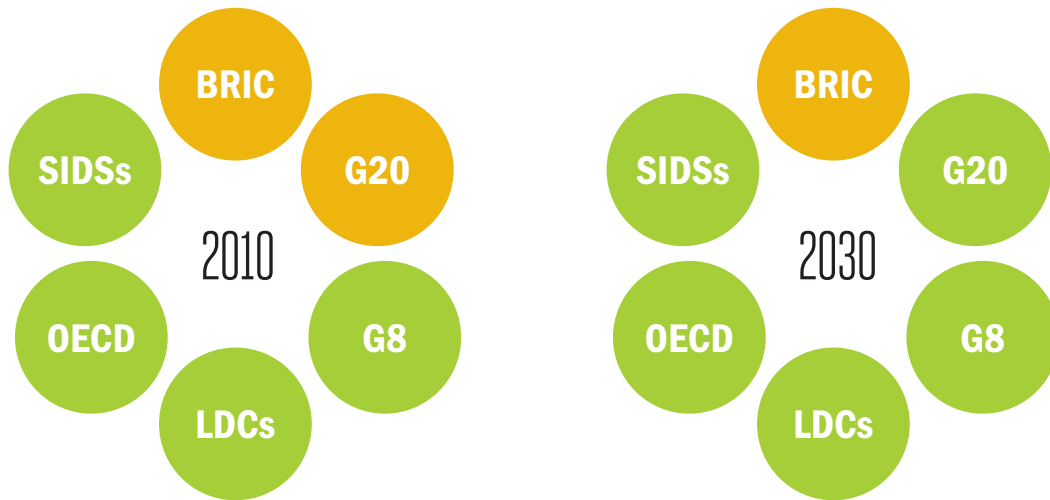
DEATHS DUE TO CLIMATE AND CARBON PER 100,000



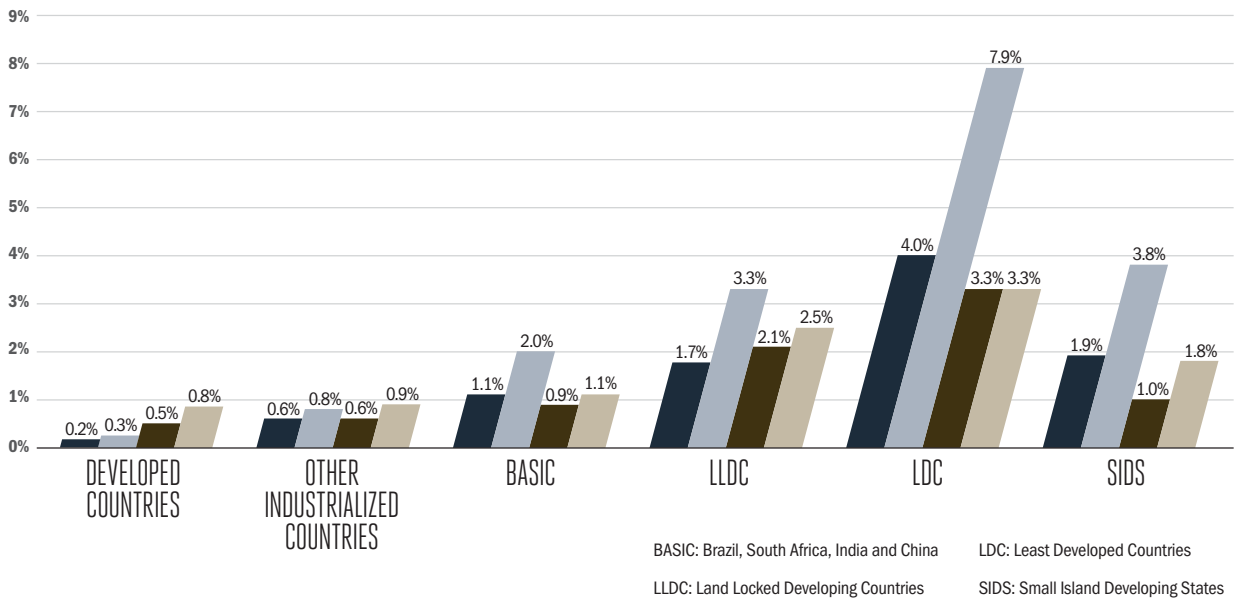
● Acute ● Severe ● High ● Moderate ● Low



CARBON



COSTS DUE TO CLIMATE AND CARBON, % OF GDP



HOTSPOTS



CLIMATE



2010 2030



2010 2030





CARBON



2010 2030



2010 2030



MILLENNIUM DEVELOPMENT GOALS



**END EXTREME
POVERTY & HUNGER**



**UNIVERSAL
EDUCATION**



**GENDER
EQUALITY**



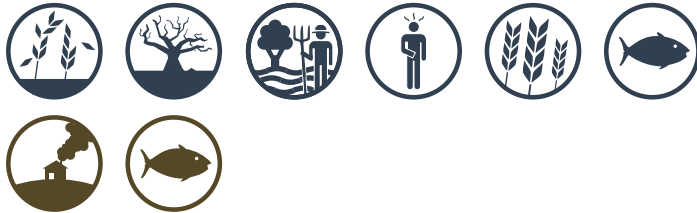
**CHILD
MORTALITY**



- Floods & landslides
- Storms
- Diarrheal infections
- Heat & cold illnesses
- Hunger
- Malaria & vector-borne
- Meningitis
- Drought
- Biodiversity
- Desertification
- Heating and Cooling
- Labour productivity
- Sea-level rise
- Agriculture
- Fisheries
- Tourism
- Water
- Forestry
- Hydro Energy
- Biodiversity
- Fisheries
- Oil sands
- Air pollution
- Indoor smoke
- Oil Spills
- Water



**MATERNAL
HEALTH**



**COMBAT
HIV/AIDS
& INFECTIOUS
DISEASES**



**ENVIRONMENTAL
SUSTAINABILITY**



INJUSTICE



- Floods & landslides
- Storms
- Diarrheal infections
- Heat & cold illnesses
- Hunger
- Malaria & vector-borne
- Meningitis
- Wildfires
- Permafrost
- Forestry
- Tourism
- Desertification
- Fisheries
- Sea-level rise
- Hydro Energy
- Transport
- Biodiversity
- Heating & Cooling
- Drought
- Labour Productivity
- Water
- Agriculture



2010 2030



2010 2030

EUROPE

EASTERN EUROPE



NORTHERN EUROPE



WESTERN EUROPE



SOUTHERN EUROPE



ASIA-PACIFIC

AUSTRALASIA



CENTRAL ASIA



EAST ASIA



MIDDLE EAST



PACIFIC



RUSSIA/NORTH ASIA



SOUTH ASIA



SOUTHEAST ASIA



2010 2030



2010 2030

AMERICAS

CARIBBEAN



CENTRAL AMERICA



NORTH AMERICA



SOUTH AMERICA



AFRICA

CENTRAL AFRICA



EAST AFRICA



NORTH AFRICA



SOUTHERN AFRICA



WEST AFRICA



CLIMATE FINANCE



PRIORITY



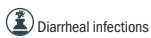
Climate



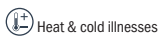
Floods & landslides



Storms



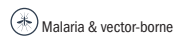
Diarrheal infections



Heat & cold illnesses



Hunger



Malaria & vector-borne



Meningitis



Wildfires



Permafrost



Forestry



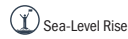
Tourism



Desertification



Fisheries



Sea-Level Rise



Hydro Energy



Transport



Biodiversity



Heating & Cooling



Drought



Labour Productivity



Water



Agriculture

In 2010, developed countries provided 14 billion dollars of their Official Development Assistance (ODA) as climate finance, a significant increase from around 7 billion in 2009. However, the degree to which these resources are “new and additional” as agreed at the international climate change talks at Copenhagen and Cancún is seriously in question. The Fast Start Finance target of 30 billion dollars over the three years from 2010 to 2012 would imply approximately 10 billion dollars’ worth of new climate finance per year. While collectively climate finance for 2010 was a respectable 7 billion dollars higher than in 2009, only 5 billion is derived from increases in donors’ ODA volumes – i.e. approximately 2 billion dollars of those resources have been either diverted or reclassified from existing ODA flows.

If, however, other commitments related to ODA are taken into account, the level of “additionality” and new finance diminishes considerably. In the 1970s, a collective commitment to provide 0.7% of the Gross National Income (GNI) of developed countries as ODA to developing countries was agreed to in the UN General Assembly. That commitment has been consistently met by a handful of developed country donors since the mid-1970s and has been reconfirmed in numerous official international contexts. The 2005 G8 summit at Gleneagles and the UN 2005 World Summit, which launched the Millennium Development Goals for 2015, saw a spate of new ODA commitments – including countries far behind the 0.7% target – all attempts to reach 0.7% by 2015, with interim ODA volume goals for 2010.

Only 2 billion dollars of new climate finance for 2010 is actually additional to these targets for progressing towards 0.7% of GNI or flows above that – commitments that had already been made by the same group of countries in order to support the achievement of the Millennium Development Goals, among other sustainable development

priorities, such as Agenda 21. Given that today still only a fraction of countries have actually provided in excess of 0.7% GNI as ODA, just 1 billion dollars of new climate finance alone can be considered additional to this particular commitment.

To the degree, therefore, that commitments on climate finance are delivering, they are also unquestionably at the expense of previous commitments to related sustainable development priorities. Neither is the picture for 2011 likely to be substantively different, since under preliminary reporting, overall ODA has increased by just 3.9%, broadly enough to keep up with one year of global inflation over this period as reported by the International Monetary Fund. Furthermore, almost 90% of this finance was targeted towards mitigation activities, with 14% committed to adaptation – a clear discrimination versus the agreements made at Copenhagen and Cancún, whereby it was firmly agreed that there would be a balance of resources for the two purposes.

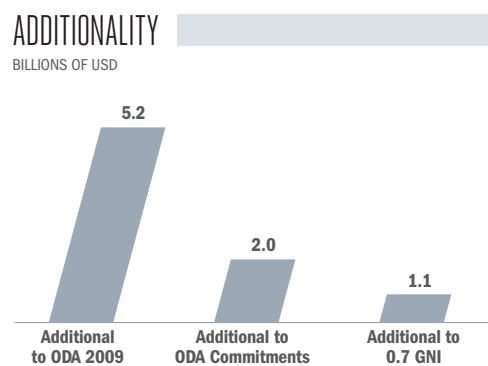
Financial flows in the form of aid or climate finance have been central to policy debate and intergovernmental negotiations for responses to sustainable development challenges and climate change. But ODA-related flows are only a fraction of the picture. Investment linked to projects of the UNFCCC’s Clean Development Mechanism, for instance, are now several times the level of climate finance through ODA. More than half of ODA is, in any case, concessional debt – and a possible liability. More than half of all CDM projects, on the other hand, are estimated to result in a technology transfer of one form or another – a further bonus. Despite this, the CDM arguably absorbs much less of the attention of policy makers than finance. This is partly ascribed to the faltering political support currently enjoyed by the Kyoto Protocol mechanism. But the fact that China to-date accounts for almost 80% of all CDM investments by volume,

and India for another 15%, does mean all other developing countries capture just over 5% of any investment flows. Many countries have no CDM projects at all and no national capacity to register CDM projects.

In an ongoing financial and economic crisis that runs parallel to time-restricted policy windows for addressing core global concerns such as climate change, a heavy reliance on further delivery through ODA finance is clearly a restrictive avenue of action. The example of the CDM also demonstrates

the large-scale impact possible through policy frameworks with a bearing in the private sector, as opposed to ODA finance efforts, even when these are only moderately effective (given CDM coverage limitations alone). Effective policies for technology development and transfer, capacity building and regulatory mechanisms have the potential to yield significant impact in terms of implementation of sustainable development visions, including in the climate agenda, the Rio agenda and otherwise.

Climate change finance from developed countries to developing countries is reported by all donors as a part of their Official Development Assistance (ODA). This analysis was based on the Organization for Economic Co-operation and Development’s (OECD) CRS database – the only truly comprehensive and comparable source of financial tracking available, although it is exclusively a donor reporting mechanism. Research focused on the latest data accessible, which is for the year 2010. 2010 is also the first year of so-called Fast Start Finance – additional commitments to climate change finance agreed at the UN Climate Summit at Copenhagen (COP15) and further confirmed at the next Summit in Cancún (COP16). The analysis has benefitted from the Rio markers for climate change used by donor governments and the OECD. Only finance to projects reported to have climate change as a principal objective were included in the analysis so as to retain comparability with sector-based development finance analysis, where partially related funding is ignored. That focus also partly addresses further concerns over the misrepresentation and double-counting of a share of climate finance as reported by other recent independent research into the topic. The approach used here represents just one perspective on monitoring international climate finance flows; other methodologies could have been chosen and would have likely yielded different results and conclusions.



INDICATOR OVERVIEW

Impact Areas	Indicators	Confidence	Severity	Surge	Injustice	Priority	Gender Bias	Affected Country Group	
								A	R
CLIMATE	DROUGHT	✓	⚠️ ⚠️	▶	⚖️	⋯			
	FLOODS & LANDSLIDES	✓	⚠️ ⚠️	▶▶	⚖️	⋯	♀		
	STORMS	✓	⚠️ ⚠️ ⚠️	▶▶	⚖️	⋯			
	WILDFIRES	✓	⚠️	▬▬	⚖️	⋯			
	BIODIVERSITY	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶	⚖️	⋯			
	DESERTIFICATION	✓	⚠️ ⚠️	▶	⚖️	⋯			
	HEATING & COOLING	✓	⚠️	▶▶	⚖️	⋯			
	LABOUR PRODUCTIVITY	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶	⚖️	⋯	♀ ♂		
	PERMAFROST	✓	⚠️ ⚠️ ⚠️	▶▶	⚖️	⋯			
	SEA-LEVEL RISE	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶	⚖️	⋯			
	WATER	✓	⚠️ ⚠️ ⚠️	◀	⚖️	⋯			
	DIARRHEAL INFECTIONS	✓	⚠️ ⚠️ ⚠️	▶	⚖️	⋯			
	HEAT & COOL ILLNESSES	✓	⚠️ ⚠️	◀	⚖️	⋯			
	HUNGER	✓	⚠️ ⚠️ ⚠️ ⚠️	▶	⚖️	⋯			
	MALARIA & VECTOR BORNE	✓	⚠️ ⚠️	▬▬	⚖️	⋯			
	MENINGITIS	✓	⚠️ ⚠️	▶	⚖️	⋯			
	AGRICULTURE	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶	⚖️	⋯			
	FISHERIES	✓	⚠️ ⚠️ ⚠️	▶▶▶	⚖️	⋯			
	FORESTRY	✓	⚠️ ⚠️	▶▶	⚖️	⋯			
	HYDRO ENERGY	✓	⚠️	◀	⚖️	⋯			
TOURISM	✓	⚠️ ⚠️	▬▬	⚖️	⋯				
TRANSPORT	✓	⚠️ ⚠️	▶	⚖️	⋯				
WORLD									
CARBON	OIL SANDS	✓	⚠️ ⚠️	▶▶					
	OIL SPILLS	✓	⚠️ ⚠️ ⚠️	◀					
	BIODIVERSITY	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶					
	CORROSION	✓	⚠️ ⚠️	▶					
	WATER	✓	⚠️ ⚠️	◀					
	AIR POLLUTION	✓	⚠️ ⚠️ ⚠️ ⚠️	▶▶▶					
	INDOOR SMOKE	✓	⚠️ ⚠️ ⚠️ ⚠️	◀			♀		
	OCCUPATIONAL HAZARDS	✓	⚠️ ⚠️ ⚠️	▶			♂		
	SKIN CANCER	✓	⚠️ ⚠️	▶					
	AGRICULTURE	✓	⚠️ ⚠️	◀◀					
	FISHERIES	✓	⚠️ ⚠️	▶▶					
	FORESTRY	✓	⚠️ ⚠️ ⚠️	▶▶					
WORLD									

Absolute (largest overall share of total negative impact)
 Relative (highest share of total losses vs. GDP/per capita)
 Model
 Emission scenario
 Additional mortality - yearly average

Info		Change			Impact				
Mo	ES	☠	\$	#	2010 ☠	2030 ☠	2010 \$	2030 \$	
Corti et al., 2009; Hoekstra et al., 2010; Rubel and Kottek, 2010; Sheffield and Wood, 2007	SRES A1B (IPCC, 2007)		☝71%	10			5,000	20,000	🌳
Kharin et al., 2007	SRES A1B (IPCC, 2007)	☝4%	☝231%	8	2,750	3,500	10,000	95,000	🌳
Donat et al., 2011; Mendelsohn et al., 2011	IPCC SRES A1B (IPCC, 2000)	☝24%	☝129%	7	2,500	3,500	15,000	100,000	🌳
Krawchuk et al., 2009	IPCC SRES A2 (IPCC, 2000)		☝106%	14			-15	-90	🌳
Baumgartner et al., 2012; Thomas et al., 2004	IPCC SRES A1B (IPCC, 2000)		☝74%	3			80,000	400,000	🌳
Hansen et al., 2007	IPCC SRES A1B (IPCC, 2000)		☝56%	11			5,000	20,000	🌳
Isaac et al., 2008	TIMER/IMAGE reference scenario for the ADAM project (Isaac et al. 2008)		☝19%	22			-35,000	-75,000	☢
Euskirchen, 2006; Kjellstrom et al., 2009	SRES A2 (IPCC, 2000)		☝174%	1			300,000	2,500,000	🌳
Hoekstra et al., 2010; Nelson et al., 2001	UKTR GCM-based scenario (Nelson et al., 2001)		☝71%	5			30,000	150,000	☢
DIVA, 2003	A1F1 (IPCC, 2000)		☝115%	2			85,000	550,000	🌳
Hoekstra et al., 2010; McKinsey and Company, 2009; Nohara, 2006; Portmann et al., 2010; Rosengrant et al., 2002	IPCC SRES A1B (IPCC, 2000)		☝68%	12			15,000	15,000	💧
McMichael et al., 2004	S750 (IPCC, 2007)	☝56%		15	85,000	150,000			🌳
Curriero et al., 2002; Knutti et al., 2008; Toulemon and Barbieri, 2006; Van Noort et al., 2012	IPCC SRES A1B (IPCC, 2000)	☝20%		16	35,000	35,000			🌳
McMichael et al., 2004	S750 (IPCC, 2007)	☝42%		17	225,000	380,000			🌳
McMichael et al., 2004	S750 (IPCC, 2007)	☝15%		18	20,000	20,000			🌳
Adamo et al., 2011; Sheffield and Wood, 2008	SRES A1B (IPCC, 2000)	☝25%		19	30,000	40,000			🌳
Cline, 2007	Cline, 2007		☝157%	4			50,000	350,000	🌳
Cheung et al., 2010; O'Reilly et al., 2003	SRES A1B (IPCC, 2000)		☝355%	6			15,000	150,000	🌳
US Forest Service (2010)	SRES A1B (IPCC, 2000)		☝182%	9			5,000	45,000	🌳
Lehner, 2003; Nohara, 2006	SRES A1B (IPCC, 2000)		☝134%	21			-5,000	-25,000	🌳
ECLAC, 2011; Steiger, 2011	SRES A1B (IPCC, 2000)			20					🌳
Jonkeren et al., 2011; Nohara et al., 2006	SRES A1B (IPCC, 2000)		☝96%	13			1,000	5,000	🌳
					400,250	632,000	575,985	4,299,910	
CAPP, 2011; CERES, 2010			☝12%	5			5,000	25,000	🌳
Muehlenbachs et al., 2011; Schmidt, 2004; Westwood, 2010			☝5%	3			10,000	40,000	🌳
Costanza, 2006; Hooper, 2012; Reilly, 2008			☝109%	1			300,000	1,750,000	🌳
OECD, 2012			☝24%	7			1,000	5,000	🌳
OECD, 2012			☝18%	6			5,000	10,000	💧
Bell et al., 2007; OECD, 2012; Sheffield et al., 2011		☝32%		8	1,400,000	2,100,000			🌳
OECD, 2012		☝17%		9	3,100,000	3,100,000			🌳
BP, 2012; Mathers and Loncar, 2006		☝26%		10	55,000	80,000			🌳
Martens, 1998; WHO IARC, 2005		☝87%		11	20,000	45,000			🌳
Avnery, 2011; Hansen et al., 2007; Ramanathan et al., 2008; World Bank, 2005		☝494%		12			15,000	-150,000	🌳
IGBP-DIS SoilData(V.0), 2008; OECD, 2012		☝203%		2			10,000	75,000	🌳
Costanza et al., 1997; OECD, 2012; Reilly, 2008; Wentzel, 1982		☝5%		4			30,000	85,000	🌳
					4,575,000	5,325,000	376,000	1,840,000	

⑤ Additional economic costs in 2010 USD (negative numbers show gains) (thousands) - yearly average

Order no. of impact by overall economic scale versus the climate section (or carbon section for carbon indicators)

A VERY SHORT
HISTORY
OF CLIMATE
SCIENCE



CLIMATE CHANGE HAS BEEN SUBJECT TO SCIENTIFIC AND POPULAR DEBATE FOR WELL OVER A CENTURY.

The greenhouse effect was first proven by Irish physicist John Tyndall in 1859. The possibility of human-engineered global warming was raised by the Nobel Laureate Swedish chemist Svante Arrhenius in 1896 (Tyndall, 1869; Arrhenius, 1896). Arrhenius initially concluded that a doubling of atmospheric carbon dioxide (to over 550ppm) might result in 5–6 degrees Celsius (9–11° Fahrenheit) of warming. This estimation is closely aligned with current science: the prediction falls just outside the confidence intervals of the latest reference scenarios of the Intergovernmental Panel on Climate Change (IPCC) (Arrhenius, 1896; IPCC, 2000). At the then current rates of emissions Arrhenius thought the process might take millennia. However, a decade later, after observing the intervening rise in industrial CO₂ emissions, Arrhenius revised the warming timeframe to just a few centuries (Arrhenius, 1908). In the 1930s, English engineer Guy

Stewart Callendar was the first to report an actual warming trend and to ascribe it to human activities. The “Callendar effect”, estimated then as an annual temperature increase of 0.005°C, was still not on timescales relevant to people but might usefully impede the onset of a new ice age (Callendar, 1938; Weart, 2011). Subsequent technological progress improved monitoring of CO₂ and temperature, boosting evidence for human-induced climate change. This led the American physicist Gilbert Plass to assert in 1956 that a doubling or halving of atmospheric CO₂ would lead to an increase or decrease in temperature of around 3.5°C or 6.3°F (Kaplan, 1952; Plass, 1956). It was thought warming would be evident by the end of the century. By the mid-1980s, records of atmospheric CO₂ and temperature frozen in time kilometres deep in Antarctic ice cores confirmed the relationship between GHG emissions and climate change on the basis of 150,000 years of meteorological history (Lorius et al., 1986; Mayewski and White, 2002). By the end of the century, the record had been



extended to over 400,000 years, strengthening the conclusions, and confirming the unprecedented nature of contemporary levels of CO₂ in the Earth’s atmosphere (Petit et al., 1999). By 1990, and publication of the first assessment report by the IPCC, the scientific community had reached a firm understanding and generalized level of agreement over the basic characteristics of climate change, the central role of human activities in shaping it and the potential danger for people alive today (IPCC, 1990). It constituted a wake-up call to policy-makers to address climate change. In 1992, the UN Framework Convention on Climate Change marked the international community’s first step towards a serious response (UNFCCC, 1992). At the turn of the century, warming of the planet and the increase of GHG emissions in faithful synchrony was observationally manifest (IPCC, 2001). By 2007, it had become scientifically indisputable (IPCC, 2007).

TABLE VII.—Variation of Temperature caused by a given Variation of Carbonic Acid.

Latitude	Carbonic Acid=0.01					Carbonic Acid=0.1					Carbonic Acid=1.0					Carbonic Acid=25				
	Max.	Min.	Mean.	Diff.	Max.	Min.	Mean.	Diff.	Max.	Min.	Mean.	Diff.	Max.	Min.	Mean.	Diff.	Max.	Min.	Mean.	Diff.
75	-20	-84	-54	34	-21	-83	-54	33	-22	-82	-53	34	-23	-81	-52	35	-24	-80	-51	36
60	-20	-74	-47	27	-20	-74	-47	27	-20	-74	-47	27	-20	-74	-47	27	-20	-74	-47	27
45	-20	-64	-42	22	-20	-64	-42	22	-20	-64	-42	22	-20	-64	-42	22	-20	-64	-42	22
30	-21	-54	-37	17	-21	-54	-37	17	-21	-54	-37	17	-21	-54	-37	17	-21	-54	-37	17
15	-21	-44	-32	12	-21	-44	-32	12	-21	-44	-32	12	-21	-44	-32	12	-21	-44	-32	12
0	-21	-34	-27	7	-21	-34	-27	7	-21	-34	-27	7	-21	-34	-27	7	-21	-34	-27	7
-15	-21	-24	-22	2	-21	-24	-22	2	-21	-24	-22	2	-21	-24	-22	2	-21	-24	-22	2
-30	-21	-14	-17	4	-21	-14	-17	4	-21	-14	-17	4	-21	-14	-17	4	-21	-14	-17	4
-45	-21	-4	-12	1	-21	-4	-12	1	-21	-4	-12	1	-21	-4	-12	1	-21	-4	-12	1
-60	-21	6	-8	0	-21	6	-8	0	-21	6	-8	0	-21	6	-8	0	-21	6	-8	0
-75	-21	16	-5	0	-21	16	-5	0	-21	16	-5	0	-21	16	-5	0	-21	16	-5	0

302 Prof. S. Arrhenius on the Influence of Carbonic Acid



THE
MONITOR

THE MONITOR

EXPLAINED

THE CLIMATE VULNERABILITY MONITOR

In mid 2010, the first Climate Vulnerability Monitor (or, “the Monitor”) was commissioned on the initiative of the founding chair of the Climate Vulnerable Forum, the Maldives, as an independent global study of the gathering climate change crisis. The Monitor provides a framework for understanding global vulnerability to climate-related concerns. It enables a weighing of the possible costs, benefits and needs associated with different ways to address this crisis. The framework is grounded in third-party research by dozens of other research groups and scientists assimilated in the Monitor.

Subtitled “The State of the Climate Crisis”, the first Monitor was issued in December 2010 in conjunction with the UN climate change talks in Cancún. DARA developed the report, and two external advisory bodies were formed to solicit wide-ranging third-party input. A second edition of the Monitor was subsequently commissioned in November 2011 at the Ministerial Meeting of the Climate Vulnerable Forum held in Dhaka, Bangladesh. DARA was mandated to develop the second edition of the Monitor, overseen by a joint Steering Group comprising Climate Vulnerable Forum and DARA officials and with continued input from external advisory bodies.

ITS PURPOSE

The Monitor was first assembled to contribute to a fuller understanding of the global climate crisis and to support communities facing serious challenges as a result of this emerging concern. It aims to inform the public and policymakers and help shape more effective climate change policies. The Monitor’s second edition essentially measures the global impact of climate change and the carbon economy in socio-economic terms, both for today and for the near future. In doing so, it reveals information that enables a comparison of the vulnerability of different countries around the world to climate-related effects. It highlights the key issues at hand, assesses the scale of the problem overall and in its different aspects and anticipates the

rates of change and the distribution of effects across various countries. The report is not an attempt to “predict” the future but to explore what implications current patterns of core economic and social activities hold for the near future. Its estimations of socio-economic impact should be considered broad indications as opposed to precision appraisals.

The Monitor is a country-level tool that also provides for sub-regional, regional, geopolitical and global analysis. The development of the Monitor’s second edition further benefitted from in-country research conducted in Ghana and Vietnam; key insights from these exercises are detailed in the relevant sections of this report and have also been used to support analysis elsewhere. The country studies provide an idea of how the Monitor’s information can be employed in national contexts. However, the Monitor is *not* a replacement for regional, national and sub-national analysis in any respect. Any global study involves use of highest-common-denominator information across countries for the sake of comparability. The Monitor is therefore most accurate at the international level and least accurate at sub-national levels. At all levels, however, it is designed to serve as complementary input and as a reference point.

The body of data amassed here could also help establish possible relationships, causal and otherwise, between climate-related phenomena and social and political vulnerabilities, such as propensity to armed violence, instability and migration. This report, for instance, particularly focuses on the relationships between climate-related impacts and transnational flows of

climate change finance and of progress towards the Millennium Development Goals for 2015, the international community’s leading objectives for poverty reduction.

Finally, as the first edition of the Monitor made clear, this report can be improved upon in the future. In spite of its 19th century roots, the science and analysis of climate change is still a relatively new field of study as conventionally defined, and it is evolving rapidly. Several of the indicators in this report rely on information that was not available when the first Monitor was being developed only two years ago. Only a few of the indicators in the report rely on studies published prior to the last major IPCC report in 2007. Its practical shelf-life depends on how quickly this highly active and interdisciplinary field continues to advance.

ITS USERS

The Monitor is specifically prepared to serve as a resource to Climate Vulnerable Forum officials tasked with negotiations and policy development related to climate change. The Monitor has also been used by analysts, policy makers, senior representatives and topic specialists from the following groups:

- Civil society organizations
- Development Aid agencies and intergovernmental and international non-governmental humanitarian and development organizations
- Financial institutions, such as investment banks
- Government climate change, environment, foreign affairs and resources or planning departments
- Heads of state and government
- Journalists, commentators, bloggers

- and the wider media
- Lead climate change negotiators active in the UN talks
- Members or representatives of parliaments in developed and developing countries
- NATO member military intelligence institutions and strategic studies groups
- Research institutions and think tanks with a development, humanitarian or environment focus

APPLICATIONS

The data and perspectives the Monitor provides have been used for a number of applications, including policy development guidance, resource allocation, financial analysis and communication on climate-change issues.

Policy Development

With respect to policy development, the Monitor serves as an additional reference for helping national policy makers and international organizations design and calibrate programmes to respond to climate change. This is particularly valuable in lower-income developing countries, where local decision makers might otherwise not be able to afford a third-party reference to compare with the analysis of other foreign consultants and external experts (Ayers, 2010).

A brief review of National Adaptation Programmes for Action lodged with the UN Framework Convention on Climate Change (UNFCCC) highlights the differences and gaps between countries’ existing policies and the assessment here. Labour Productivity, the most serious climate effect in the Monitor, is barely considered. Cooling of indoor space is also a non-issue in most cases. Perhaps more alarming is recent World Health Organization research highlighting that just 3% of resources for priority projects in Least Developed Countries and small island states target health (WHO, 2010). If these policies had been developed while consulting reference publications like the Monitor, oversights and missed priorities would likely have been more readily avoided. And the impact of national policies addressing climate

change might have been enhanced. Another example is the international humanitarian system. The Climate section on Environmental Disasters estimates that in less than 20 years, climate change could cause thousands of deaths and hundreds of billions of dollars in damage due to a further aggravation of weather (this is after accounting for any anticipated reductions in risk as wealth increases). Is the humanitarian system prepared for such rapid increases in the scale of emergencies? Are more capacities, resources and institutional coordination needed to ensure the international community is prepared? Climate change means the world now operates in a highly variable and dynamically evolving natural environment where the future will constantly be different from the past. International policies of all kinds will have to account for such evolutions in medium- to long-term planning in order to remain effective. Climate change should be taken into account when setting agendas and making policies at the village, regional and global level. And decision makers will need to draw on as many different forward-looking studies, such as the Monitor, as possible.

Climate Finance

Because it compares current and future levels of vulnerability to climate change, the Monitor can help decision makers prioritize where to spend their resources. This not only relates to legal obligations under the UNFCCC that developed countries have assumed to help developing countries. It also relates to countries being able to see the benefits and pitfalls of how they allocate resources across various sectors or strategies. There is however no internationally accepted definition of “vulnerable” countries among intergovernmental agencies such as the UNFCCC. Nor is the Monitor an attempt to establish a fixed definition. The Monitor does, however, provide arguments for why a wide range of countries – particularly developing and least developed, land-locked, or small island developing states – may have very serious climate-related vulnerabilities.

15 billion dollars of climate finance currently flow each year from taxpayers in developed countries to developing countries, including just over 2 billion dollars for support to adapt to climate change impacts. Are those resources being allocated according to who is most vulnerable? Are those resources being prioritized according to the co-benefits they would deliver to the environment or human health? There are almost no comprehensive, up-to-date tools for assessing the near-term effects of climate change and the carbon economy and how they differ from country to country. And yet international actors have to make choices about where to focus energies and resources today – and have been doing so for over a decade now. Despite the imperfections of such tools, including this one, policy makers without this kind of reference are passing equally imperfect or worse judgements on these issues or are allowing political, cultural, strategic or military factors to play a determining role in climate change investment decisions. Some combination of all approaches is most likely. However, adding reference points from independent assessments can enrich the decision-making landscape and support more effective and cost-efficient policy.

Business and Investment

This report estimates the extent to which climate change has already affected the global economy, determining the wealth and growth prospects of different countries. As climate change accelerates and triggers new effects, it could have an even larger impact on a country’s economic state. The Monitor provides a range of insights into the risks different countries will face on this front in the near term. Those insights are of interest both for the purpose of analysing a country’s overall risk and for developing investment strategies.

Communication

The Monitor is useful to the lay person as a broad introductory work as well as to politicians and advocates across a variety of organizations that can use the data and analysis to question new or prevailing policies, be they government, corporate or otherwise.

FOCUS AND STRUCTURE

Years


2010 and 2030


Countries

184

Assessments

A global examination of wide-ranging negative and positive effects across two separate climate-related themes.

 **Climate:** The impact of climate change on society.

 **Carbon:** The independent impact of the carbon economy on society (separate from climate change).

Vulnerability Levels

An indicator of the level of vulnerability of a country, region or group to a particular climate or carbon stress in relation to levels experienced by other countries.

● Acute ● Severe ● High ● Moderate ● Low
Most vulnerable Least vulnerable

CLIMATE INDICATORS

ENVIRONMENTAL DISASTERS

Drought
Floods & Landslides
Storms
Wildfires

HABITAT CHANGE

Biodiversity
Desertification
Heating and Cooling
Labour Productivity
Permafrost
Sea-Level Rise
Water


HEALTH IMPACT


Diarrheal Infections
Heat & Cold Illnesses
Hunger
Malaria & Vector-Borne
Meningitis


INDUSTRY STRESS


Agriculture
Fisheries
Forestry
Hydro Energy
Tourism
Transport

Impact Areas

 **Environmental Disasters:** Economic and health effects of environmental disasters generated or worsened by human activity.

 **Habitat Change:** Economic effects of shifts and changes to the environment.

 **Health Impact:** Health and economic effects for different diseases grouped by illness or cause.

 **Industry Stress:** Economic effects experienced by specific sectors of the economy.

CARBON INDICATORS

ENVIRONMENTAL DISASTERS

Oil Sands
Oil Spills

HABITAT CHANGE

Biodiversity
Corrosion
Water

HEALTH IMPACT

Air Pollution
Indoor Smoke
Occupational Hazards
Skin Cancer

INDUSTRY STRESS

Agriculture
Fisheries
Forestry

KEY CONCEPTS AND DEFINITIONS

CLIMATE

Climate is taken to mean the average weather. The classical time period used by the World Meteorological Organization to determine the climate is 30 years. So the climate is the average weather over a given period of 30 years. Parameters such as temperature, rainfall and wind can be examined to determine key characteristics of the state of the climate at different periods in time, and to identify variation across time periods. The section of the Monitor labelled "Climate" is concerned with the socio-economic effects of a changing climate.

CLIMATE CHANGE

Climate change is a change in average weather. For the purpose of this study, it is assumed that human activities are the principal and overwhelming – if not exclusive – cause of the contemporary warming of the climate, in accordance with the broad consensus and more recent evidence on this subject (IPCC, 2007; Rohde et al., 2012; Muller, 2012).

According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change occurs "in addition to natural climate variability observed over comparable time periods" (UNFCCC, 1992). The Monitor controls for natural variability in a number of ways, including by judging all impacts against a 1975 baseline period (i.e. the change in temperature and other variables versus the 1975 climate), even though considerable warming of the climate system had occurred well prior to 1975. Therefore the Monitor's assessment of climate change should be understood to align with that of the UNFCCC.

Climate change is caused by alterations to the composition of the Earth's atmosphere, in particular, through emissions of GHGs such as CO₂, and through changes to the land, such as through deforestation and land conversions. The process

is additionally tempered by a range of positive or negative environmental feedbacks, for instance the extent of heat-reflective sea ice in the Arctic. Climate change has as its consequences a wide variety of environmental, social and economic effects, many of which are the subject of this report. These consequences are the exclusive focus of the first part of the Monitor's assessment, labelled "Climate".

CLIMATE VULNERABILITY

Climate vulnerability, or vulnerability to climate change, is taken to mean the degree to which a community experiences harm as a result of a change in climate. These communities may be regional, sub-regional, national, sub-national, or other. Vulnerability encapsulates socio-economic concerns, such as income levels, access to information, education, social safety nets and other meaningful determinants of the resilience of a given community. It also encapsulates environmental or so-called "bio-physical" factors, such as geographic location, topography, natural resource supplies, vegetation and otherwise. A community's vulnerability in all these respects may be determined intrinsically, for example, through a local government's aversion to corruption, or exogenous factors, such as globalized markets.

The definition of "vulnerability" used here aligns closely with the IPCC definition, termed "outcome vulnerability" – higher levels of harm are the outcome in large part of higher levels of vulnerability, and vice versa, impacts are lower where vulnerability is lower (IPCC, 2007; Füssel, 2009). The Monitor's concept of vulnerability, therefore, is a composite of exposure and vulnerability and may also be referred to as "risk" (Peduzzi et al., 2012a).

CARBON

Carbon dioxide (CO₂) is a principal greenhouse gas along with numerous other "heat-trapping" pollutants, such as methane, black carbon or nitrous oxide. Like these other pollutants, CO₂ is typically generated as a by-product of combustion when carbon-based fuels – e.g. coal, oil, charcoal/wood, natural gas – are burned. So the terms "carbon" and "carbon economy" have come to embody the problem at the root of the climate challenge and are used here as a blanket name for all greenhouse pollutants that are related to human activity and can cause climate change, or detract from resolving it. Not covered under the rubric of "Carbon" is the full breadth of socio-economic impacts related to the industrial economy. Toxic factory refuse, industrial solvent disposal and waste, or agricultural pesticides and other such issues are deliberately not considered here. The Monitor also assumes that any societal or environmental costs of a low-carbon economy, i.e. externalities of renewable or low-emissions energy solutions, are negligible with respect to this framework of analysis, since carbon intensive energy modes generate 10 to 100+ times greater negative externalities for the environment and society than low-carbon alternatives (IPCC, 2012b).

ADAPTATION

Adaptation is understood as actions that help communities or their ecosystems cope with a changing climate, in particular, steps that reduce any losses or harm inflicted. The IPCC defines adaptation as an adjustment in natural or human systems to reduce the harm or exploit the benefits of actual or expected climatic stimuli or their effects. Although there is variation from indicator to indicator, the Monitor does assume communities have a baseline capacity to adapt and that a degree of forced adaptation is already occurring. This is seen in

various socio-economic datasets that underlie certain indicators. So, for instance, the level of mortality risk for Bangladesh estimated by the UN reflects the current sum of exposure and vulnerability there, including any efforts that have been made to adapt to a changing climate. The Climate Water indicator is another example, where the line between impact and adaptation blurs since the assumption is that the next cheapest option will be chosen to replace lost water resources at cost and according to demand, so the value of water lost or gained is its market value. In addition, the Monitor has made various dynamic adjustments, such as adjusting a community's vulnerability measure due to its economic growth prospects. For Climate and Carbon health indicators, for instance, there is strong evidence that many diseases decline as countries gain in wealth, so that is accounted for in the Monitor (Mathers and Loncar, 2005).

MITIGATION

Mitigation is broadly understood as action that stems global warming, i.e. that mitigates the warming effect. The IPCC defines mitigation as human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation policies could be programmed to minimize the negative (and positive) impacts measured in the Carbon part of the Monitor. In the scenarios and indicators of the Climate and Causes section, the Monitor has factored in carbon use or emissions according to reference scenarios – the IPCC's mid to high A1B scenario is the most common assumption used (IPCC SRES, 2000).

USING THE MONITOR

The Monitor is divided into three main parts: first, a region-by-region, then country-by-country overview of the assessment for all 184 countries included in the analysis; then the two key sections, Climate and Carbon.

These detailed sections provide data and an explanation for each indicator and detail the principal causes and effects for each instance.

The Monitor's second edition is not directly comparable with the 2010 Monitor because updates to the methodology, including a significant expansion in the breadth of analysis, make the new edition substantially more comprehensive than the original.

The country studies follow the Climate section, as their focus relates primarily to the Monitor's Climate assessment. And the report provides an analysis of the interrelationships between Climate and Carbon as a bridge between the two sections. The reader will find country-level information for each of the report's 34 indicators. The data tables and the upper map of each indicator groups countries by their level of vulnerability. The level given, which is for 2030, assumes that no deliberately scaled-up attempts will be made to reduce risks. The climate change impact in 2030 is understood to be largely committed because the oceans have absorbed a certain amount of heat that they will release back into the atmosphere, ensuring continued warming for decades to come (Hansen et al., 2005). Figures in absolute terms are given either in mortality or US dollars (2010 PPP) or both. Other metrics are provided for some of the indicators where appropriate and feasible.

The values given represent this research project's best estimates of possible country-level outcomes. Larger countries invariably have larger impacts when measured in absolute terms, but the level of vulnerability registered identifies the intensity of the effects relative to size. The figures are basically averages and, despite the impression of precision

they convey, it's important to note that it is nearly impossible to achieve any real precision. All figures should be considered plausible but simply a broad indication of the level of impact that could be expected.

CONFIDENCE

It is also important to note, when reviewing information at the indicator level, that each indicator has been assigned a level of "Confidence" and, in the case of the Climate section, "Regional Climate Uncertainty". Confidence is noted as "Robust" (highest confidence), "Indicative", or "Speculative" (least confidence). That evaluation is based on judgements that are explained in this book's Navigator and in more detail in the Monitor's methodological annex at: www.daraint.org/cvm2/method.

Localized Uncertainties

Climate outcomes are deemed more certain for some regions than for others. Therefore, the Climate section includes maps of regional climate uncertainty (lower map). These indicate the level of disagreement among leading climate models by region on whether there will be increases or decreases in the main driving climate variables, such as rainfall or temperature. When uncertainty is "Limited", it denotes for instance that less than 10% of models disagree for that region on an increase or decrease. When it is "Considerable", more than one third of models disagree. This information is particularly relevant for indicators based on highly uncertain climate parameters, such as rainfall. A lot more rain or a lot less would make a significant difference for any response to climate change, and different models sometimes show little agreement on such key points (Tebaldi et al., 2011). Uncertainty related to the degree of change is not represented in these maps but is one of the factors accounted for in the Confidence evaluation. The Monitor's assessment

is based on the average point of models whenever a group of these was available. An exception is the model drawn on for the Storms indicator, specifically for tropical cyclones. The models available gave such completely opposing outputs that a mean was uninformative.

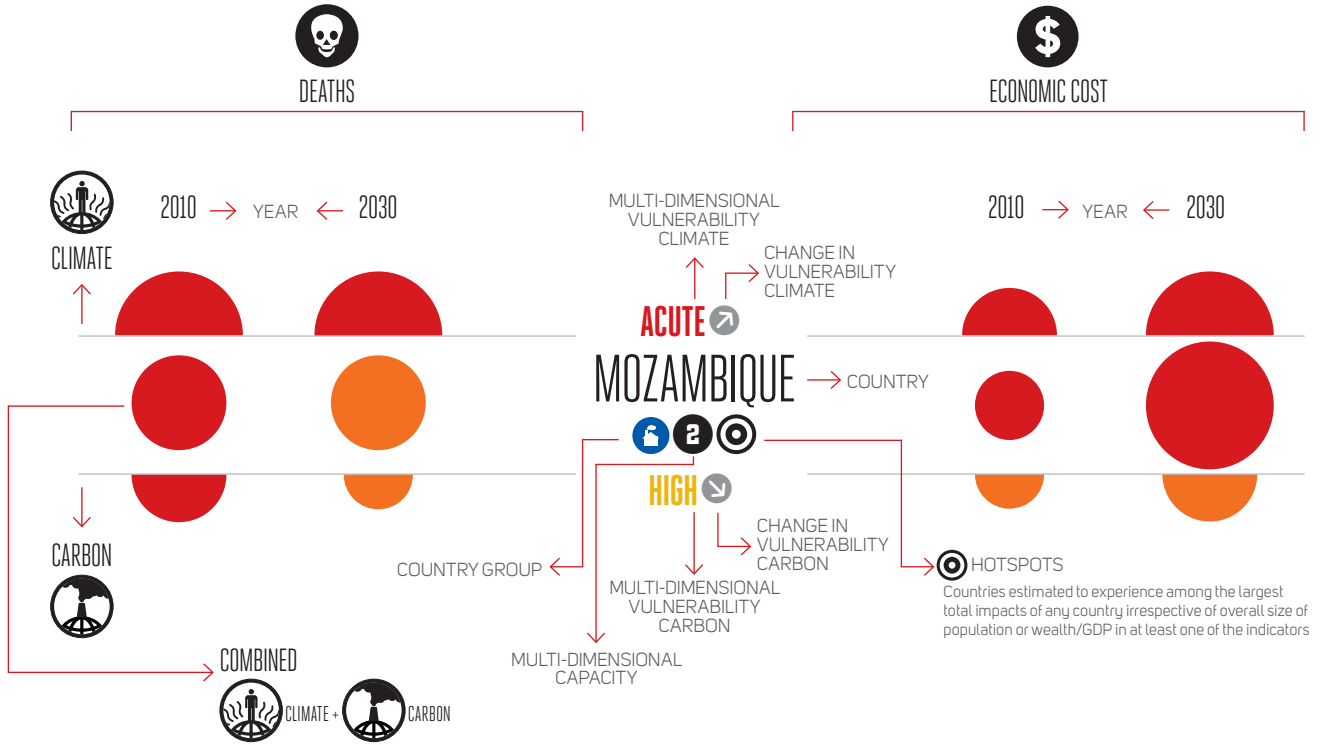
The model most aligned with observational evidence was chosen instead (Mendelsohn et al., 2012; IPCC, 2007). This disagreement is captured in regional uncertainty maps, where most key areas of the globe affected by tropical cyclones (although not North America) carry "Considerable" uncertainty. The Storms indicator is labelled "Speculative" in part due to discord on the scale of changes predicted by different models.

COUNTRY-LEVEL INTERPRETATION

When consulting the Monitor at the country level, readers are encouraged to take advantage of these multi-point considerations. If an indicator is "Speculative" and the country of interest is within a region with "Considerable" uncertainty on the direction of change, the assessment provided in the Monitor should be treated with much more caution than if the inverse confidence and uncertainty values had been given. However, just because models disagree does not mean that the values provided could not be potential future outcomes. Responses to the impacts of climate change should ideally be robust to a range of different outcomes (Dessai et al., 2009). Therefore, planning should be capable of coping with at least the level of impact suggested here. Countries with negative or very low impacts projected for low confidence, high uncertainty indicators like Storms should also respond with caution. The model chosen for Storms predicts a decrease of cyclone activity in the Pacific basin, the likelihood of which has been confirmed by other studies,

although there is no consensus on any clear trend (Mendelsohn et al., 2012; Callaghan and Power, 2010; IPCC, 2012a). Given the levels of uncertainty and lack of agreement among experts, it is likely wiser to take more precautions than the Monitor indicates as necessary.

KEY TO THE MONITOR



VULNERABILITY

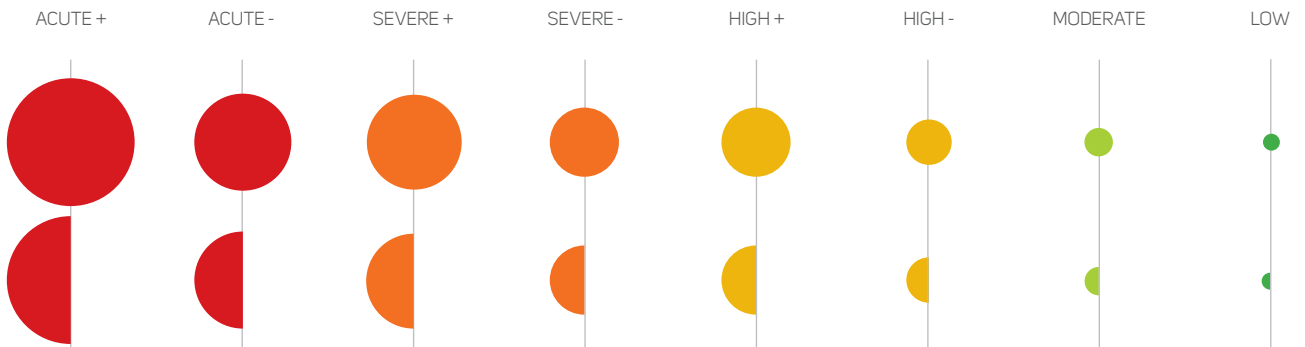
- ↗ INCREASING
- STABLE
- ↘ DECREASING
- ACUTE
- SEVERE
- HIGH
- MODERATE
- LOW

COUNTRY GROUPS

- 🏭 DEVELOPED
- 🏭 OTHER INDUSTRIALIZED
- 🌐 DEVELOPING COUNTRY HIGH EMITTERS
- 🌐 DEVELOPING COUNTRY LOW EMITTERS

MULTI-DIMENSIONAL CAPACITY

- 4 EXTENSIVE
- 3 INTERMEDIARY
- 2 RESTRICTED
- 1 HIGHLY RESTRICTED



AFRICA

2010

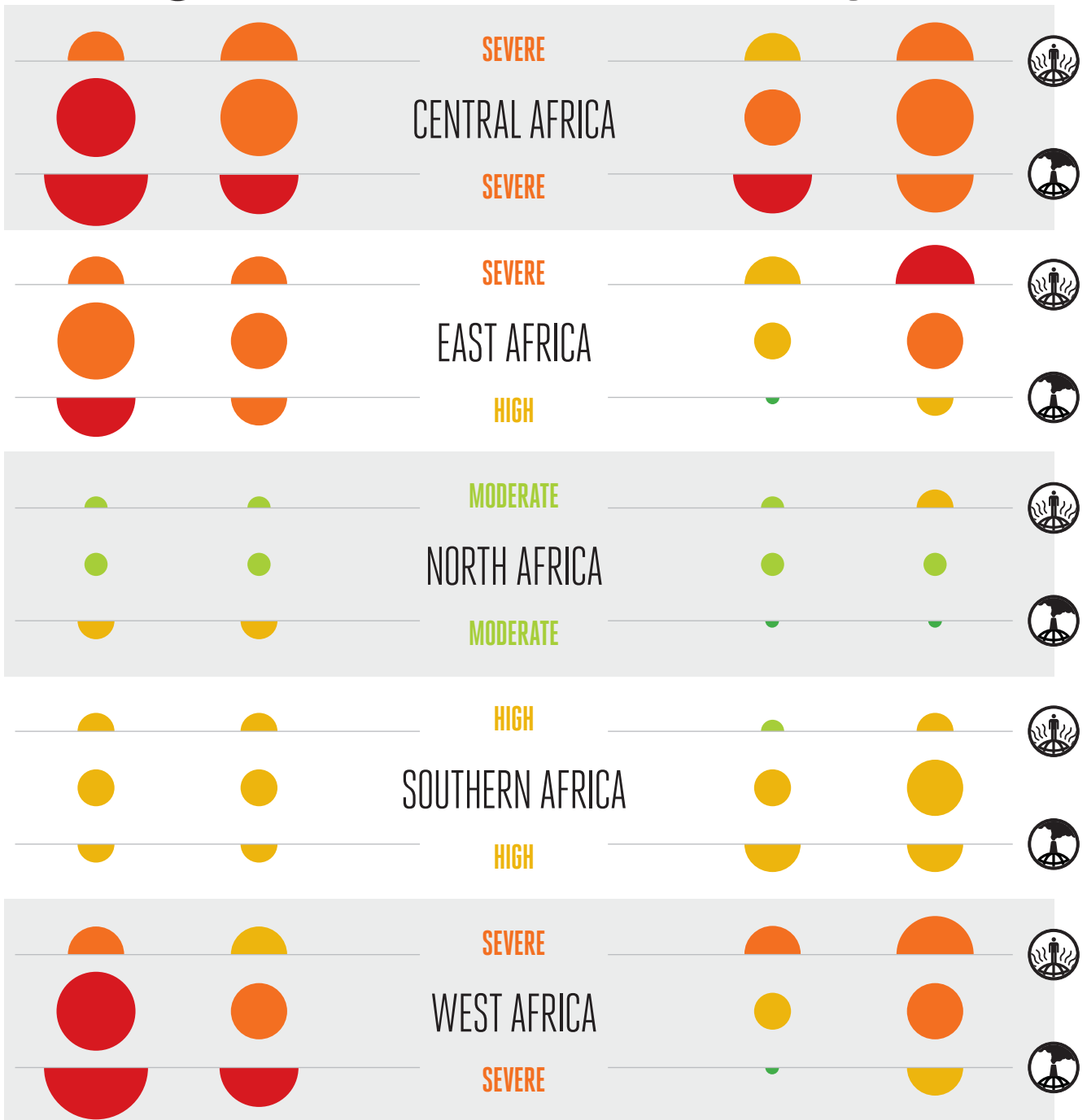


2030

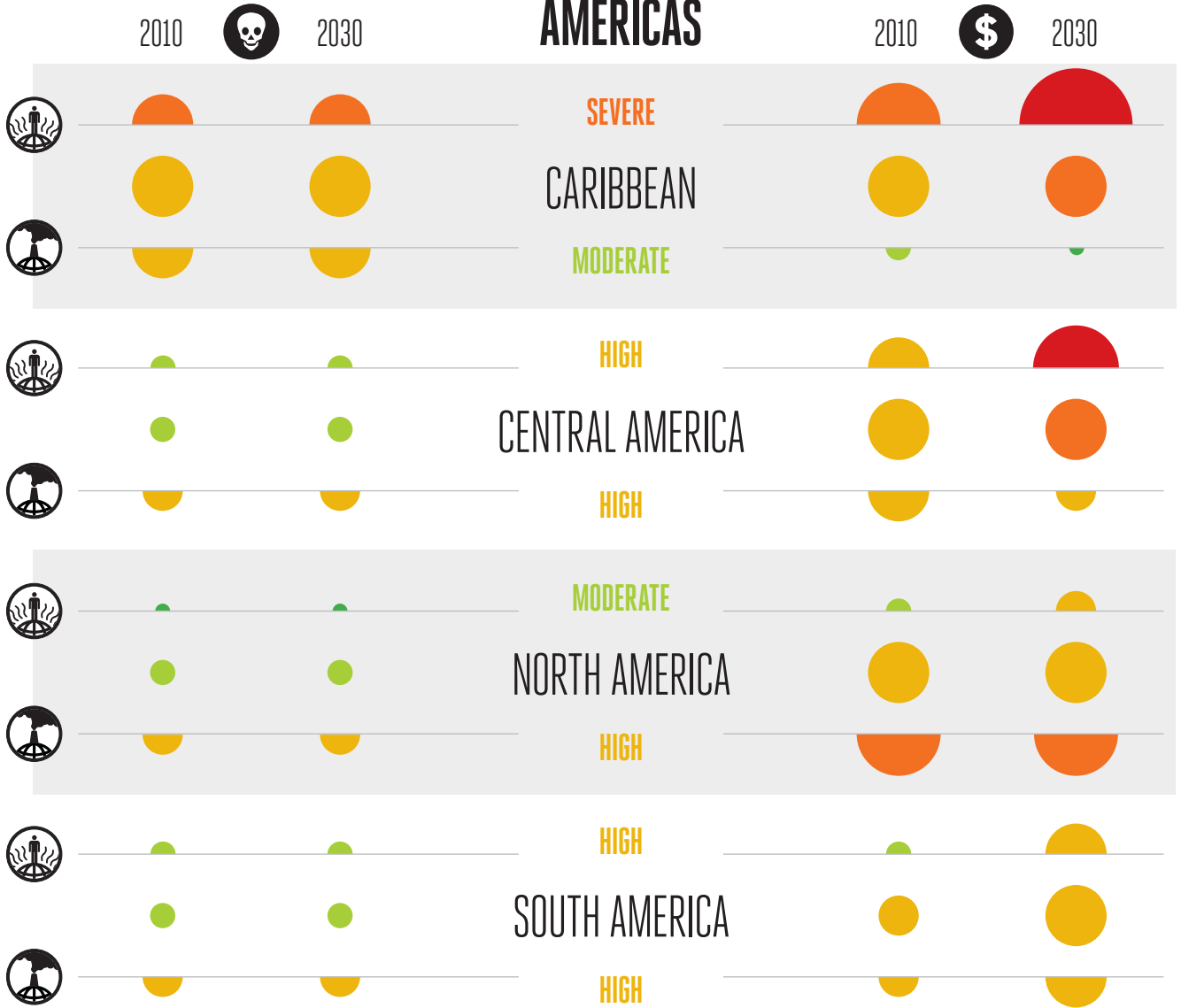
2010



2030



AMERICAS



ASIA-PACIFIC

2010

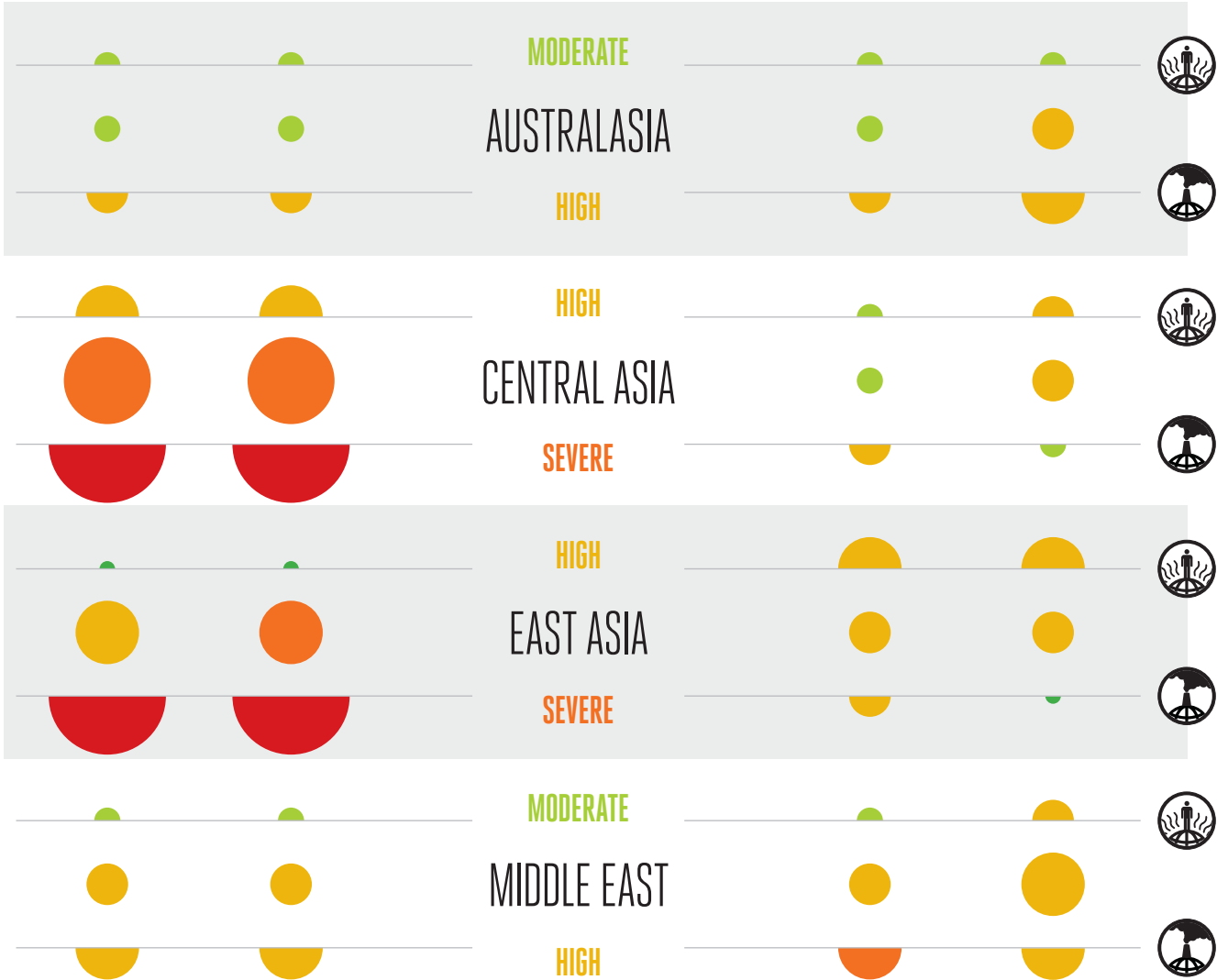


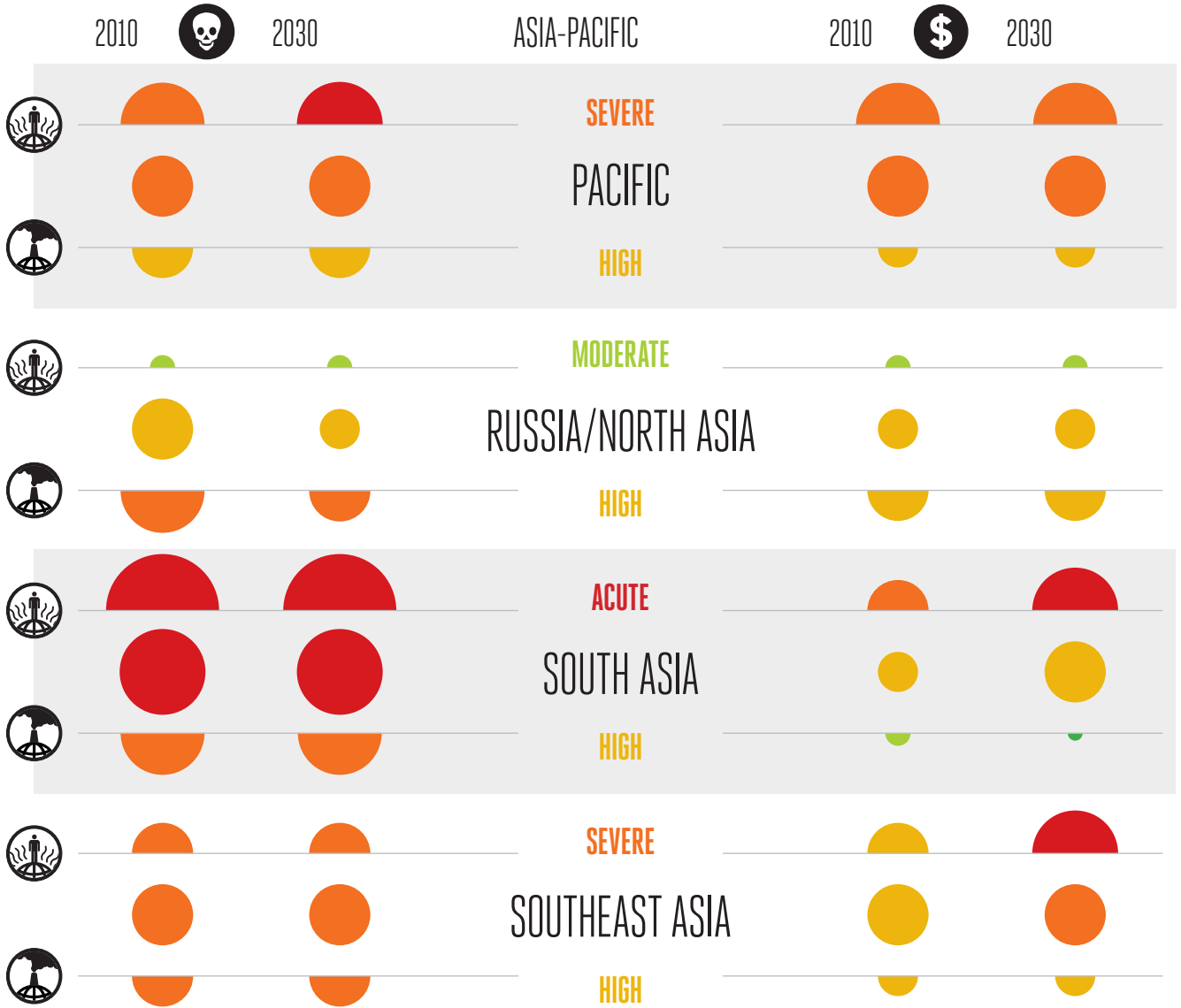
2030

2010



2030





EUROPE

2010

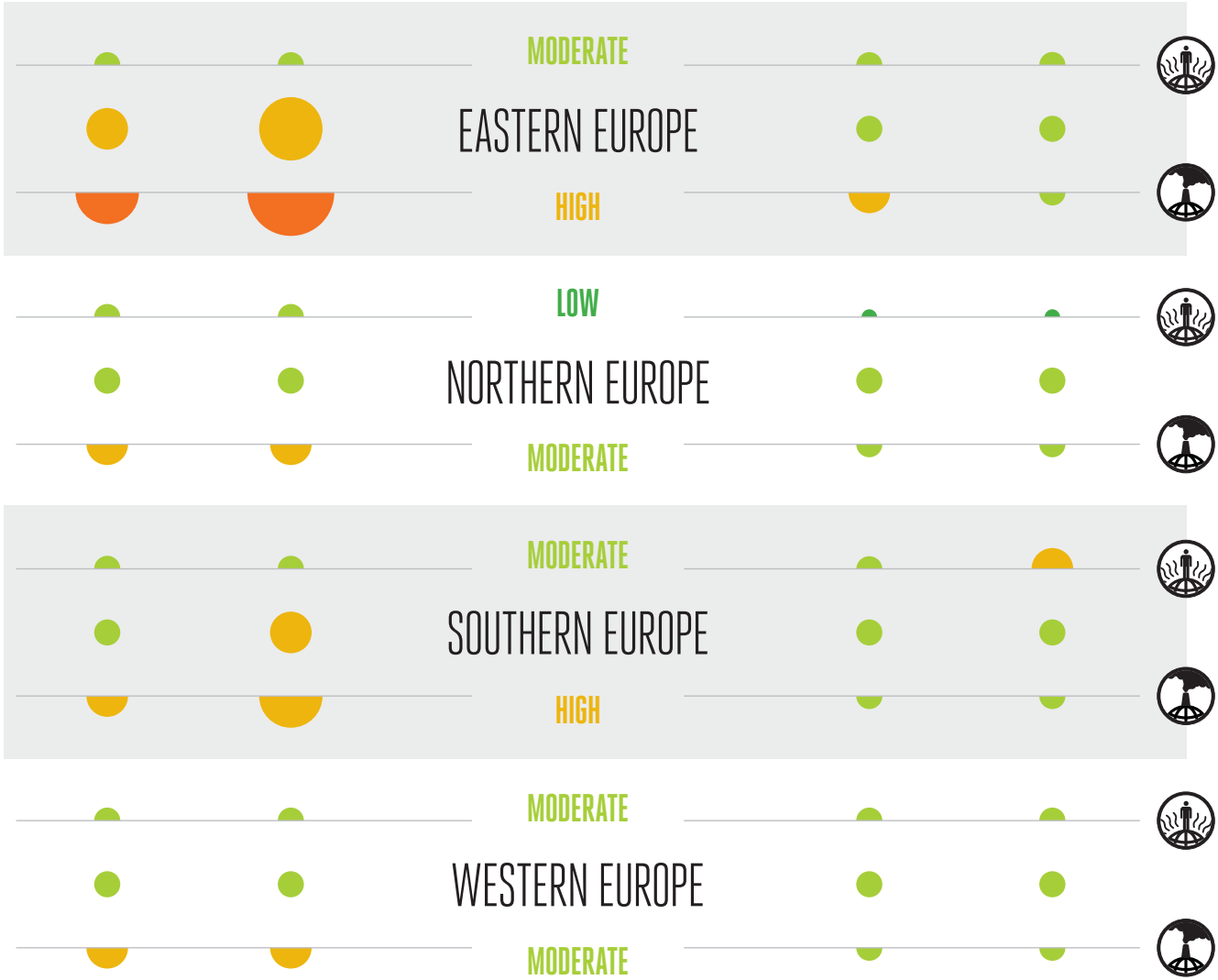


2030

2010



2030



AFRICA

2010



2030

2010



2030



MODERATE →

ALGERIA



LOW →



ACUTE →

ANGOLA



ACUTE →



ACUTE →

BENIN



MODERATE ↓



MODERATE →

BOTSWANA



ACUTE →



ACUTE →

BURKINA FASO



MODERATE ↓



ACUTE →

BURUNDI



MODERATE ↓



2010



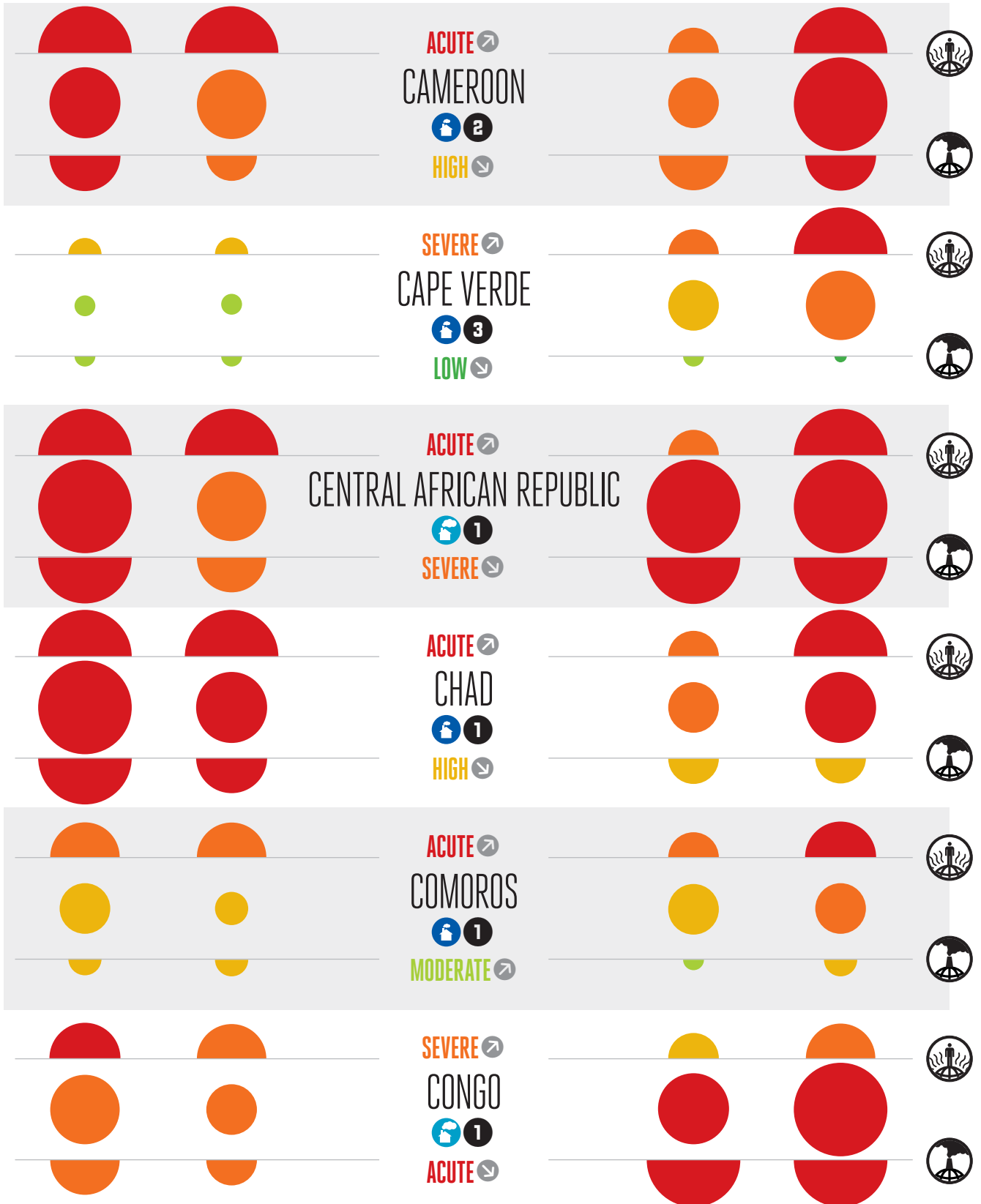
2030

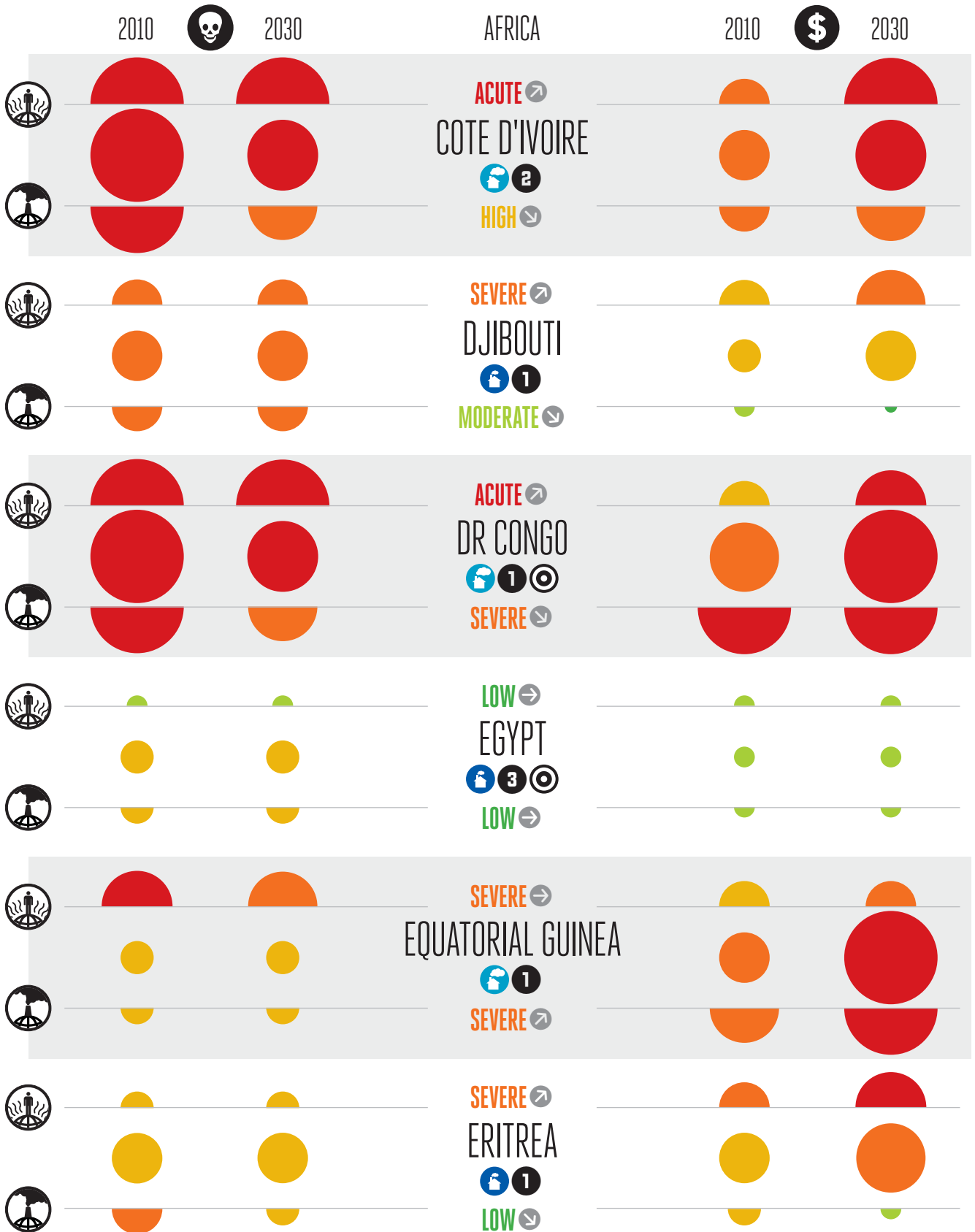
AFRICA

2010



2030





2010



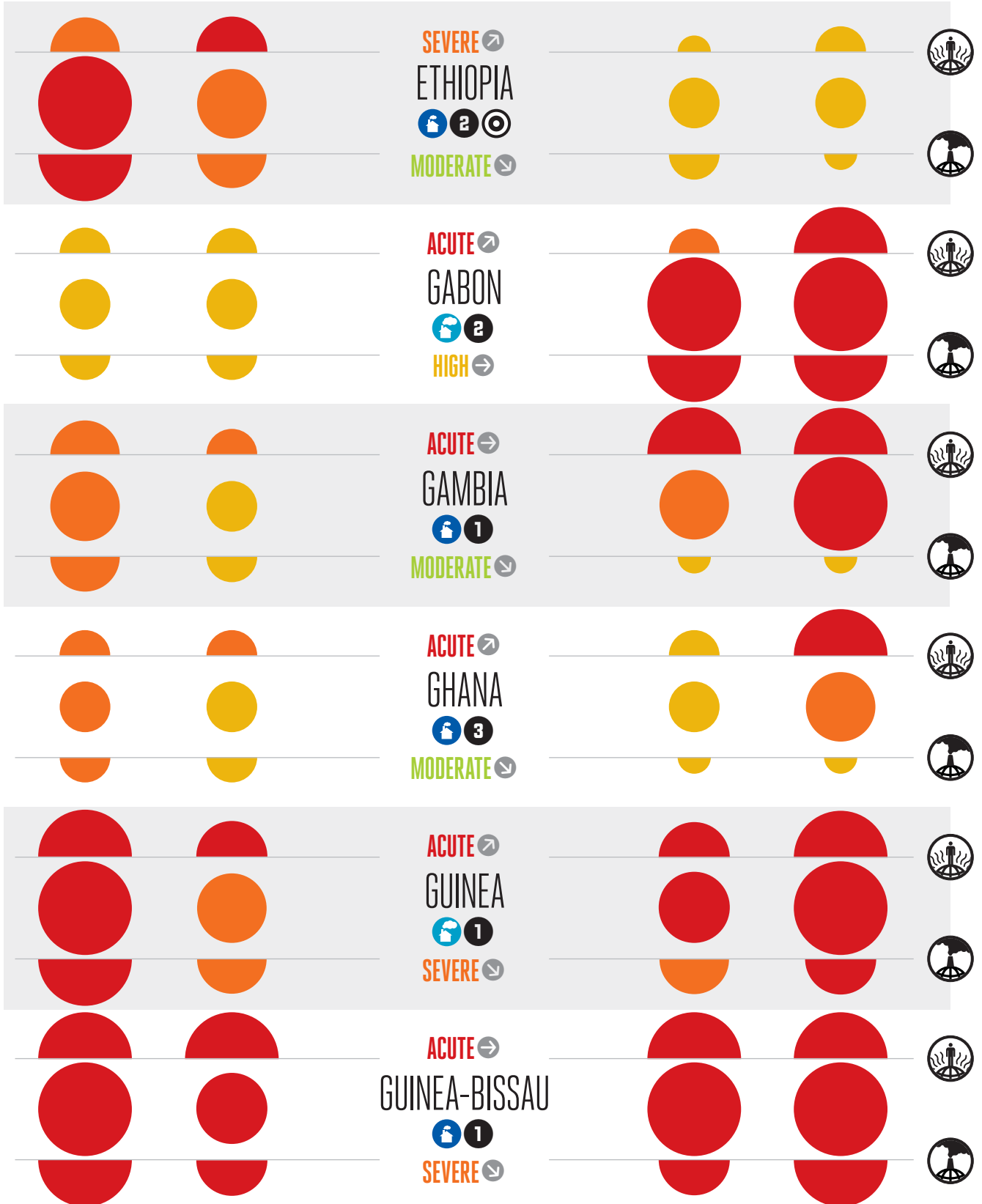
2030

AFRICA

2010



2030



2010



2030

AFRICA

2010



2030



HIGH ↗



KENYA



MODERATE ↘



MODERATE ↗



LESOTHO



MODERATE →



ACUTE →



LIBERIA



SEVERE →



MODERATE →



LIBYA



MODERATE →



ACUTE ↗



MADAGASCAR



ACUTE →



ACUTE ↗



MALAWI



MODERATE ↘



2010



2030

AFRICA

2010



2030

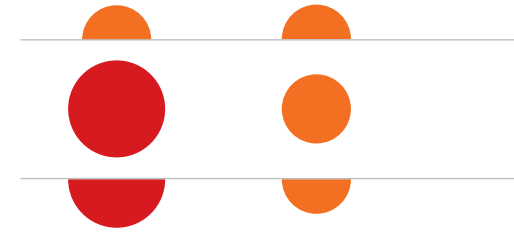
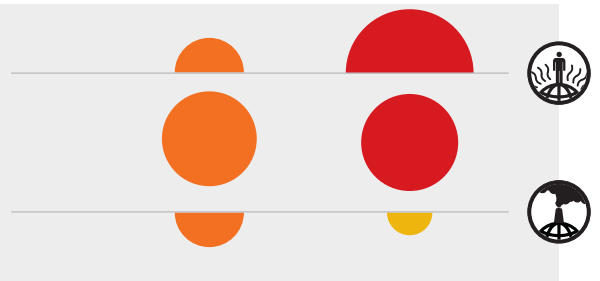


ACUTE ↗

MALI

1

MODERATE ↘

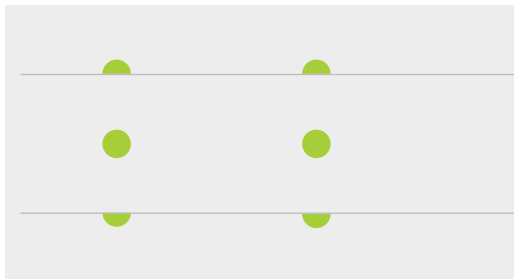
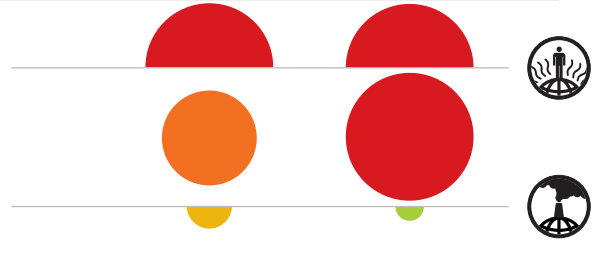


ACUTE ↗

MAURITANIA

1

MODERATE ↘

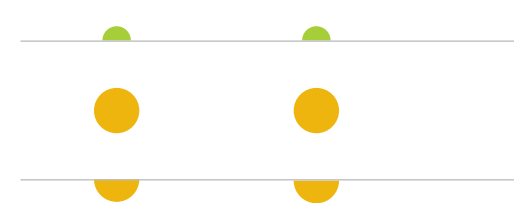
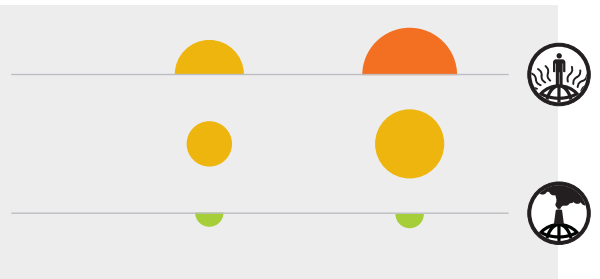


SEVERE ↗

MAURITIUS

3

LOW ↗



HIGH ↗

MOROCCO

4

LOW ↗

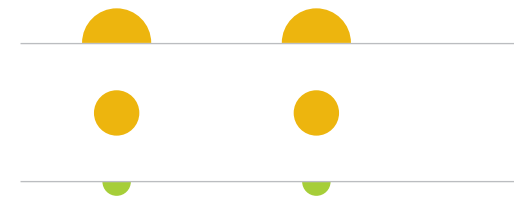
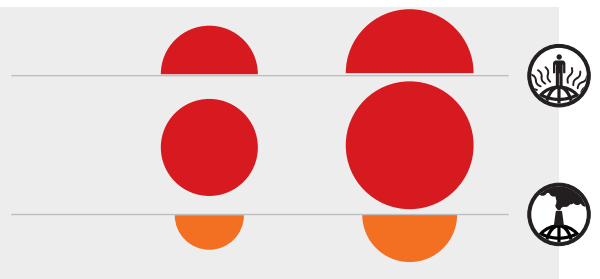


ACUTE ↗

MOZAMBIQUE

2

HIGH ↘

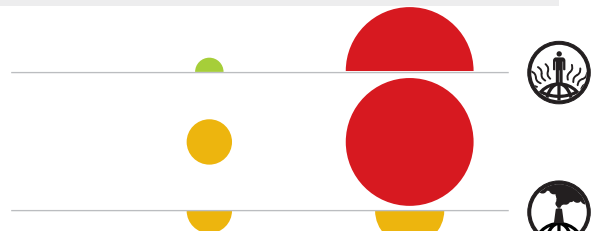


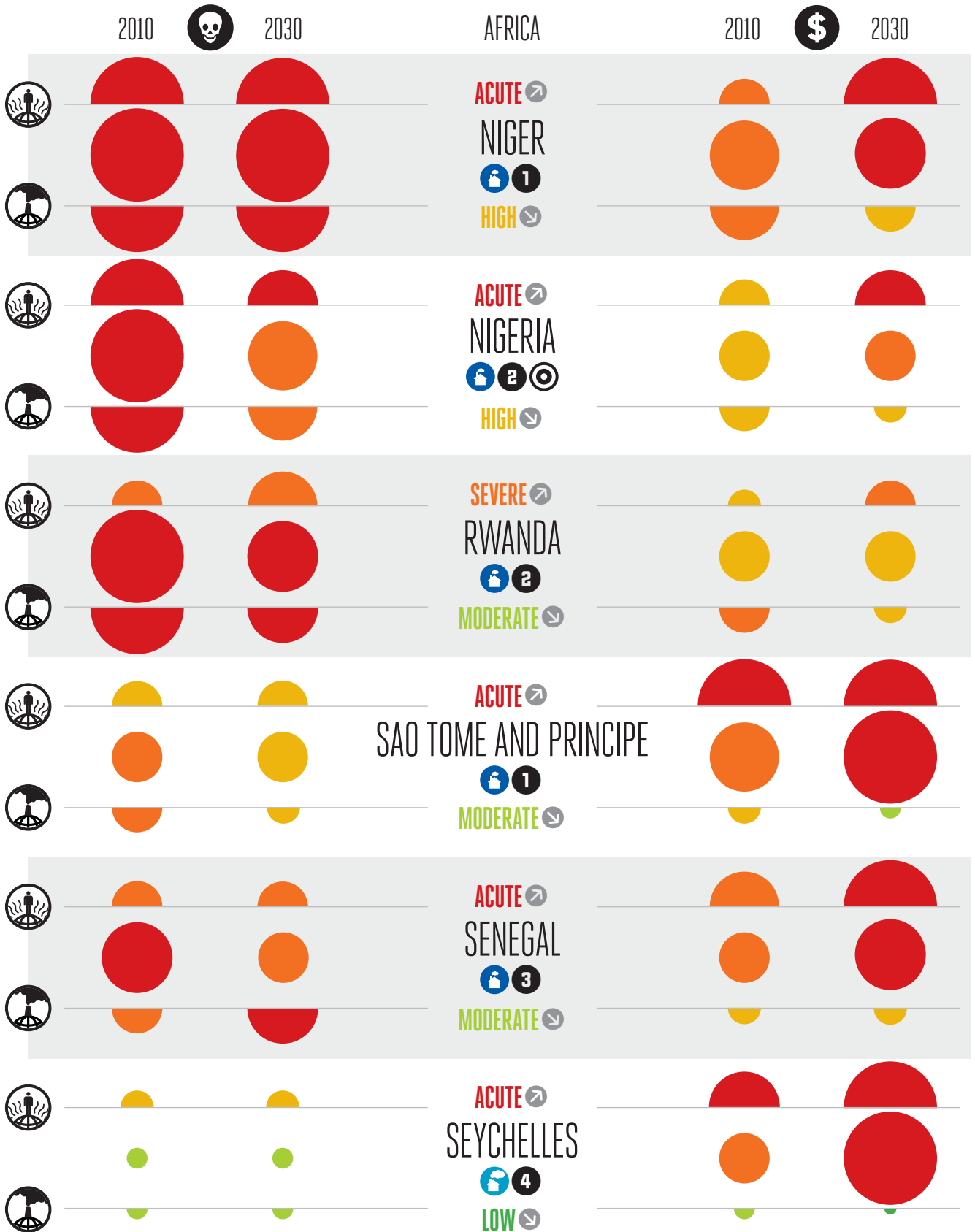
SEVERE ↗

NAMIBIA

3

MODERATE ↗





2010



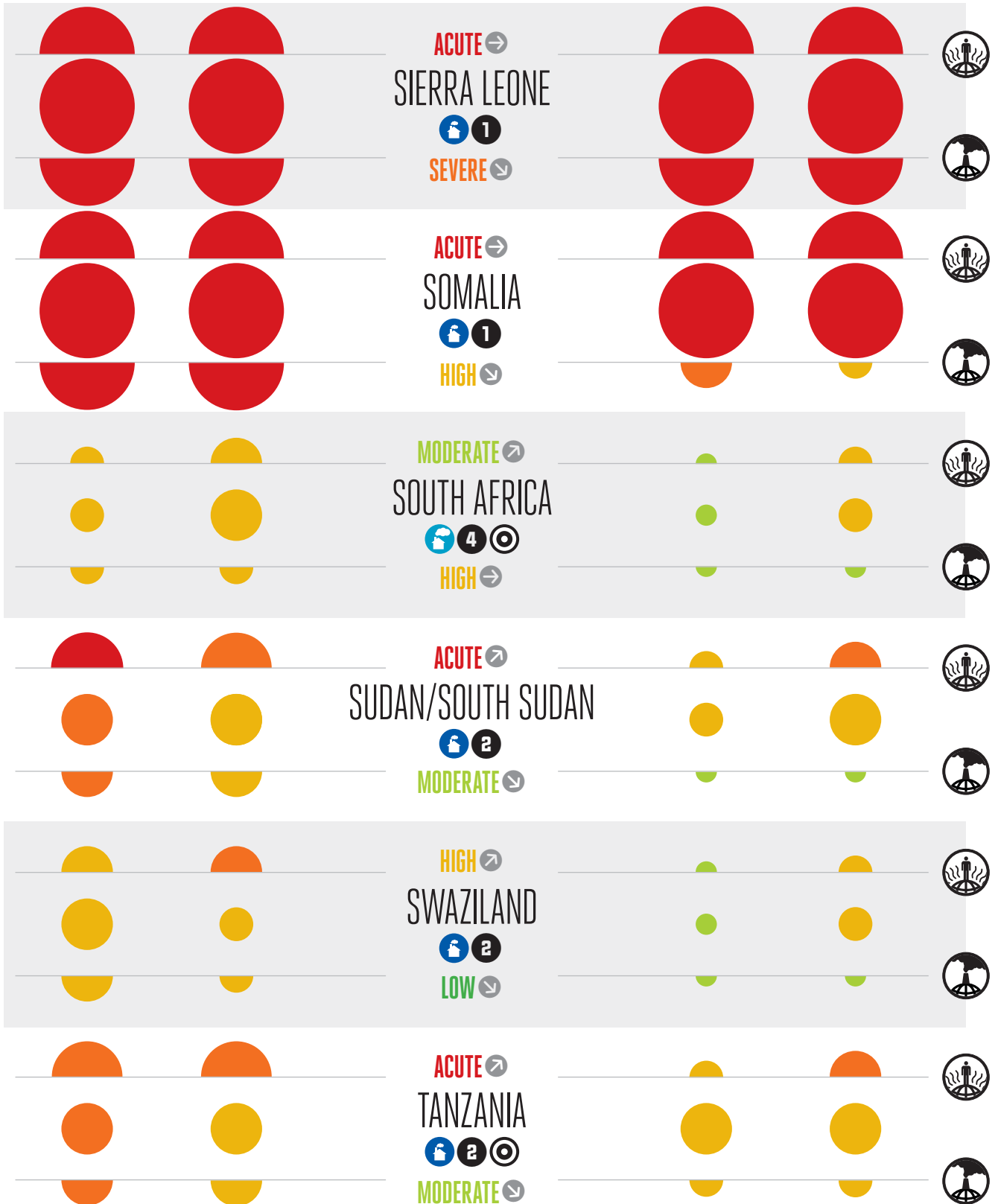
2030

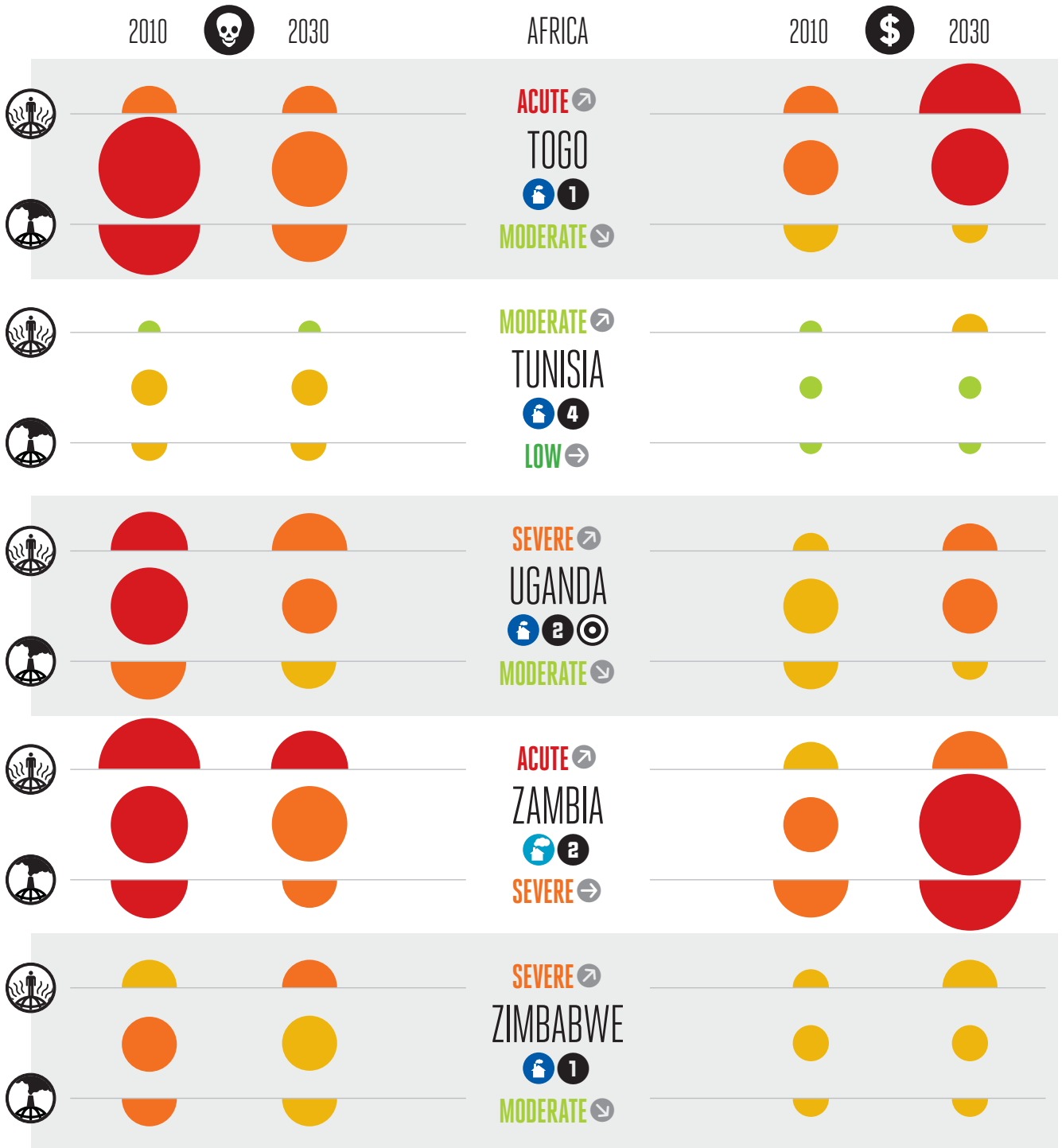
AFRICA

2010



2030





2010



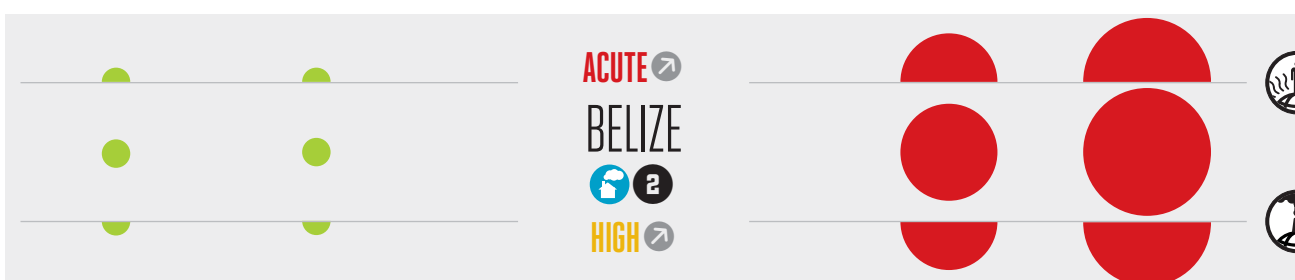
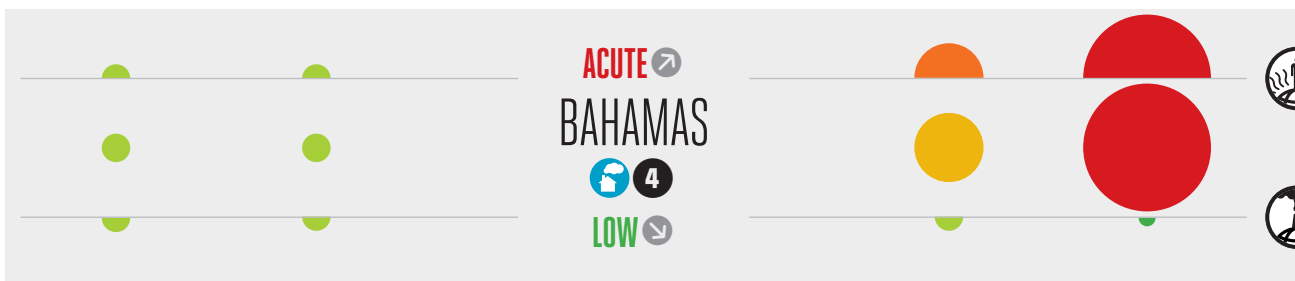
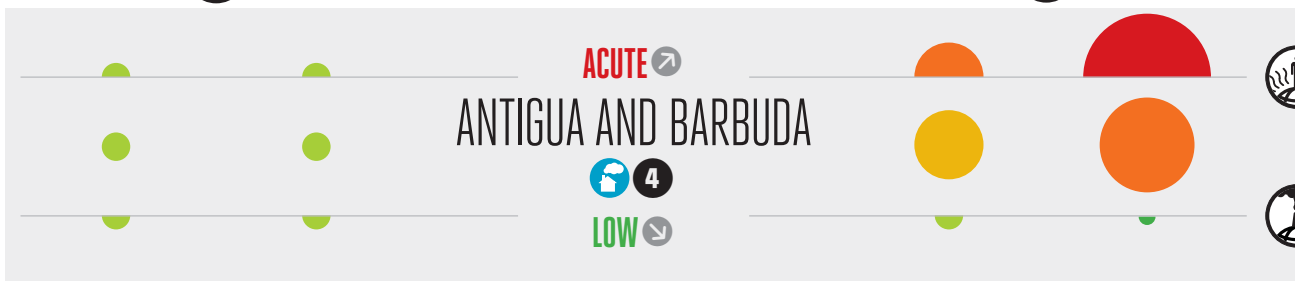
2030

AMERICAS

2010



2030



2010



2030

AMERICAS

2010



2030



MODERATE →



BRAZIL



HIGH ↗



LOW →



CANADA



ACUTE ↗



MODERATE ↗



CHILE



MODERATE ↗



MODERATE ↗



COLOMBIA



HIGH ↗



HIGH ↗



COSTA RICA



LOW →



SEVERE ↗



CUBA



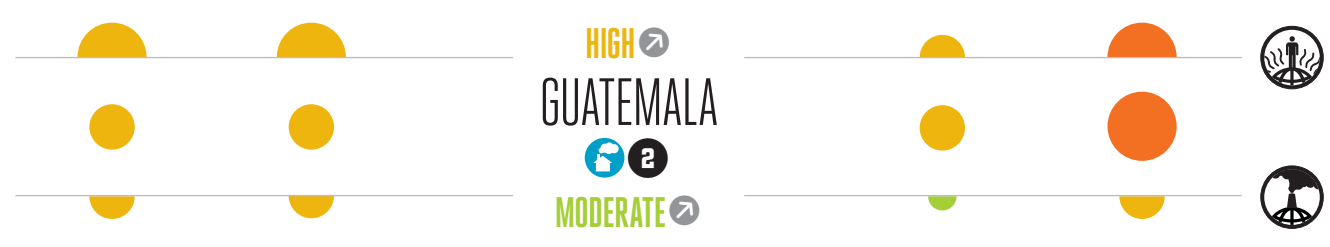
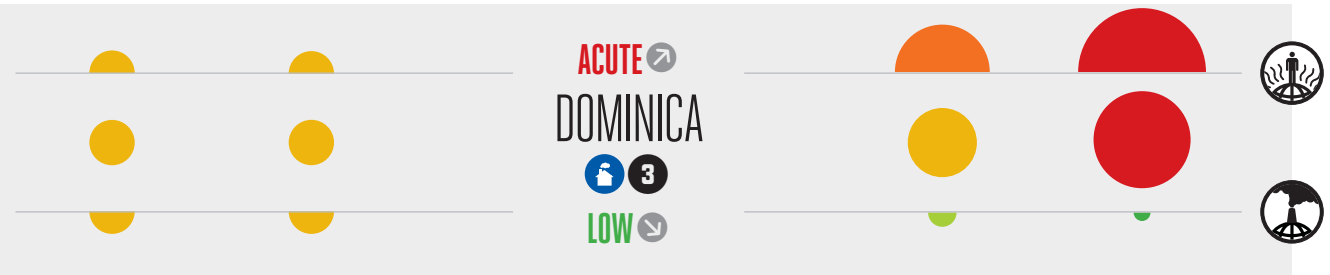
MODERATE →



2010  2030

AMERICAS

2010  2030



2010



2030

AMERICAS

2010



2030



ACUTE ↗



GUYANA



ACUTE ↗



ACUTE ↗



HAITI



MODERATE ↘



ACUTE ↗



HONDURAS



MODERATE ↗



ACUTE ↗



JAMAICA



MODERATE ↘



HIGH ↗



MEXICO



MODERATE ↗



ACUTE ↗



NICARAGUA



HIGH ↗



2010



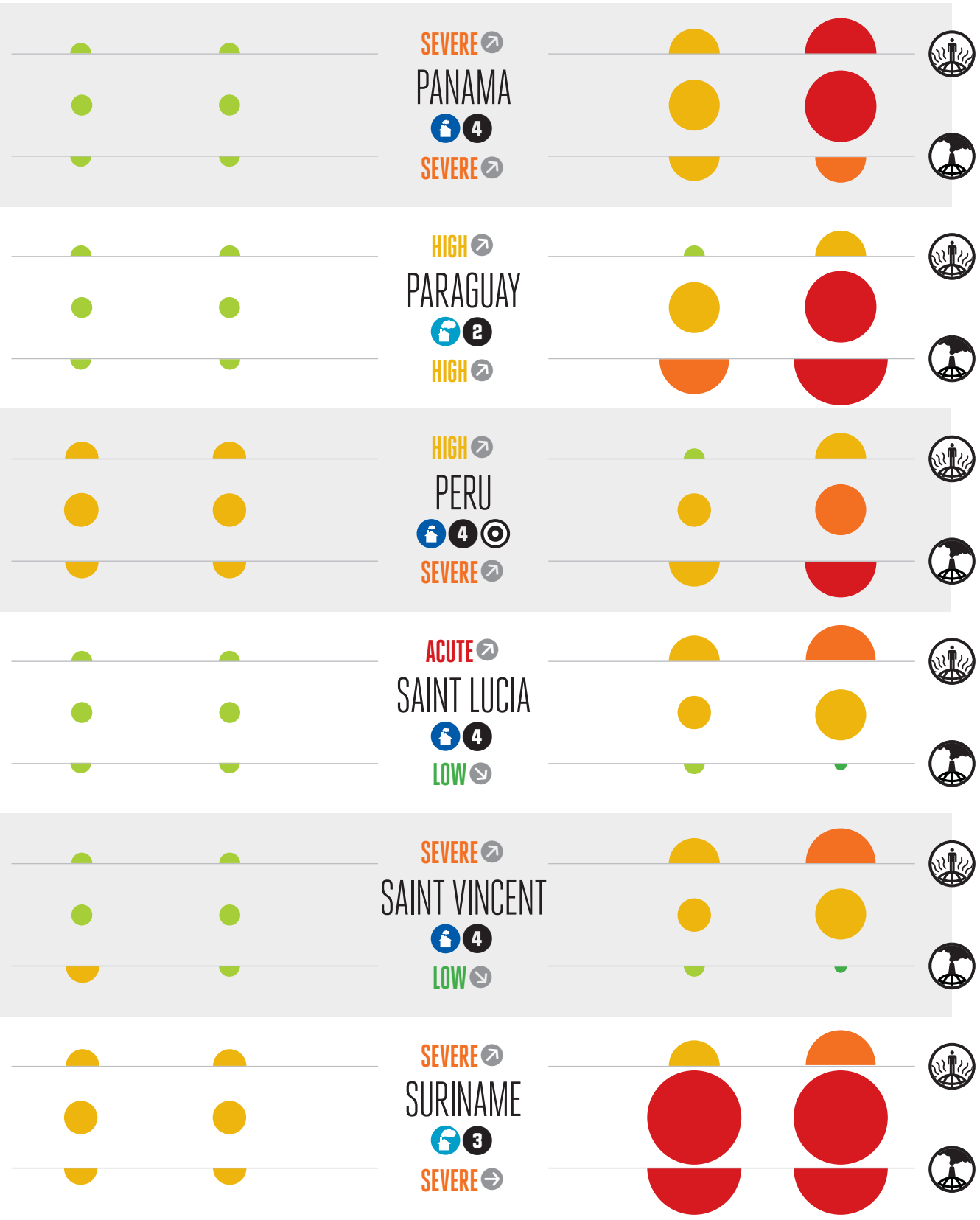
2030

AMERICAS

2010



2030



SEVERE ↗

PANAMA

4

SEVERE ↗

HIGH ↗

PARAGUAY

2

HIGH ↗

HIGH ↗

PERU

4

SEVERE ↗

ACUTE ↗

SAINT LUCIA

4

LOW ↘

SEVERE ↗

SAINT VINCENT

4

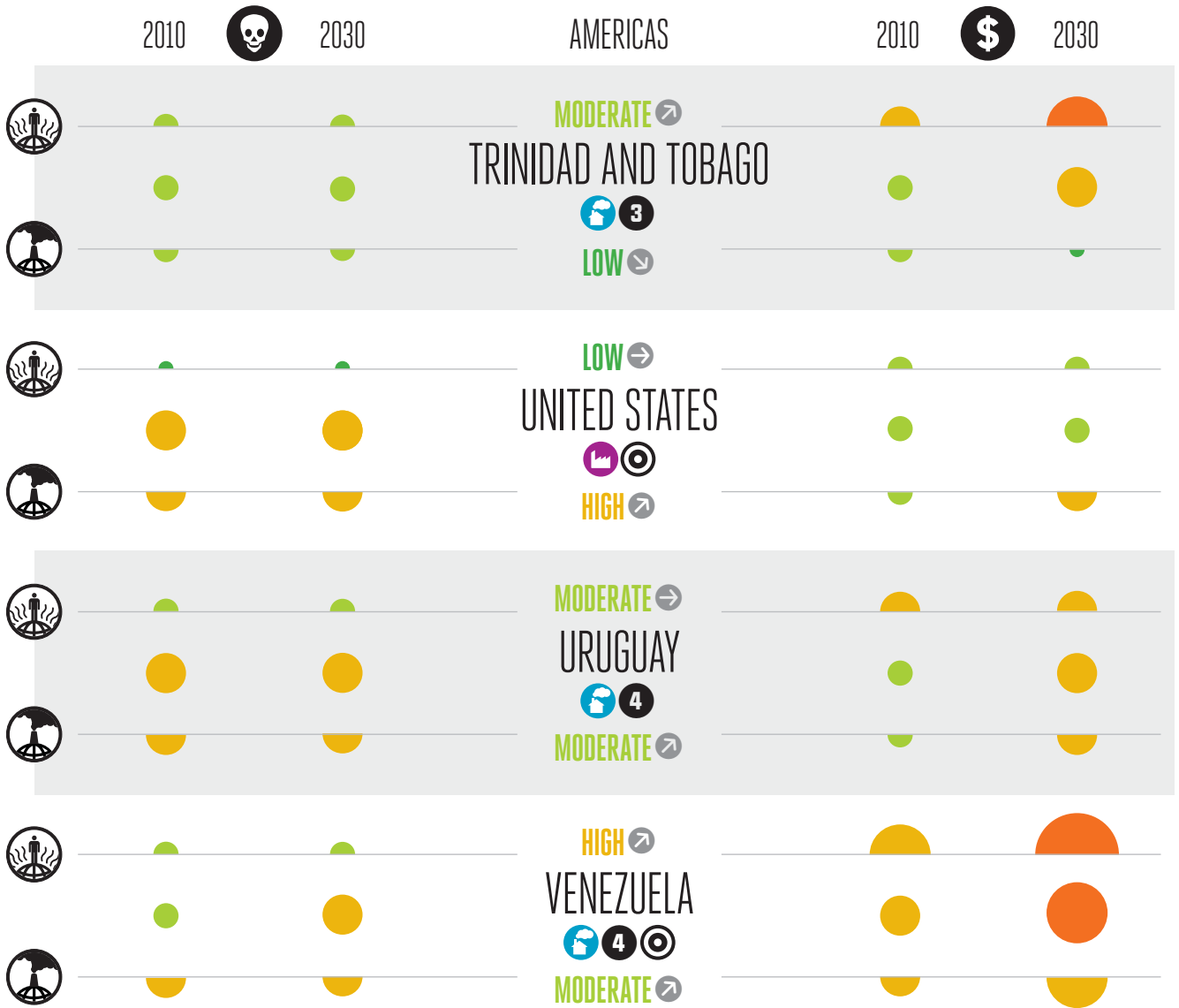
LOW ↘

SEVERE ↗

SURINAME

3

SEVERE ↗



2010



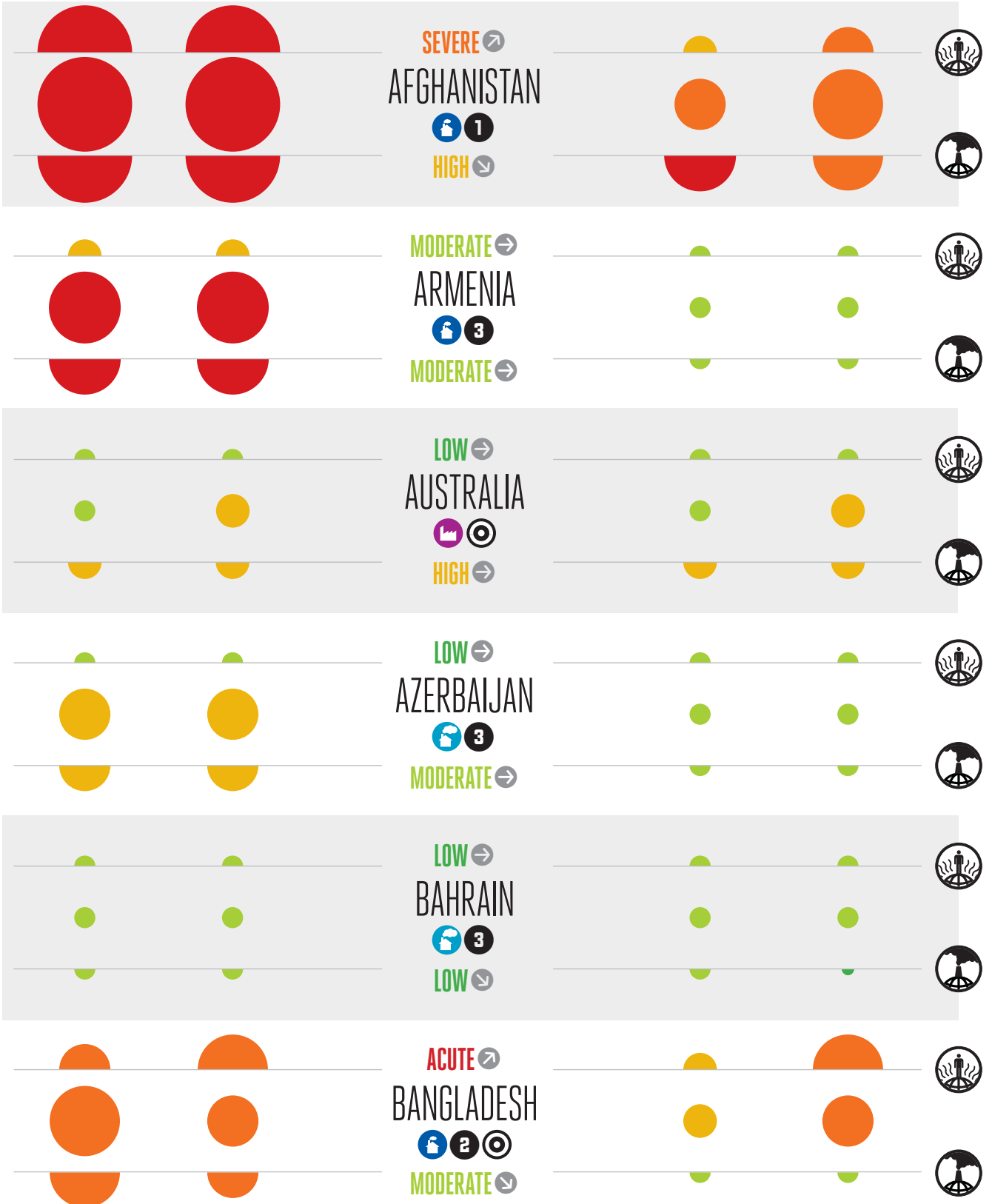
2030

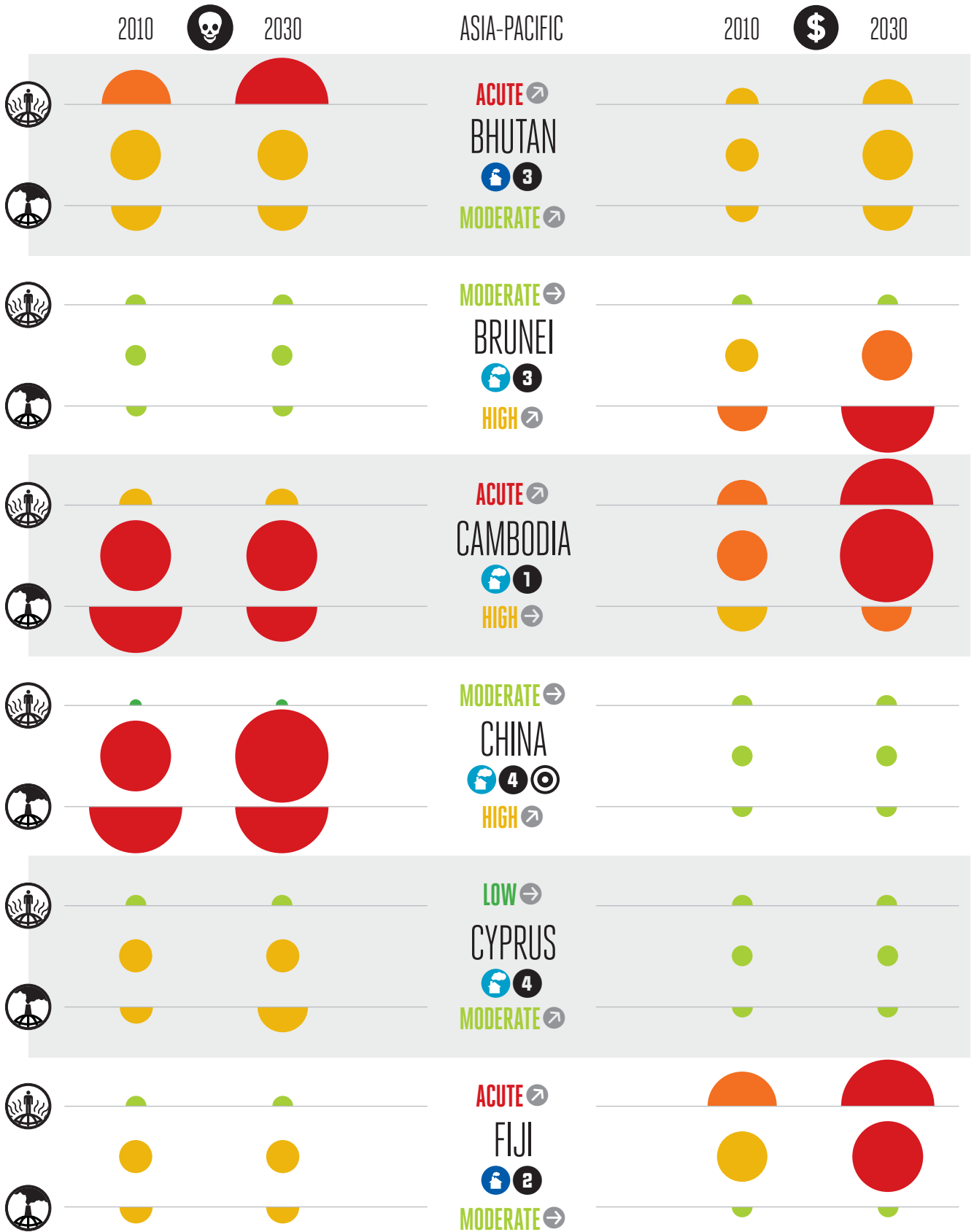
ASIA-PACIFIC

2010



2030





2010



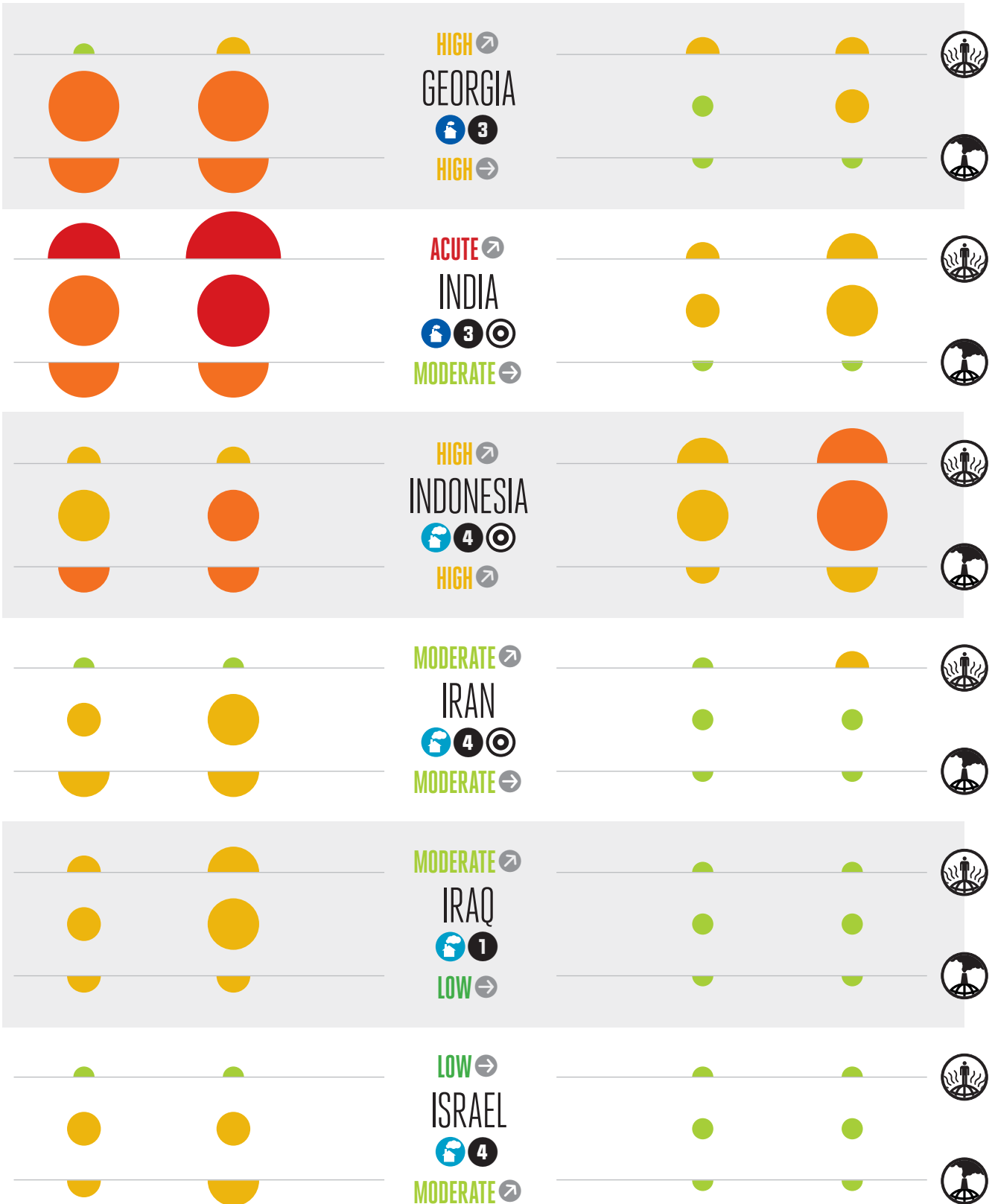
2030

ASIA-PACIFIC

2010



2030



2010  2030

ASIA-PACIFIC

2010  2030



LOW →

JAPAN



MODERATE →



LOW →

JORDAN



LOW →



LOW →

KAZAKHSTAN



MODERATE →



ACUTE →

KIRIBATI



LOW ↓



LOW →

KUWAIT



HIGH →

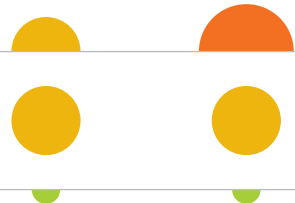
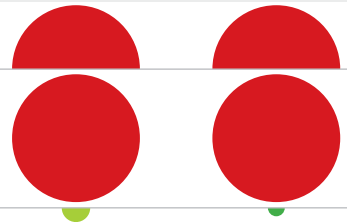


HIGH ↗

KYRGYZSTAN



MODERATE ↓



2010



2030

ASIA PACIFIC

2010



2030



ACUTE →

LAOS

1

HIGH →

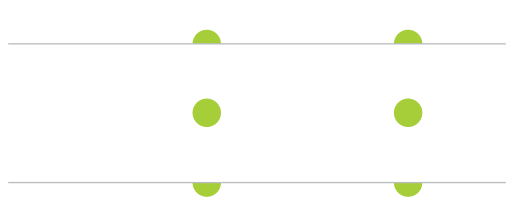
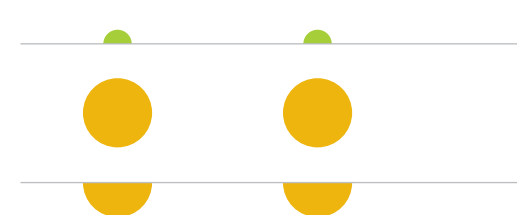


MODERATE →

LEBANON

4

HIGH →

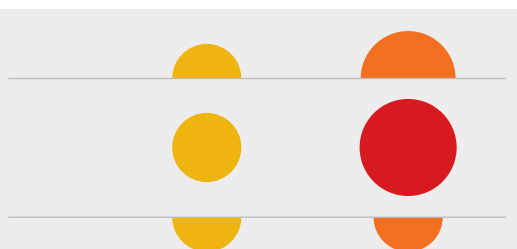
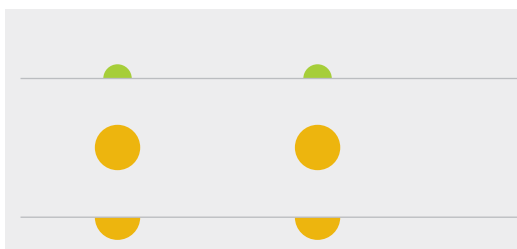


HIGH →

MALAYSIA

4

SEVERE →

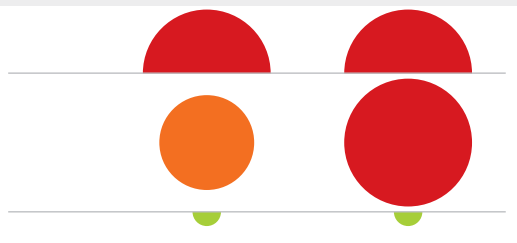
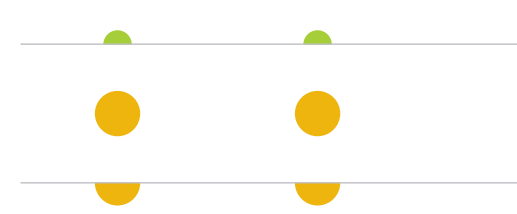


SEVERE →

MALDIVES

3

LOW →

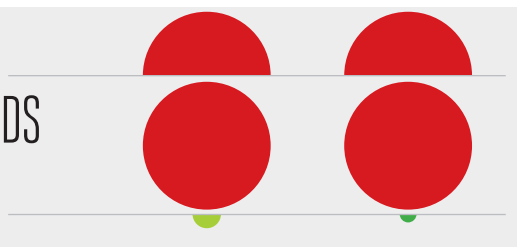
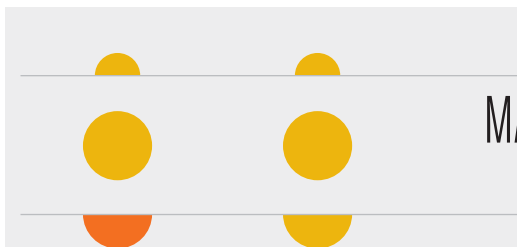


ACUTE →

MARSHALL ISLANDS

1

MODERATE ↓

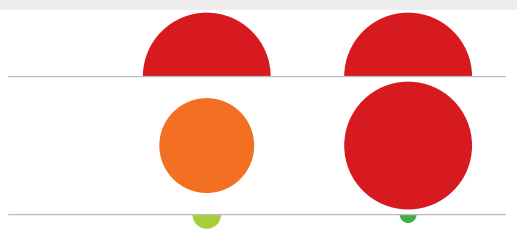
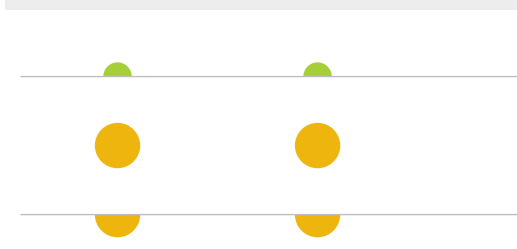


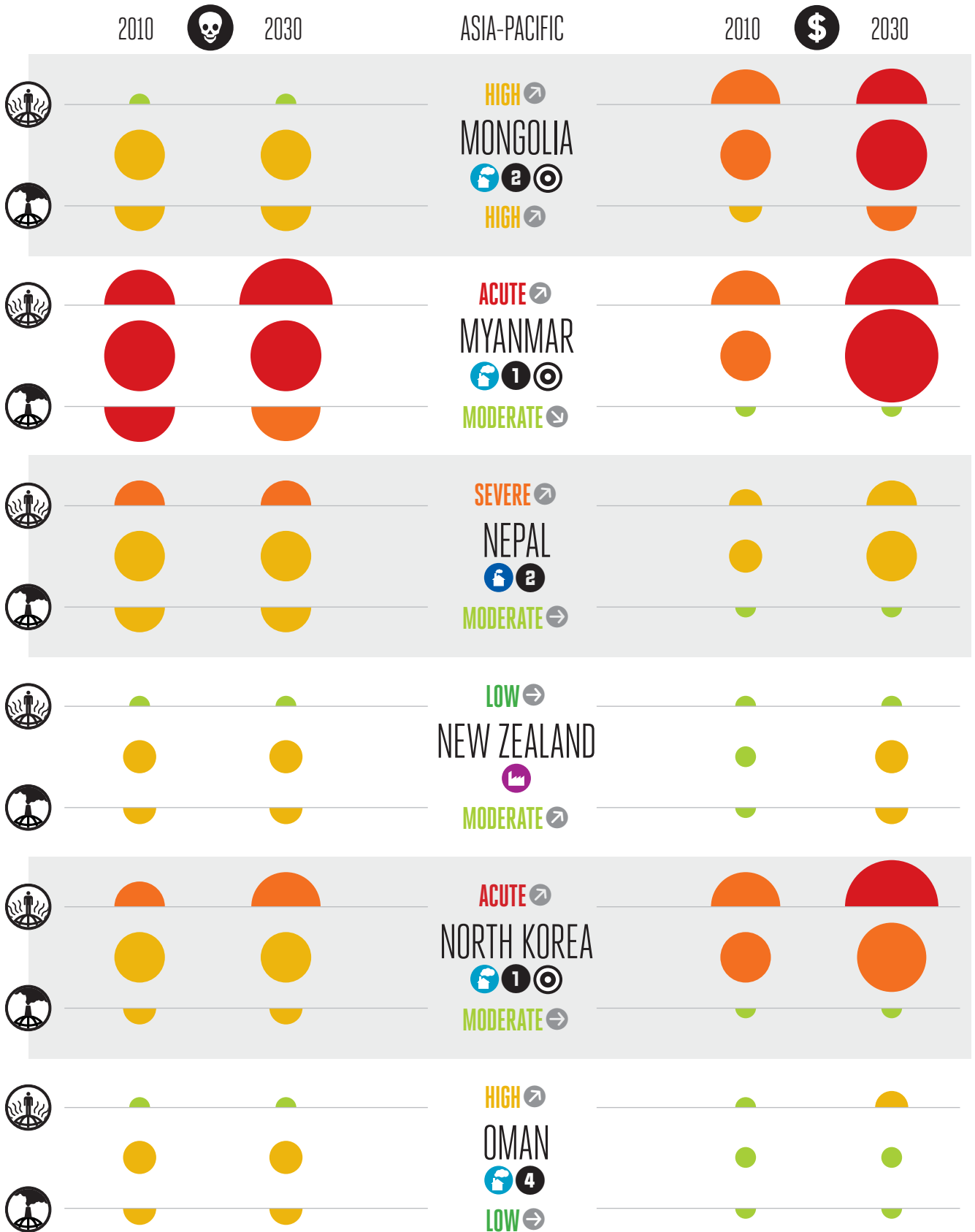
ACUTE →

MICRONESIA

1

LOW ↓





2010



2030

ASIA-PACIFIC

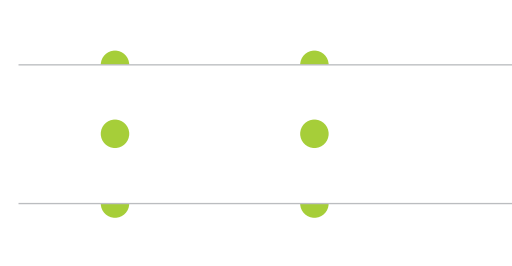
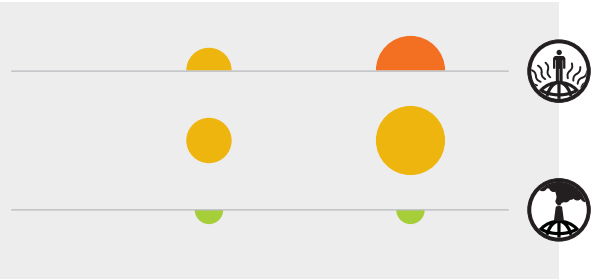
2010



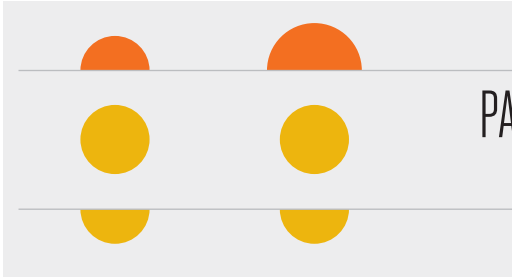
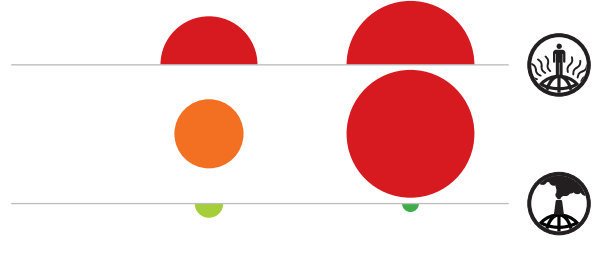
2030



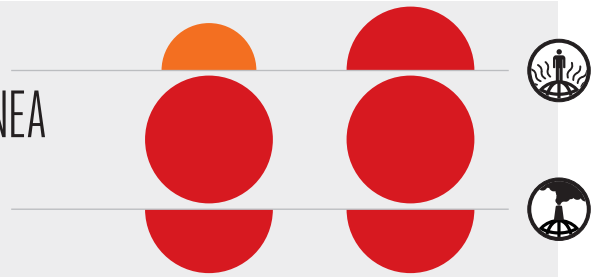
ACUTE ↗
PAKISTAN
 2
HIGH →



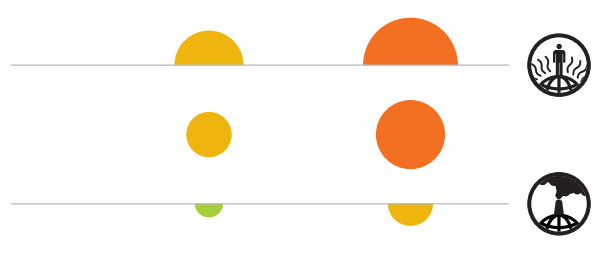
ACUTE ↗
PALAU
 1
LOW ↘



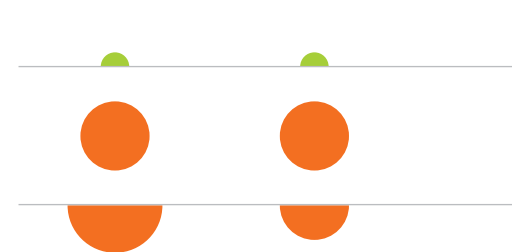
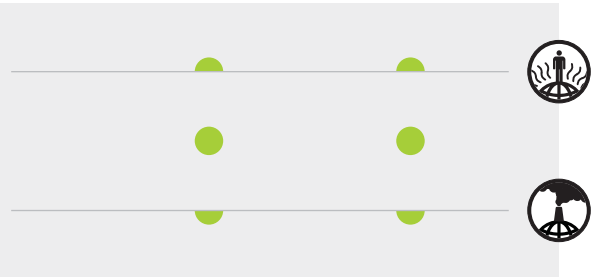
ACUTE ↗
PAPUA NEW GUINEA
 2
HIGH →



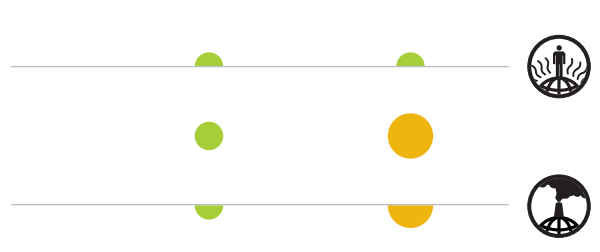
SEVERE ↗
PHILIPPINES
 3
MODERATE ↗

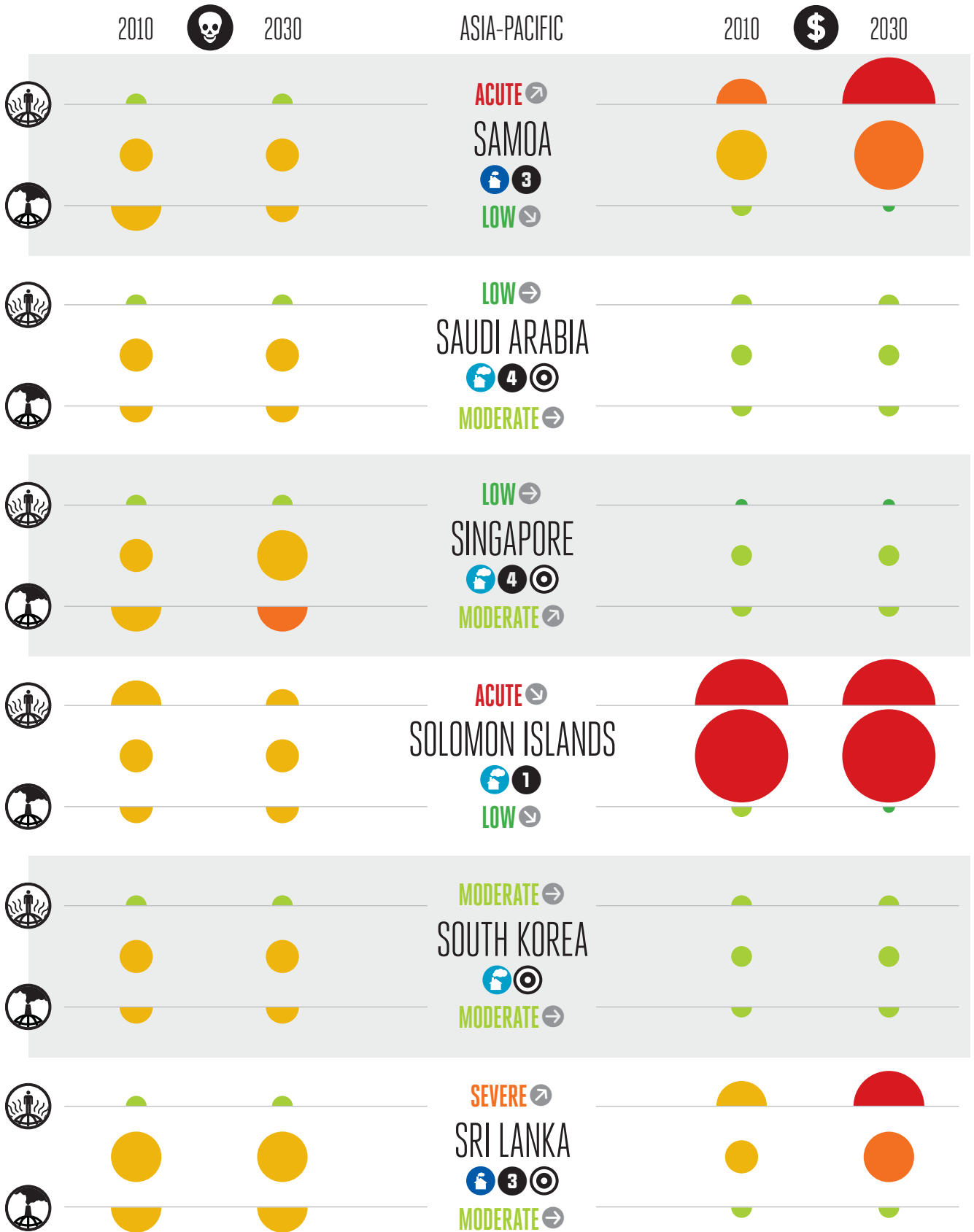


LOW →
QATAR
 4
MODERATE →



LOW →
RUSSIA
HIGH →





2010



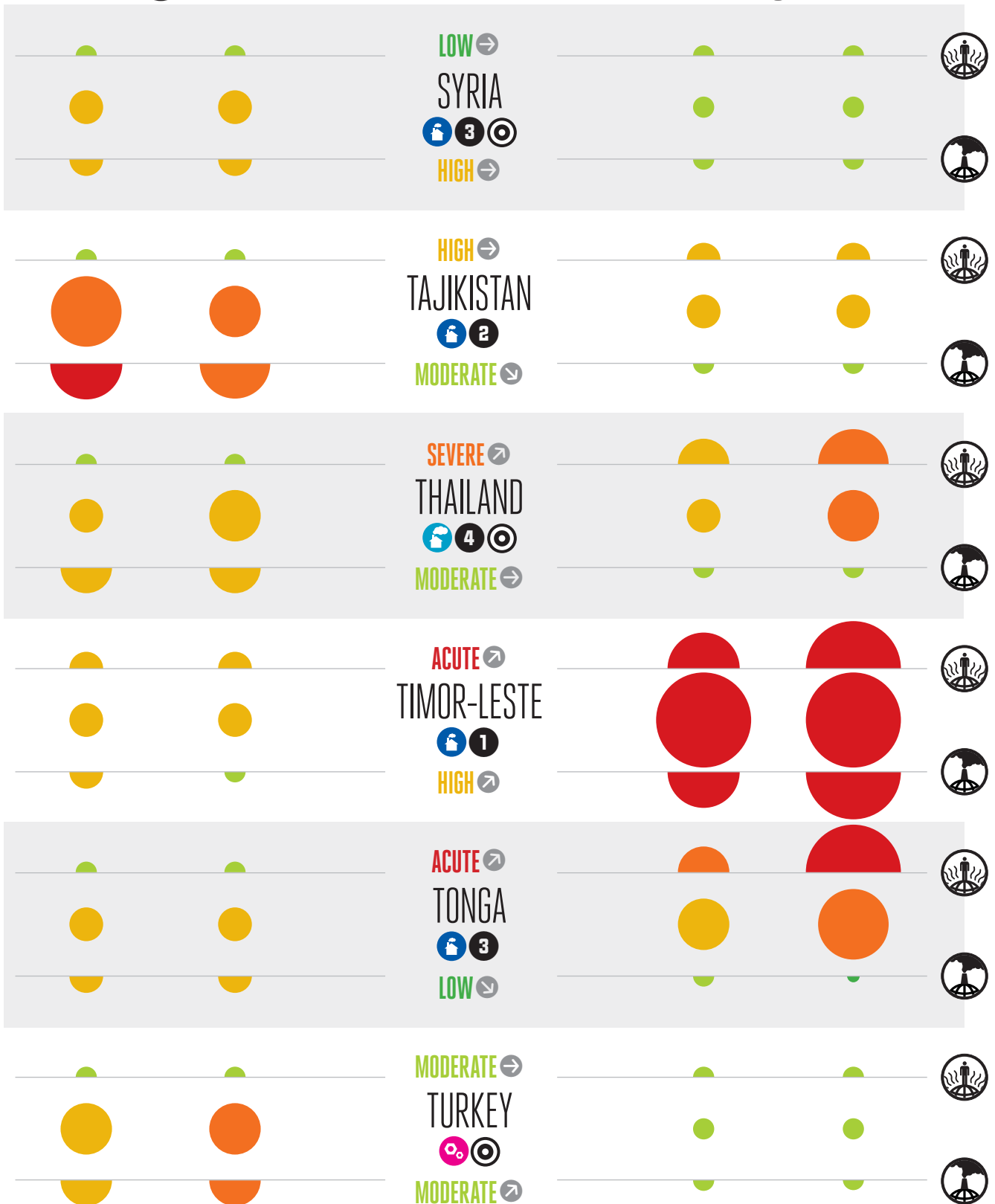
2030

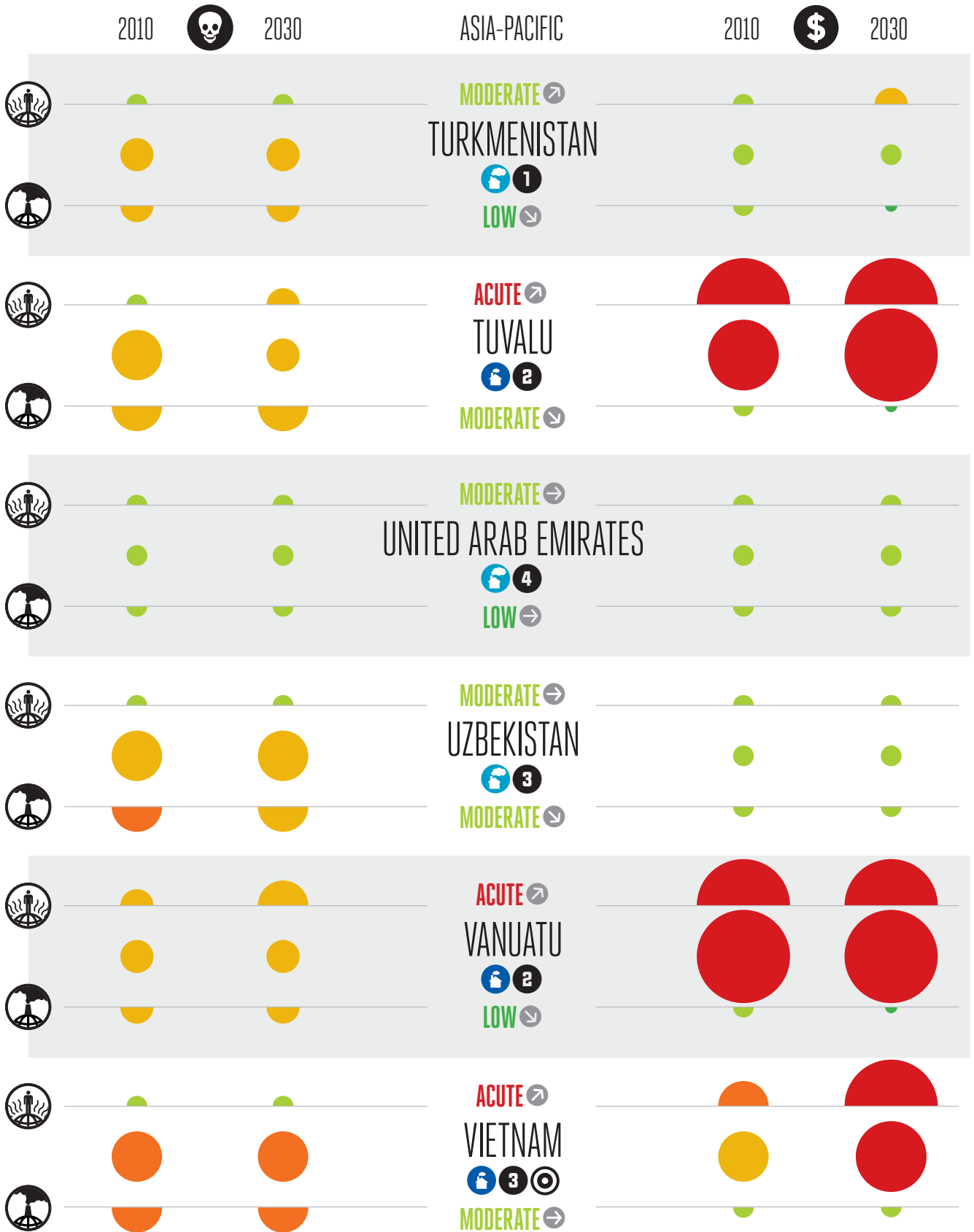
ASIA-PACIFIC

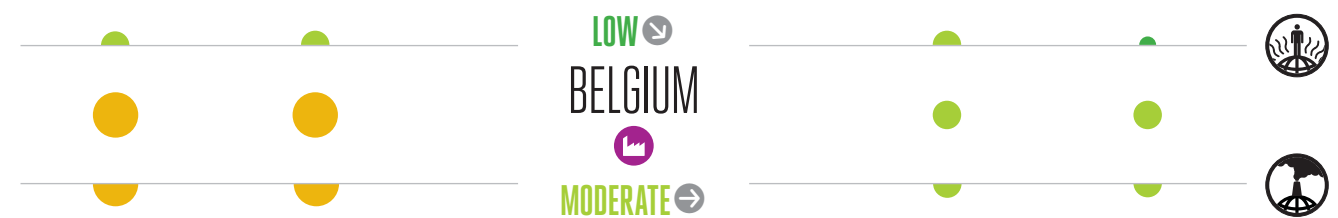
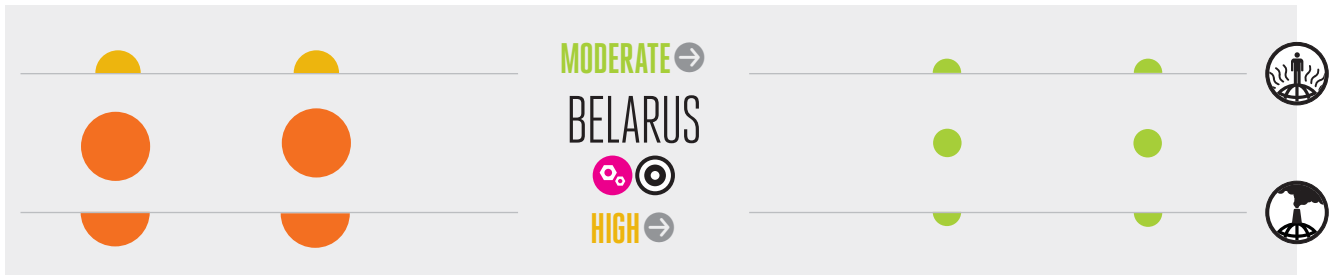
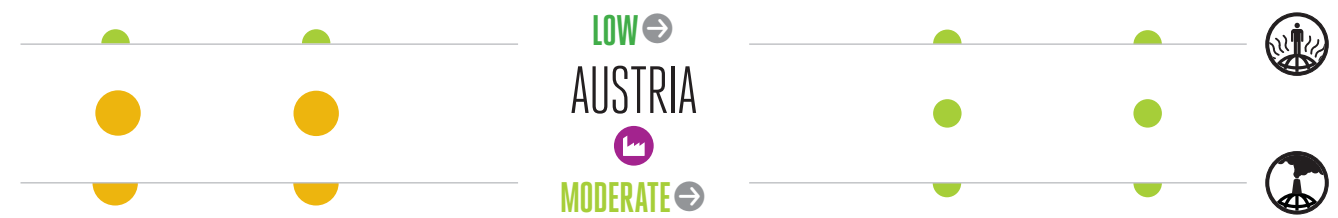
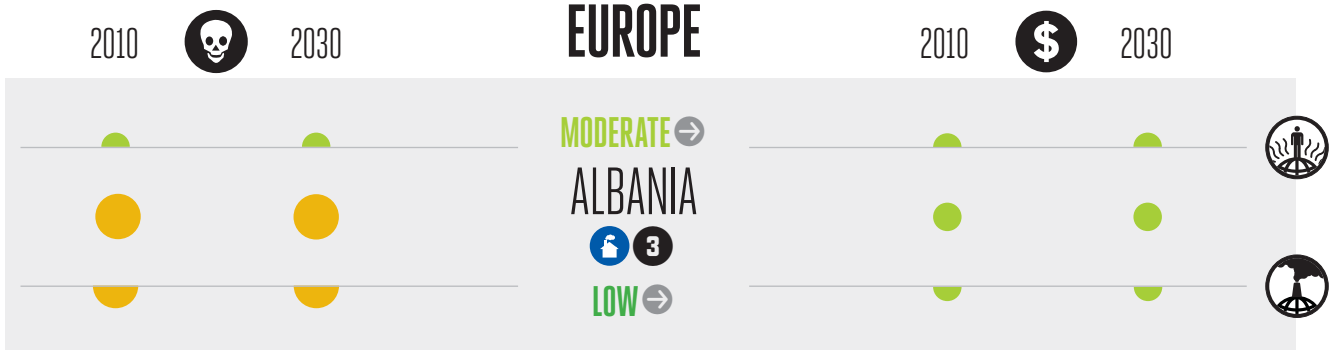
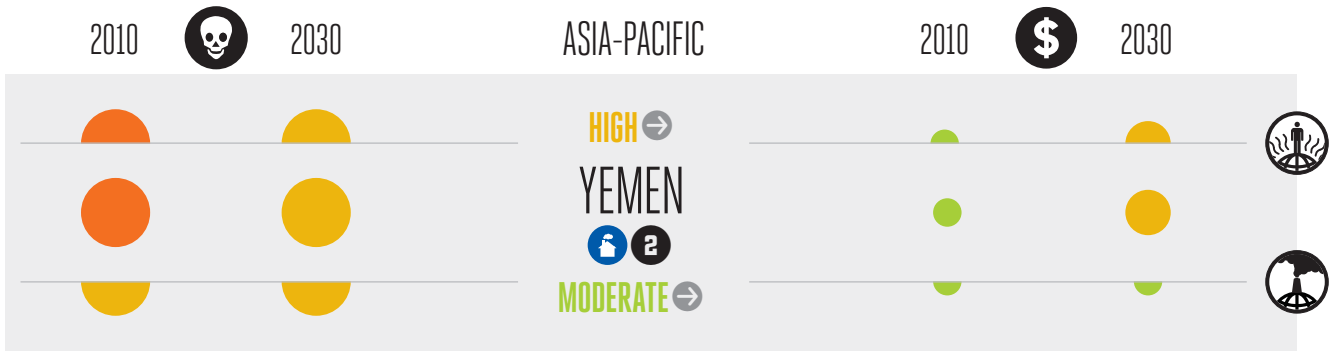
2010

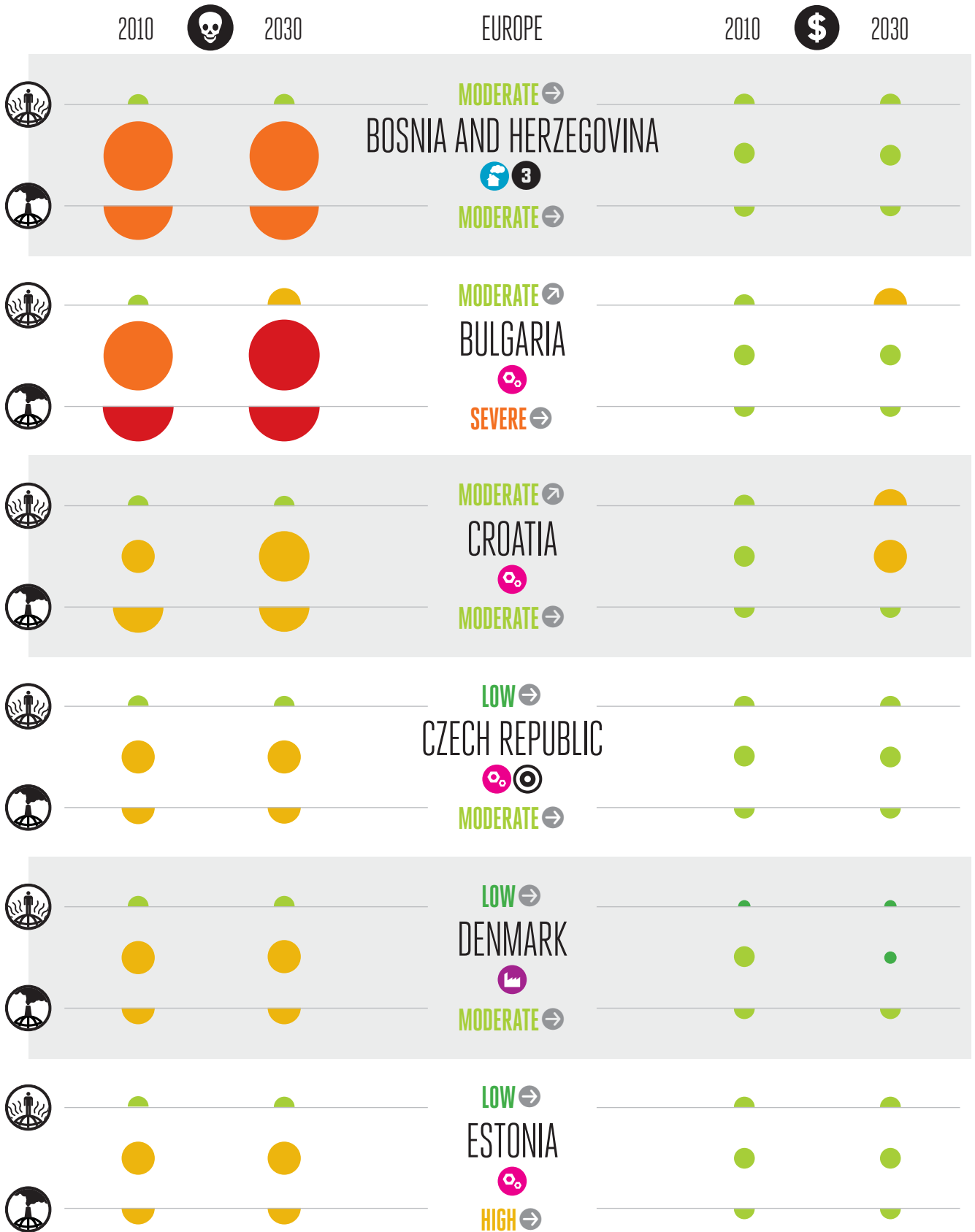


2030





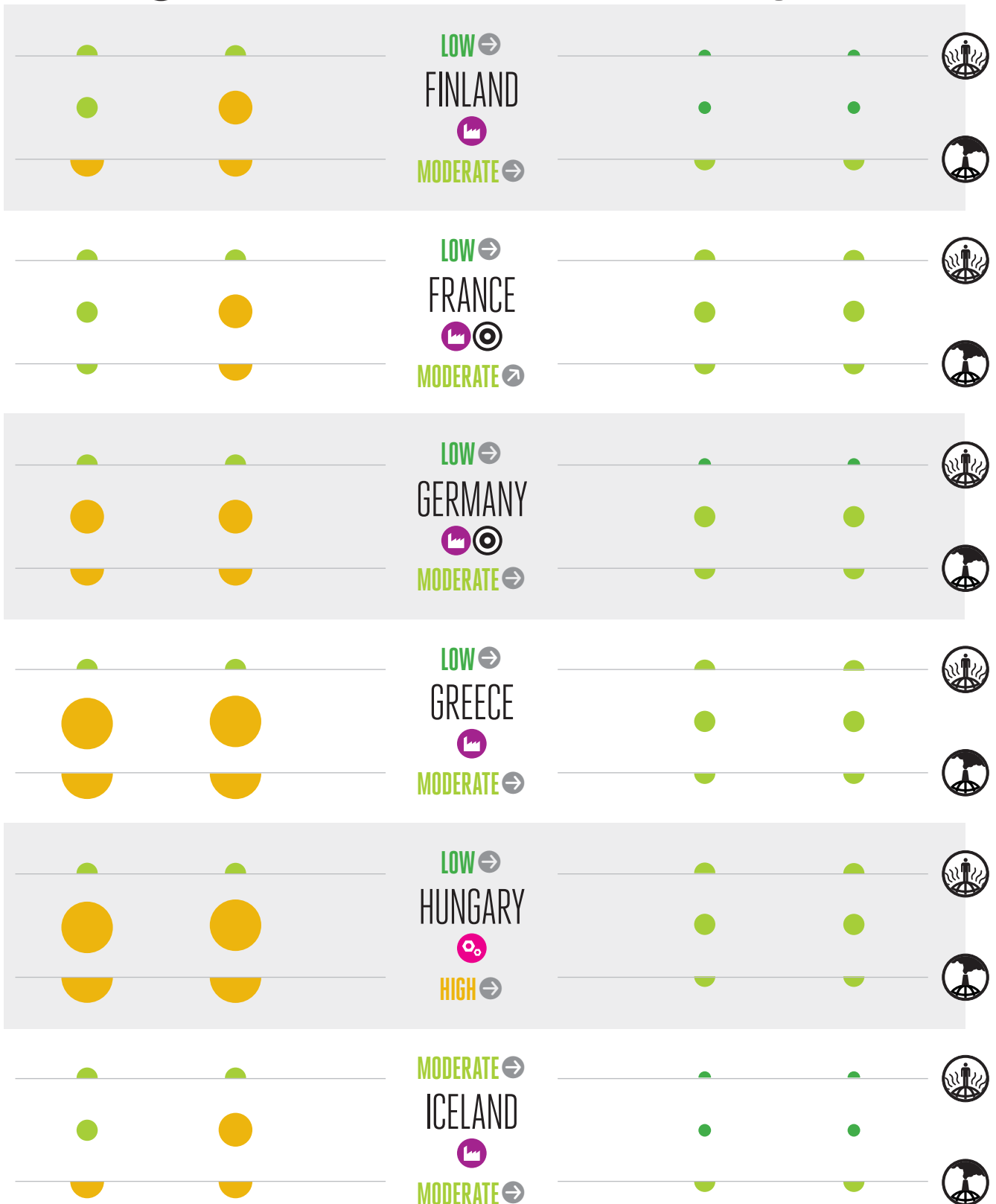




2010  2030

EUROPE

2010  2030



2010



2030

EUROPE

2010



2030



LOW ↘

IRELAND



MODERATE →



LOW →

ITALY



MODERATE →



LOW →

LATVIA



HIGH ↗



LOW →

LITHUANIA



MODERATE →



LOW →

LUXEMBOURG



LOW →



MODERATE ↗

MACEDONIA



3

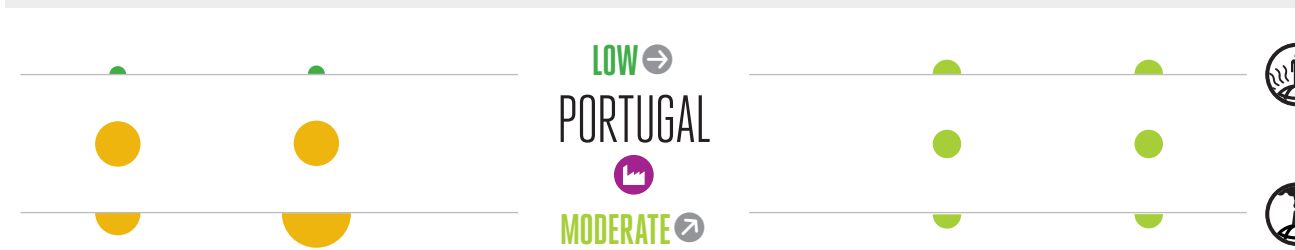
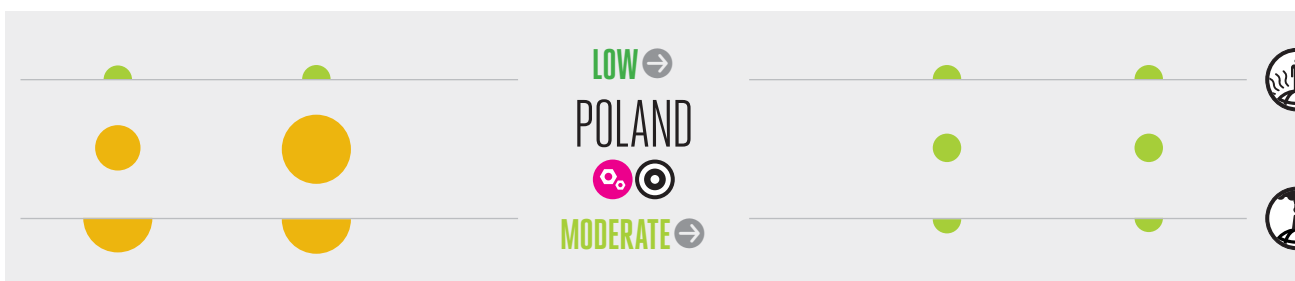
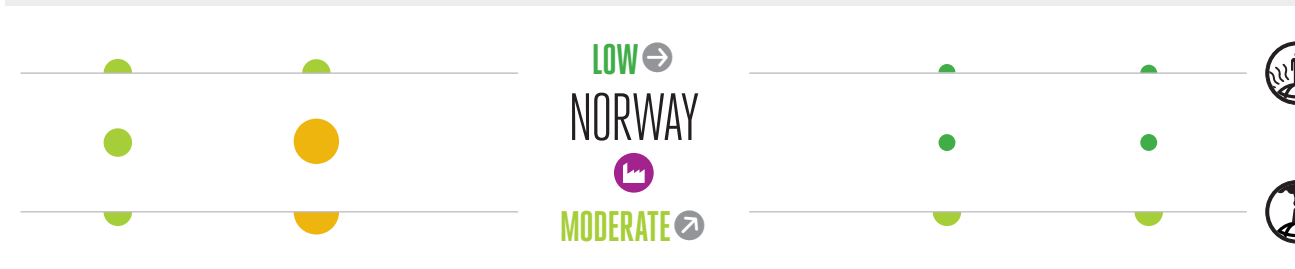
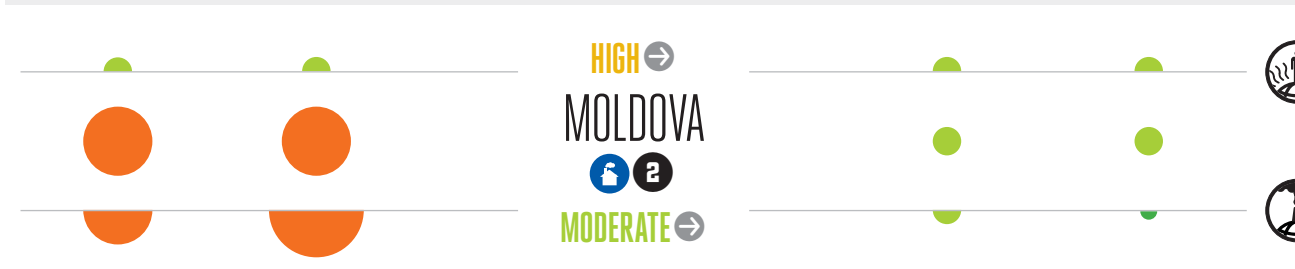
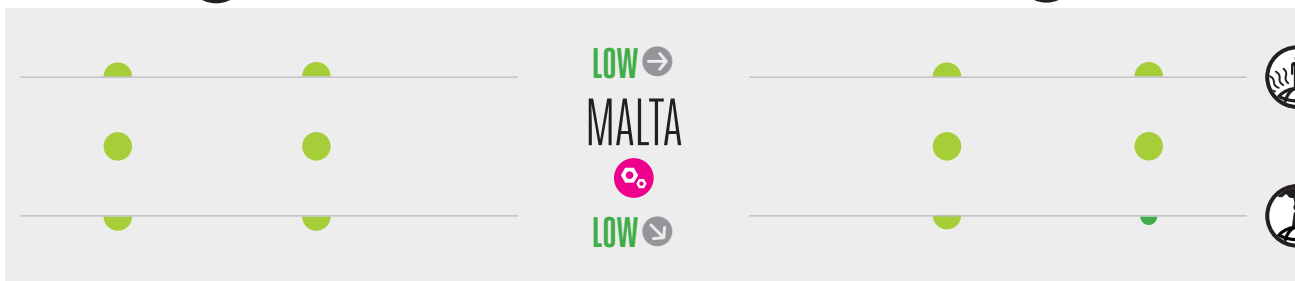
MODERATE →

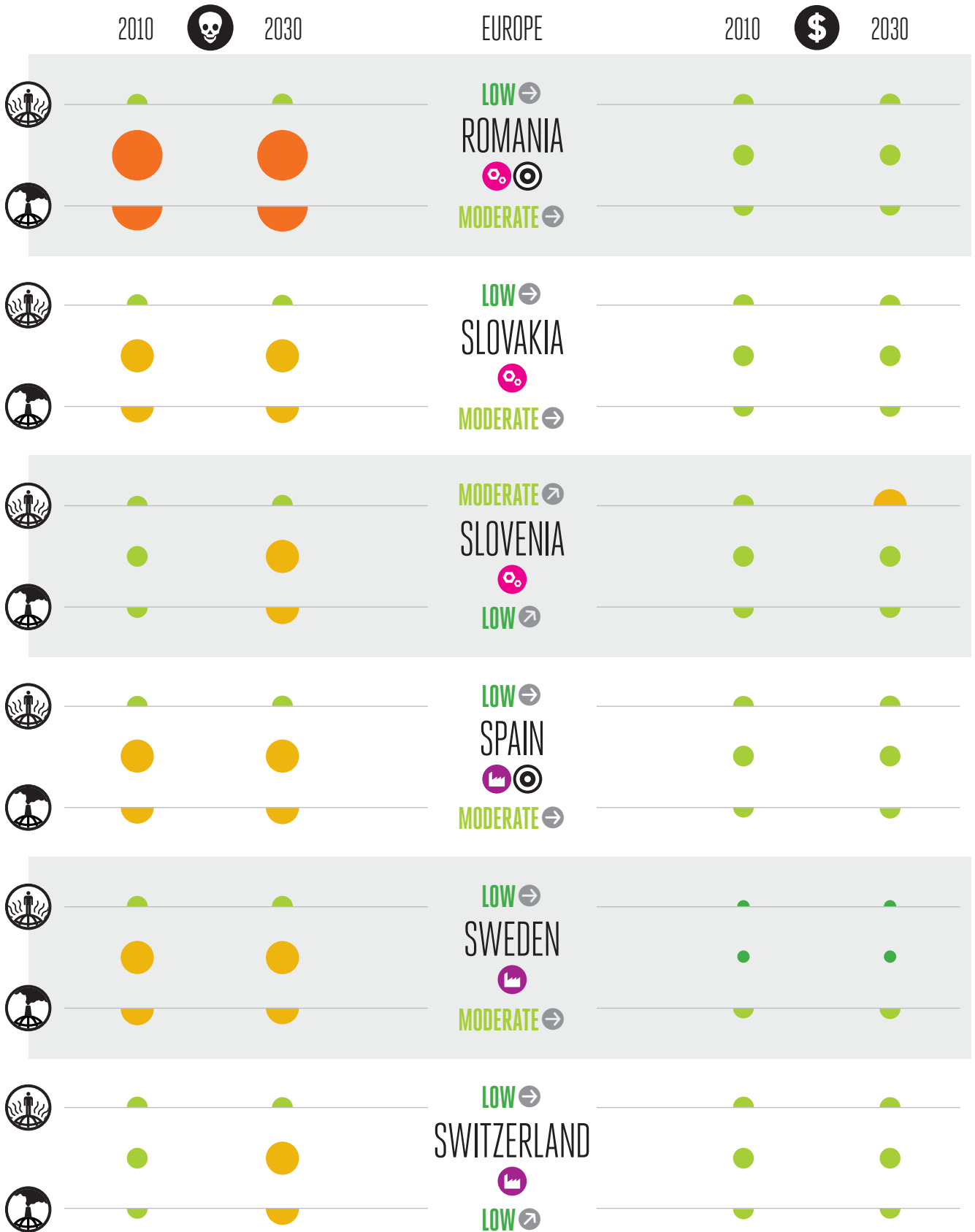


2010  2030

EUROPE

2010  2030





2010



2030

EUROPE

2010



2030



MODERATE →

UKRAINE



HIGH →

LOW →

UNITED KINGDOM



MODERATE →





CLIMATE





ENVIROMENTAL DISASTERS



DROUGHT



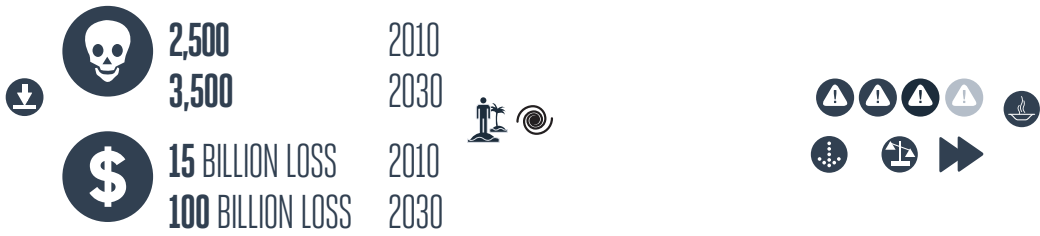
FLOODS & LANDSLIDES



STORMS



WILDFIRES



DROUGHT



ESTIMATES GLOBAL CLIMATE IMPACT

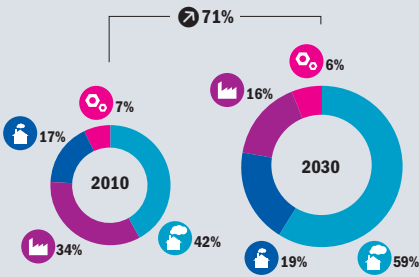
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **5** BILLION

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **20** BILLION

ECONOMIC IMPACT



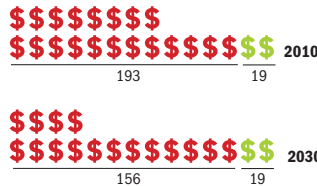
➤ As the planet's temperatures reach new highs drought will become more common and more severe

➤ Climate change also means more rain, but most of it is falling in the far north or far south where fewer people live, and much of this rain falls during the wet season while dry seasons tend to become drier

➤ When drought hits, agriculture comes under extreme pressure, crops may fail and livestock perish with important localized economic, health and social repercussions

➤ Catching and conserving water will be critical to ensure a resilient agricultural sector and food and water security during periods of extreme drought

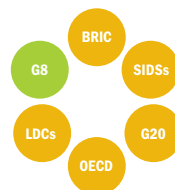
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **f** Developed
H Developing Country High Emitters **o** Other Industrialized

★ \$ = Losses per million USD of GDP
↗ Change in relation to overall global population and/or GDP

◎ \$ Millions of USD (2010 PPP non-discounted)

The increase in heat is already being experienced. It is virtually certain to increase in the coming years (IPCC, 2007). Parts of the world experiencing additional rainfall will also experience drought (Sheffield and Wood, 2008; Helm et al., 2010). Drought can diminish crop yields and kill livestock, generating serious economic losses for affected communities (Pandey et al. (eds.), 2007). Some of the world's major agriculturally productive regions, such as Brazil and Australia, are already affected (Saleska et al., 2011; LeBlanc et al., 2009). Deforestation and other forms of environmental degradation only worsen risk of drought (Turner II et al., 2007). Reducing losses and safeguarding communities will require the tackling of these problems as well stimulating increased water availability through effective capture, storage and distribution measures and policies (McKinsey & Company, 2009). Displacing risks to the insurance industry would also alleviate the severity of losses to individuals and communities (Linnerooth-Bayer and Mechler, 2006).

Wood, 2008). This is qualified by the fact that because of climate change there will also be more moisture and rain in the atmosphere (Allen and Ingram, 2002; Huntington, 2006; Kharin et al., 2007). Additional rain however tends to fall far north or south, where it is not lacking, and less rain tends to fall in the tropical areas of the planet which are already near thermal maximums and where a majority of the world's population live (Helm et al., 2010; Sherwood and Huber, 2010). In parts of the tropics, clouds are gaining in altitude and failing to deposit their moisture on mountain ranges (Malhi et al., 2008). As evidenced in cities, even if more rain falls, provided heat rises faster, any additional water would evaporate and not benefit the soil and its vegetation (Schmidt in Hao et al. (eds.), 2009). Hence, global aridity has increased and is expected to continue increasing, including in areas like the US, which have largely escaped the most severe forms of drought to date (Dai, 2011). Even where rainfall is declining, it is becoming more concentrated generating longer dry spells (Trenberth, 2011). Moreover, country level analysis in Vietnam for instance shows how in regions prone to extreme heat rain will

likely decline in dry seasons and only increase in wet seasons when there will be an overabundance (Vietnam MONRE, 2010). Extreme forms of heat experienced today, such as the European heat wave of 2003, the Russian heat wave of 2010, or the extreme summer temperatures of 2011 in Texas would have been extremely unlikely to occur in the absence of climate change (Hansen et al., 2012). When drought hits, plant productivity is directly affected and the mortality risk for livestock, such as cattle or birds, is greatly raised and indirectly can create vulnerabilities which invasive pests can exploit, further increasing damage (Chaves et al., 2009; Lesnoff et al., 2012; Wolf, 2009; Cherwin, 2009). Economic losses clearly result (Pandey et al. (eds.) 2007; Ding et al., 2011). Drought also damages buildings and infrastructure due to the shrinking and swelling of soil under extreme heat and aridity. This can lead to structural failure or accelerate asset depreciation (Corti et al., 2009).

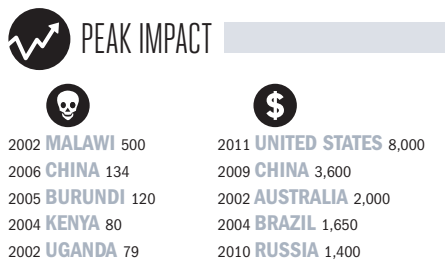
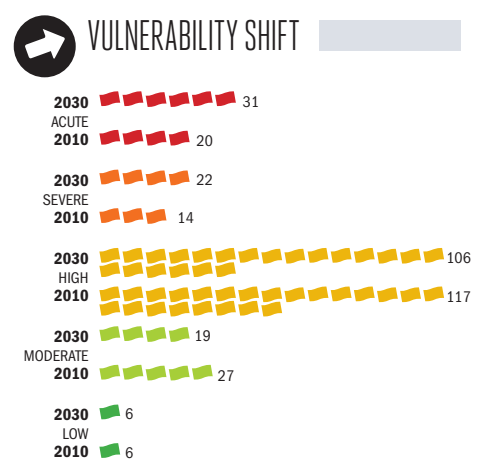
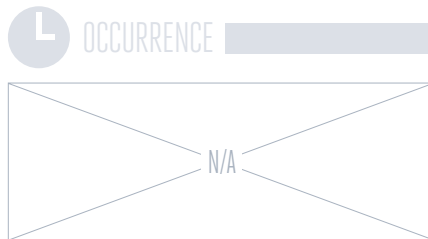
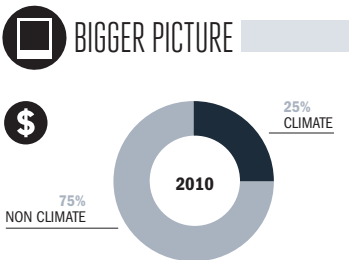
2030 when average annual losses would reach close to 20 billion dollars a year. The impact is very widespread with some 160 countries experiencing high vulnerability to drought by 2030. There are many regions which are seriously affected, especially the wider Mediterranean basin and Black Sea, North Africa, the Middle East and southern and eastern Europe. In addition, parts of Central Asia and Southern Africa are also expected to experience severe effects. While mainly developing countries are affected, since developed nations in general are located geographically in the far north or south, a handful of major advanced economies are exposed to the most severe effects, in particular Spain, Portugal, Greece and Australia. Large numbers of least developed countries figure among those countries with Acute or Severe levels of vulnerability. The largest total impact is felt in China whose estimated losses in 2010 of 800 million dollars would surpass six billion dollars a year in damage by 2030. Other countries with particularly large-scale impacts include India, Iran, the US, Spain, Mexico, Brazil and Russia – several are estimated to experience impacts in excess of 1 billion dollars in annual losses by 2030.

CLIMATE MECHANISM

A hotter planet not unsurprisingly implies more drought (Sheffield and

IMPACTS

The global impact of climate change on drought is estimated to cause close to four billion dollars in damage a year in 2010, set to increase as a share of GDP to



INDICATOR INFORMATION

MODEL: Corti et al., 2009; Hoekstra et al., 2010; Rubel and Kottek, 2010; Sheffield and Wood, 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: Corti et al., 2009; CRED EM-DAT, 2012

THE BROADER CONTEXT

Virtually all of the costliest drought years have occurred in the last two decades (CRED/EM-DAT, 2012). For statistical reasons it is still difficult to conclusively discern and pronounce on any global trends in drought losses; however the IPCC and insurance industry have reported increases in drought impact, and regional drought has become extreme in recent years (Quarantelli, 2001; IPCC, 2007; Bouwer, 2011). Major agricultural zones of Australia have experienced prolonged drought for a decade, not attenuated by a return to pre-drought levels of rainfall as the heat rises (LeBlanc et al., 2009). A 2010 drought in Brazil and across the Amazon regions was one of the worst ever (Saleska et al., 2011). The insurance industry is gauging growing losses as a result of drought-triggered soil subsidence and damage to buildings and infrastructure, estimated to cost €340 million per year in France alone (Swiss Re, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Geography is a prime vulnerability, since countries in the far north receive

considerably more rainfall (IPCC, 2007; Helm et al., 2010). Demand for water is another key determinant of vulnerability, since drought in the middle of the Sahara is of little consequence, while drought in the southern US, Europe or India is a major concern. Global water demand is expected to almost double by 2030, in particular due to increased water withdrawals in the agricultural sector – just as climate change will deprive many of the world's productive regions of water (McKinsey & Company, 2009; Sheffield and Wood, 2008). Land degradation from over-intensive agricultural exploitation or over-grazing and deforestation also greatly increase susceptibility to drought – another 30% loss of forest in the Amazon could push the entire region into permanent aridity (Malhi et al., 2008). A lack of adequate irrigation and water infrastructure exacerbates drought since water captured in other periods of the year cannot be drawn upon during periods of prolonged aridity. In general, water-deprived economies have been understood to be less prosperous (Brown and Lall, 2006). The human health consequences of drought are principally accounted for under the Hunger indicator of the Monitor.

RESPONSES

Any response to drought must face up to two key concerns: 1) increasing water availability, and 2) dealing with building and infrastructure damage due to sinking or destabilized land. Increasing water availability will be met at the market cost of supplying water, which varies from region to region depending on the degree of water scarcity currently prevailing locally (McKinsey & Company, 2009). Effective governments would anticipate any shortfall and stimulate action to meet any expected water demand shortfall in order to avoid economic losses and loss of tax revenues. Addressing soil subsidence through design could involve the retrofitting of buildings to withstand soil movements linked to drought. Both drought and soil subsidence impacts can be dealt with by displacing risks to the insurance (and micro-insurance) industry through policies enabling businesses and homeowners to safeguard against potential damages (Swiss Re, 2011; Churchill and Matul, 2012).

THE INDICATOR

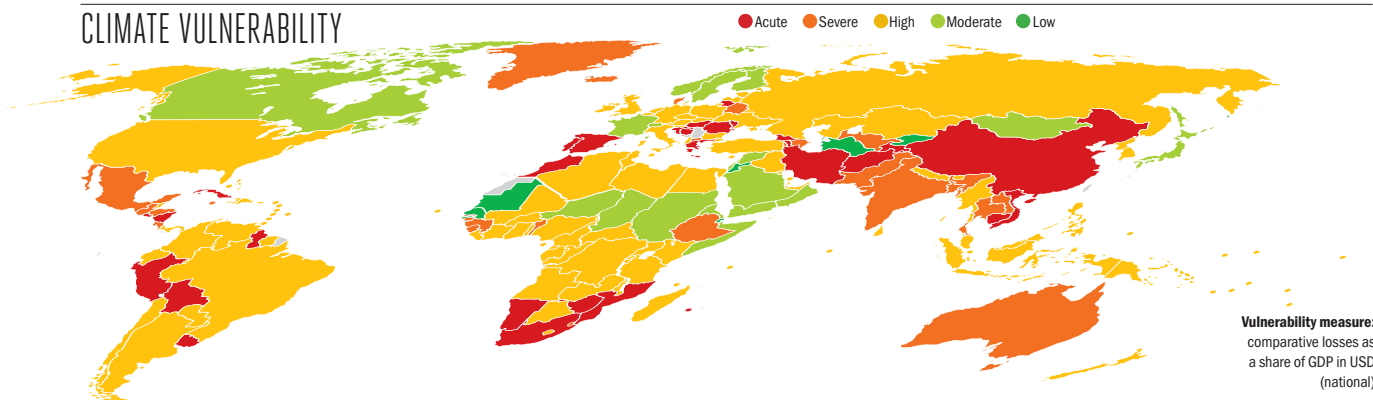
The indicator measures the impact of climate change on drought, defined as a consecutive sequence of months with “anomalously low soil moisture”. It measures the change in both disaster damages and depreciation of property due to soil subsidence damages. The change in the number of droughts expected to occur is estimated using an ensemble of eight climate models (Sheffield and Wood, 2008). Baseline data for disaster damages is derived from the main international disaster database, but is known to be incomplete (CRED/EM-DAT, 2012). Accelerated depreciation of infrastructure due to soil subsidence uses a model based on France and extrapolated based on GDP per capita and population density, but excluding arid countries where the effect is considered less relevant (Corti et al., 2009; Hoekstra et al., 2010). Limitations and uncertainties relate to difficulties in estimating rainfall change for certain regions, the simplistic 1:1 damage assumption implied and to the extrapolation used for the soil subsidence indicator.

ESTIMATES COUNTRY-LEVEL IMPACT

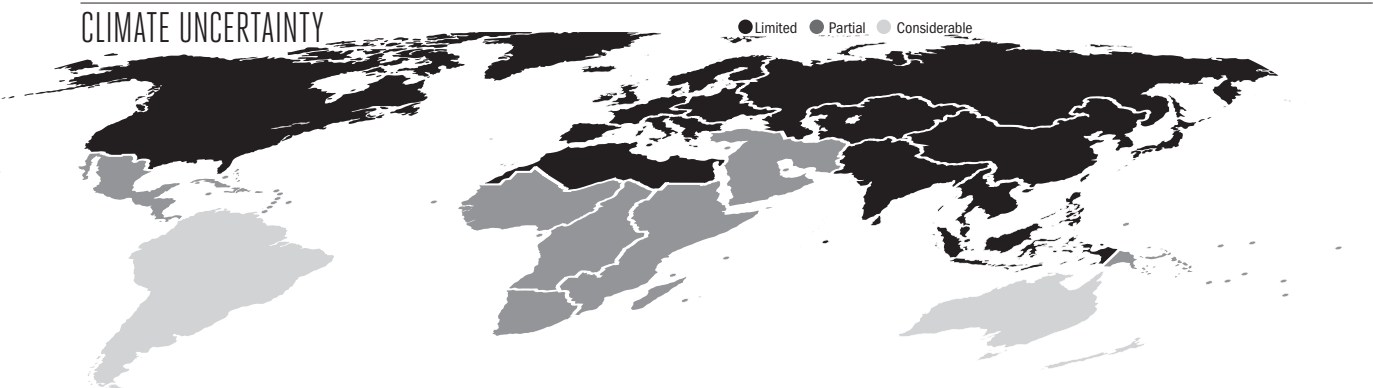
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			SEVERE					
Afghanistan	5	40	Australia	45	100	Barbados		1
Armenia	5	25	Azerbaijan	5	30	Belgium	10	15
Bolivia	5	45	Bangladesh	15	75	Belize		1
Bosnia and Herzegovina	15	100	Belarus	10	35	Bhutan		1
Cambodia	5	60	Benin	1	5	Botswana	1	5
China	800	6,250	Costa Rica	1	15	Brazil	95	550
Croatia	15	85	Denmark	10	25	Brunei	1	5
Cuba	10	65	Ethiopia	5	20	Bulgaria	5	20
El Salvador	10	70	Guatemala	5	20	Burkina Faso	1	1
Gambia		1	Guinea	1	1	Burundi		1
Georgia	10	50	Guinea-Bissau		1	Cameroon	1	5
Greece	35	95	Honduras	1	10	Cape Verde		
Guyana	1	15	India	300	1,500	Central African Republic		1
Hungary	15	90	Jamaica	1	5	Chile	15	70
Iran	200	1,500	Laos	1	5	Colombia	15	80
Lithuania	10	45	Macedonia	1	5	Comoros		
Mauritius	5	25	Mexico	95	600	Congo	1	1
Moldova	10	65	Pakistan	35	200	Cote d'Ivoire	1	5
Morocco	40	300	Sierra Leone		1	Cyprus	1	1
Mozambique	1	10	Swaziland		1	Czech Republic	10	40
Namibia	1	10	Thailand	40	200	Dominica		
Nicaragua	1	15	Uzbekistan	5	30	Dominican Republic	5	20
Peru	25	150	HIGH			DR Congo	1	5
Portugal	45	150	Albania	1	5	Ecuador	5	30
Romania	20	100	Algeria	5	30	Egypt	10	50
South Africa	50	250	Angola	5	15	Equatorial Guinea	1	5
Spain	200	650	Antigua and Barbuda			Estonia	1	5
Tajikistan	5	20	Argentina	25	150	Fiji		1
Uruguay	5	40	Austria	10	10	Gabon	1	5
Vietnam	40	350	Bahamas		1	Germany	70	100
Zimbabwe	1	10	Bahrain	1	5	Ghana	5	15
						Grenada		



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Haiti	1	1	Paraguay	1	5	Venezuela	10	45
Iceland	1	1	Philippines	20	85	Zambia	1	1
Indonesia	40	200	Poland	30	100	MODERATE		
Iraq	5	15	Qatar	5	20	Canada	25	45
Ireland	5	5	Russia	90	400	Chad		
Italy	55	150	Rwanda	1	1	Eritrea		
Kazakhstan	5	20	Saint Lucia		1	Finland	1	1
Kenya	1	5	Saint Vincent		1	France	45	75
Kiribati			Samoa			Israel	1	15
Kuwait	5	20	Sao Tome and Principe			Japan	90	150
Latvia	1	5	Seychelles		1	Luxembourg	1	1
Lebanon	1	10	Singapore	10	40	Mongolia		1
Lesotho	1	1	Slovakia	5	15	Niger		1
Liberia			Slovenia	1	10	Norway	1	5
Libya	1	10	Solomon Islands			Oman	1	5
Madagascar	1	5	South Korea	55	250	Saudi Arabia	1	10
Malawi	1	1	Sri Lanka	5	25	Somalia		
Malaysia	20	80	Suriname		1	Sudan/South Sudan	1	10
Maldives			Tanzania	5	15	Sweden	5	10
Mali	1	1	Timor-Leste		1	Switzerland	5	10
Malta		1	Togo		1	Syria	1	5
Marshall Islands			Tonga			Yemen	1	5
Micronesia			Trinidad and Tobago	1	5	LOW		
Myanmar	1	10	Tunisia	5	15	Djibouti		
Nepal	1	10	Turkey	35	65	Jordan		
Netherlands	15	25	Tuvalu			Kyrgyzstan		
New Zealand	5	5	Uganda	1	10	Mauritania		
Nigeria	15	70	Ukraine	20	75	Senegal		
North Korea	1	10	United Arab Emirates	5	25	Turkmenistan		
Palau			United Kingdom	55	90			
Panama	1	10	United States	500	1,250			
Papua New Guinea	1	1	Vanuatu					

FLOODS & LANDSLIDES



ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

DEATHS PER YEAR **2,750**

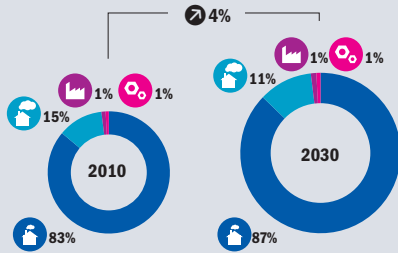
USD LOSS PER YEAR **10** BILLION

2030 EFFECT TOMORROW

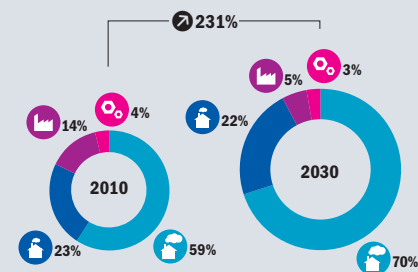
DEATHS PER YEAR **3,500**

USD LOSS PER YEAR **95** BILLION

MORTALITY IMPACT

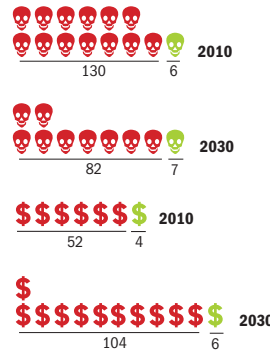


ECONOMIC IMPACT

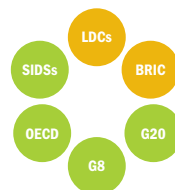


- Heavy rainfall, the main trigger of flooding and landslides, is on the rise
- Spring comes earlier and releases more water from mountains and glaciers which adds further to flood risks
- Future increases in these effects may coincide, generating more mega disasters of the scale of the 2010 Pakistan floods
- Comprehensive risk reduction efforts in implementation of the Hyogo Framework for Action are helping to reduce vulnerabilities, even as world population and exposed infrastructure expand
- Parallel efforts are not being made to deliberately adjust humanitarian relief systems to growing flood dange

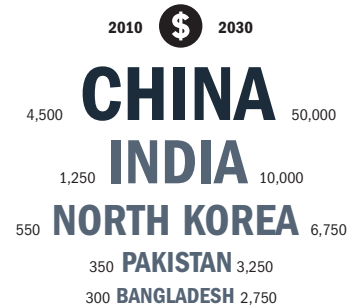
RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS



☠ Deaths \$ Economic Cost (2010 PPP non-discounted)
 🏠 Developing Country Low Emitters 🏭 Developed
 🏠 Developing Country High Emitters 🏠 Other Industrialized

☠☠ = Deaths per 100 million
 \$ = Losses per 100,000 USD of GDP
 ↗ Change in relation to overall global population and/or GDP

🎯 \$ = Millions of USD (2010 PPP non-discounted)

Flooding is a common natural hazard from increases in rainfall due to climate change. Floods are expected to worsen practically everywhere, even in areas facing declining annual rainfall, as heavy downpours become more common (IPCC, 2007). More floods mean more deaths and injuries, more damaged property and infrastructure, and growing disruption of economic activities. Where large countries like China, Pakistan, or the US are affected, the lives of millions of people may be disrupted and billions of dollars of economic damage inflicted (CRED/EM-DAT, 2012). However, the risk of death due to flooding is heavily concentrated in low-income countries, which face significant risks of setbacks in development gains, with women particularly vulnerable (UNISDR, 2011; Nelleman et al., 2011). Highly cost-effective including “low-regrets” measures to limit damages and speed recovery are also inaccessible to many for lack of the capacity and up-front resources to implement them (IPCC, 2012a). Social and political factors, including illiteracy and the over-exploitation of resources often exacerbate these problems (UNISDR, 2009).

CLIMATE MECHANISM

A warmer planet means a more active hydrological system, as water is evaporated faster from oceans and land, generating cloud and rainfall (Dore, 2005; Kharin et al., 2007). That means more rain overall and more energy in general in the global climate system as it heats up, leading to heavier downpours of rain, more variable or erratic rainfall, and more frequent heavy precipitation. Coupled with an earlier spring that discharges more water as glaciers continue to decline, the implications are that risk of flooding and landslides caused by weather, and not earthquakes or otherwise, are on an increase (Hidalgo et al., 2009; Radi and Hock, 2011; IPCC, 2007; Mirza et al., 2003; Jonkman et al., 2008; Bouwer et al., 2010). The evidence base for the flood trend is low, in particular due to inadequate gauge station records and confounding information linked to land use and engineering (IPCC, 2012a). The increase in heavy rainfall during short periods of time is assured and is not only the main trigger of flooding, but the main input variable to early warning tools to predict flooding (Prudhomme et al., 2002; Harris et al., 2007).

IMPACTS

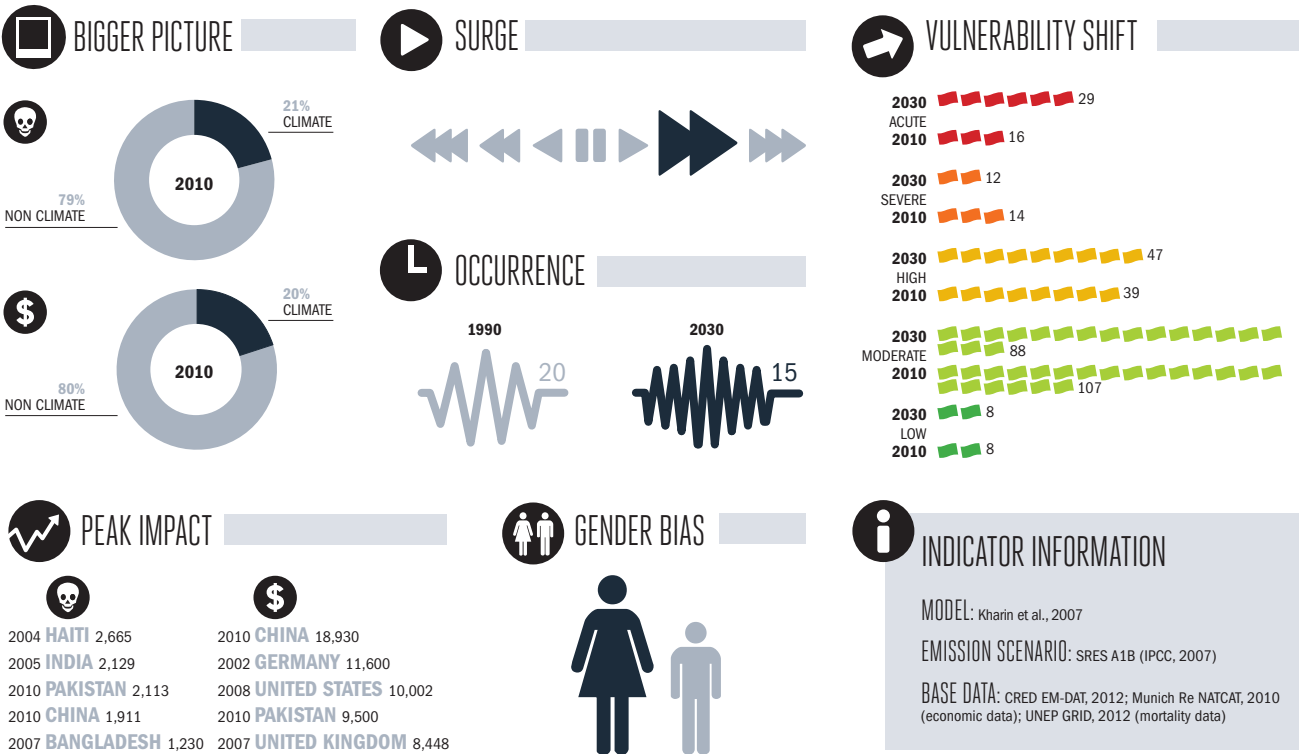
Globally, climate change is already estimated to be responsible for close to an average of 3,000 deaths per year and around 10 billion dollars in economic losses through flooding and landslides. For every death, there can be as many as 10,000 people in need of emergency assistance; each year, over 25 million more people are affected than in earlier periods when climate change was not so marked. Over the next 20 years, the climate-related flood death toll is expected to increase only modestly to 3,500 deaths per year with economic losses more than tripling as a share of global GDP, reaching 95 billion dollars per year by 2030. Approximately two-thirds of these losses are incurred in China and India alone. Populous emerging economies in Asia, such as Bangladesh, Pakistan, and Vietnam are particularly vulnerable, as are mountainous developing countries, such as Bhutan and Nepal. Effects are widely distributed around the world, with the number of countries labeled “Acute” doubling by 2030. Low-lying small island states, such as the Maldives, are unaffected by non-coastal flooding and landslides, whereas mountainous small islands, such as Haiti or Fiji are at high risk.

THE BROADER CONTEXT

The significance of socio-economic determinants of risk mean climate change is only one factor in the scale of damage generated by so-called natural disasters. Mortality risk due to extreme weather is known to fall over time with rising incomes (Pezuzzi et al., 2012). However, economic losses show increases in recent years (CRED/EM-DAT, 2012; Munich Re, 2012). These observations support the UN’s analysis that as socio-economic development improves, fewer people are killed, but infrastructure is at greater risk (UNISDR, 2009 and 2011).

VULNERABILITIES AND WIDER OUTCOMES

Vulnerability levels are often dictated by socio-economic development standing and the associated effectiveness of governments in putting in place measures that can limit dangers for populations. Poorly located, unprotected flood plain settlements are also at high risk, but sound governance should prevent or rationalize this type of development. Environmental degradation and unwise patterns of land



= Millions of USD (historic)
 Estimated time between major weather events (years)
 = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

usage, particularly deforestation, further exacerbate localized vulnerabilities, for example, by destabilizing hillsides and by increasing the flow of rainwater over land—effects especially significant in developing countries (Brashshaw et al., 2007). High rates of urbanization, common in most developing countries around the world today, often lead rural-urban migrants to settle in flood plain shanty towns adjacent to major urban centres, adding to the level of risk (Quarantelli, 2003). Flooding carries serious consequences for economic activity, especially for lower-income communities where insurance that otherwise speeds economic rebound is least prevalent (Dodman and Satterthwaite, 2008). Harm to poverty-reduction efforts has been shown to result more from widespread and regularly occurring small- to medium-scale disasters, since they repeatedly frustrate development progress, even though freak, high-profile, catastrophes typically receive more attention (Lavell, 2008). Flood damage—particularly ecological and social costs or diffuse disruptions to broad economic activities—is also difficult to fully quantify, and in extreme cases can persist for months (Messner and Meyer, 2005).

RESPONSES

Like other disasters, floods are considered to have three core components: hazard, exposure, and vulnerability. Hazard is a variable largely beyond immediate human control, so responses either aim to decrease vulnerability or exposure to hazard, or both. Measures such as rapid early warning systems, disaster education, building codes and their regulation, environmental protection against deforestation and land degradation, insurance for infrastructure or other economic assets, flood defences and storm drains, strengthening of local ecosystems, disaster volunteer programmes all reduce vulnerabilities, but may demand resources which many countries simply do not possess. Under pressure of economic and population growth, most increases in exposure are inevitable. But strategic municipal planning for infrastructure development can help minimize the extent of new exposure to risk. Urban centres with elevated population densities are also high-dividend opportunities for reducing possible disasters, provided urban authorities are willing and able to meet the needs of their residents

in managing risks (Dodman and Satterthwaite, 2008). The capacity of governments to develop and implement a range of risk-reduction measures is considered a fundamental determinant of the success of national disaster prevention and recovery strategies; this includes the ability to incorporate considerations of disaster risk into wide-ranging state agendas, from education to municipal planning and fiscal tools. Capacity to do so is also most deficient in highly vulnerable, low-income settings (Ahrens and Rudolph, 2006). A number of low-income countries, such as Bangladesh have nevertheless managed to reduce levels of vulnerability through cost-effective community and volunteer-based efforts, as alternatives to more resource-intensive measures (Khan, 2007). On the other hand, recent floods along the Mississippi and Missouri rivers in the US have shown how even the highly developed countries can be overwhelmed by large-scale events (Olson and Morton, 2012). New extremes and delays in policy changes to increase resilience mean that the world's humanitarian system should prepare for serious increases in flood response in the years ahead.

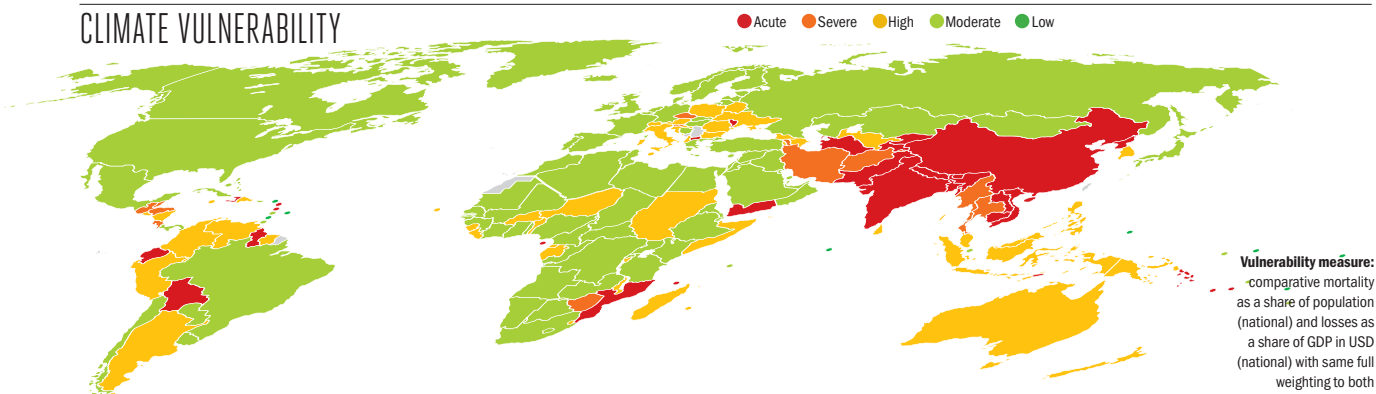
THE INDICATOR

The indicator combines exposure to floods and landslides with modeled mortality risk for estimations of deaths with socio-economic adjustments. For economic losses, a combination of 20 years of disaster data from different sources is relied upon as a baseline. The indicator then estimates how the change in, or increases in the occurrence of, heavy precipitation events would alter the current picture of flood and landslide risk. Uncertainty regarding precipitation change in some areas is an impediment to reliable national-level estimates of these changes. Likewise, country-specific variation in the effects of increased heavy rainfall is not accounted for, except through the worsening of the pre-existing topography of risk, as reflected in historic and modeled disaster data. Although records of floods are unreliable, models of the effects of climate change on heavy precipitation and observed rainfall changes do reveal the increasing trend (IPCC, 2007, IPCC, 2012a; Kharin et al.).

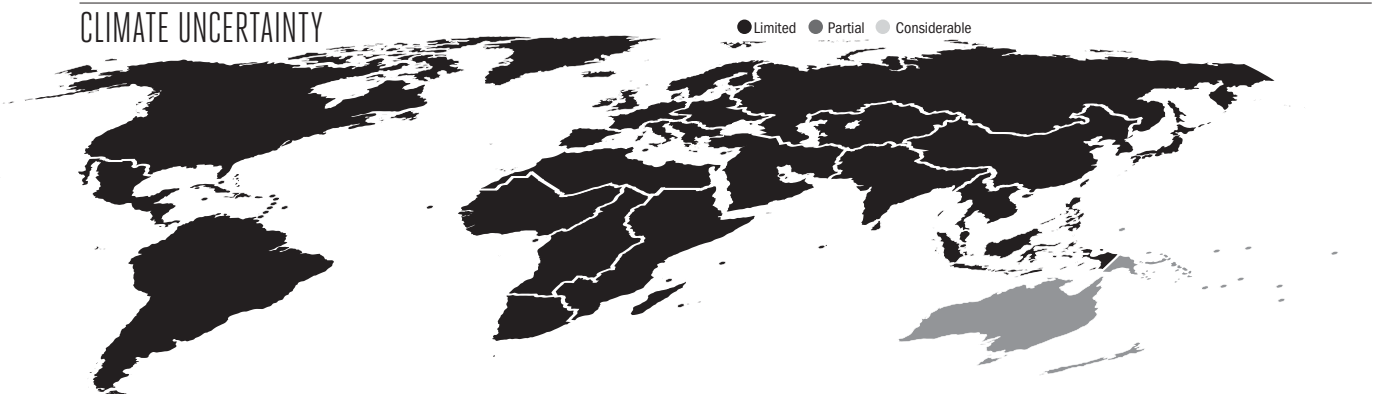
COUNTRY	👤		💰		👤		COUNTRY	👤		💰		👤		COUNTRY	👤		💰		👤		
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030	
ACUTE							ACUTE					ACUTE					ACUTE				
Bangladesh	75	100	300	3,000	600,000	900,000	Armenia	1	1	1	20,000	25,000	Italy	1	1	150	500	5,500	7,000		
Bhutan	1	1	1	15,000	25,000	Belize			1	1,500	2,000	Jamaica	1	1	1	20	3,500	4,000			
Bolivia	1	1	30	300	10,000	15,000	Costa Rica	1	1	5	55	6,500	10,000	Liberia	1	1	1	5,500	15,000		
Cambodia	10	10	20	200	65,000	85,000	Czech Republic			55	350	2,000	1,500	Madagascar	5	5	1	15	30,000	55,000	
China	200	150	4,500	50,000	2,000,000	1,500,000	Guatemala	5	10	5	60	45,000	90,000	Malawi	1	1	1	5	15,000	25,000	
Comoros	5	10			45,000	85,000	Honduras	1	1	5	70	15,000	20,000	Malaysia	5	5	20	200	15,000	15,000	
Dominica	1	1			2,500	3,000	Iran	10	10	200	1,500	40,000	50,000	Malta			1	1	200	300	
Ecuador	1	5	30	300	25,000	30,000	Myanmar	35	45	5	40	250,000	350,000	Mauritius			1		1,500	1,500	
Fiji	1	1	1	10	4,000	3,500	Slovenia			15	95	2,000	1,500	New Zealand	1	1	5	15	4,500	9,500	
Guyana			10	100	2,000	1,500	Thailand	15	10	100	1,000	150,000	100,000	Nicaragua	1	5	1	5	20,000	40,000	
Haiti	5	5	5	35	30,000	40,000	Zimbabwe	1	1	5	25	15,000	25,000	Niger	1	5	1	10	10,000	25,000	
India	2,000	2,500	1,000	10,000	20,000,000	25,000,000	HIGH						Papua New Guinea	1	5	1	5	30,000	40,000		
Kyrgyzstan	1	1	5	35	9,500	15,000	Albania	1	1	1	10	5,000	6,500	Peru	5	5	15	150	15,000	20,000	
Laos	5	10	1	15	55,000	70,000	Argentina	5	5	70	700	15,000	20,000	Philippines	25	25	30	300	200,000	250,000	
Macedonia			5	50	1,500	1,000	Australia	1	1	65	200	2,500	5,500	Poland	1	1	85	600	5,500	4,000	
Moldova	1	1	15	100	5,500	5,000	Austria	1	1	30	90	5,000	6,500	Romania	1	1	40	300	8,500	6,000	
Mozambique	1	5	10	85	20,000	30,000	Azerbaijan	1	1	5	30	10,000	10,000	Sierra Leone	1	5		1	15,000	30,000	
Nepal	10	15	15	150	85,000	100,000	Belarus	1	1	5	35	6,500	5,500	Somalia	1	5	1	1	20,000	45,000	
North Korea	10	10	550	6,500	100,000	85,000	Benin	1	1	1	5	7,500	15,000	South Korea	5	5	95	800	25,000	20,000	
Pakistan	30	45	350	3,000	300,000	450,000	Brunei					1,500	1,500	Sri Lanka	5	5	15	150	45,000	40,000	
Saint Lucia	1	1			6,000	6,000	Bulgaria	1	1	10	70	3,000	1,500	Sudan/South Sudan	5	5	5	40	40,000	55,000	
Sao Tome and Principe	1	1			15,000	25,000	Burkina Faso	1	1	1	15	3,000	7,500	Suriname					550	650	
Solomon Islands	1	1			5,000	9,000	Burundi	1	1			10,000	20,000	Swaziland			1		3,000	4,000	
Tajikistan	5	5	40	300	30,000	45,000	Cape Verde					1,500	2,000	Switzerland	1	1	25	75	2,000	3,000	
Timor-Leste	1	1			25,000	25,000	Colombia	10	10	50	450	35,000	45,000	Ukraine	1	1	40	300	25,000	15,000	
Turkmenistan	5	10	5	25	55,000	80,000	Croatia	1	1	10	85	4,000	3,000	Uzbekistan	10	15		1	95,000	150,000	
Vanuatu			1	1	2,500	4,000	Dominican Republic	1	1	1	25	7,500	8,000	Venezuela	5	5	30	300	15,000	15,000	
Vietnam	50	55	150	2,000	500,000	500,000	El Salvador	1	5			20,000	30,000	MODERATE							
Yemen	1	1	35	250	7,500	25,000	Equatorial Guinea			1		2,000	3,500	Algeria	5	5	5	60	15,000	20,000	
SEVERE							Gabon	1	1			1,500	3,000	Angola	1	5		1	20,000	45,000	
Afghanistan	5	10	5	35	55,000	90,000	Georgia	1	1	1	10	30,000	20,000	Bahamas							
							Indonesia	25	30	75	650	250,000	250,000	Bahrain					1	650	850



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	👤		\$		👤		COUNTRY	👤		\$		👤		COUNTRY	👤		\$		👤		
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030	
Belgium		1	1	5	1,500	2,000	Israel		1	1	5	1,500	2,000	Senegal	1	1	1	5	9,500	15,000	
Bosnia and Herzegovina	1	1	1	5	3,000	2,000	Japan	5	5	150	400	20,000	35,000	Seychelles							
Botswana				1	650	700	Jordan				1	2,000	3,000	Singapore			1	5			
Brazil	5	10	20	200	30,000	30,000	Kazakhstan	1	5	5	30	10,000	15,000	Slovakia	1		5	30	2,500	2,000	
Cameroon	5	5		1	35,000	50,000	Kenya	5	5	1	10	40,000	50,000	South Africa	1	1	5	35	5,500	4,500	
Canada	1	5	30	100	9,000	20,000	Kuwait					150	200	Spain	1	1	10	35	4,000	5,500	
Central African Republic	1	1			6,000	9,500	Latvia					1,000	750	Sweden					1	400	600
Chad	1	1		1	9,500	20,000	Lebanon	1	1			3,000	3,000	Syria	1	5			30,000	45,000	
Chile	1	1	5	50	4,000	4,500	Lesotho					3,500	3,500	Tanzania	1	5	1	10	20,000	30,000	
Congo	1	1			7,000	15,000	Libya			1	5	650	850	Togo	1	1	1	1	5,000	9,000	
Cote d'Ivoire	1	1			20,000	30,000	Lithuania					1,000	900	Tonga							
Cuba	1	1	1	20	2,500	2,500	Luxembourg				1	200	500	Trinidad and Tobago				1	650	600	
Cyprus					750	1,500	Mali	1	1			10,000	20,000	Tunisia		1	5	45	3,500	4,000	
Denmark				1	250	350	Mauritania			1	1	2,000	4,500	Turkey	5	10	30	100	15,000	35,000	
Djibouti					200	250	Mexico	10	10	55	500	40,000	40,000	Uganda	1	5		1	15,000	35,000	
DR Congo	10	25		1	90,000	200,000	Micronesia							United Arab Emirates	1	1	1	20	2,500	3,000	
Egypt	5	10	5	30	65,000	80,000	Mongolia	1			1	4,500	3,500	United Kingdom	1	1	100	350	3,500	5,500	
Eritrea	1	1			4,500	7,500	Morocco	1	1	5	30	15,000	20,000	United States	5	5	600	2,000	15,000	35,000	
Estonia					750	450	Namibia					1	1,000	1,500	Uruguay	1	1	1	5	1,500	1,500
Ethiopia	10	15	1	5	75,000	150,000	Netherlands	1	1	15	40	2,000	3,500	Zambia	1	1	1	1	10,000	20,000	
Finland					1		Nigeria	10	15	1	20	85,000	150,000	LOW							
France	1	1	60	200	9,000	15,000	Norway			1	5	700	1,000	Antigua and Barbuda							
Gambia					1,000	1,500	Oman			1	1	1,500	3,000	Barbados							
Germany	1	1	100	350	4,500	6,500	Panama	1	1	1	5	2,000	2,000	Grenada							
Ghana	1	1	1	5	6,500	10,000	Paraguay	1	1		1	10,000	20,000	Kiribati							
Greece	1	1	10	30	2,000	3,000	Portugal	1	1	10	30	2,000	3,000	Maldives							
Guinea	1	5		1	15,000	25,000	Qatar					300	350	Marshall Islands							
Guinea-Bissau					950	1,500	Russia	10	5	75	550	35,000	25,000	Palau							
Hungary			10	65	1,500	900	Rwanda	1	1			15,000	25,000	Tuvalu							
Iceland				1	150	250	Saint Vincent														
Iraq	5	5			35,000	60,000	Samoa														
Ireland		1	5	15	1,000	2,500	Saudi Arabia	1	10	90	1,500	3,000									

👤 Additional persons affected/in need of emergency assistance due to climate change - yearly average

STORMS



ESTIMATES GLOBAL CLIMATE IMPACT



2010 EFFECT TODAY

DEATHS PER YEAR
2,500

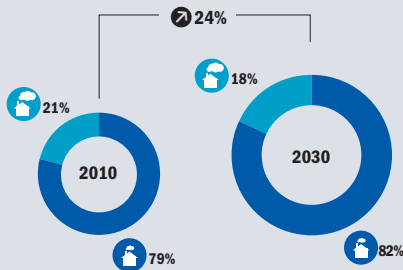
USD LOSS PER YEAR
15 BILLION

2030 EFFECT TOMORROW

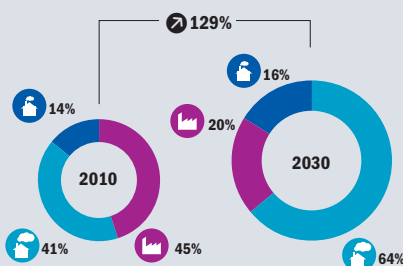
DEATHS PER YEAR
3,500

USD LOSS PER YEAR
100 BILLION

MORTALITY IMPACT



ECONOMIC IMPACT



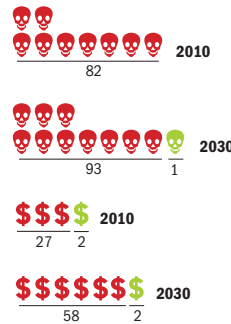
➤ All weather is affected by climate change because the Earth's atmosphere is warmer, moister, and more active today than in the recent past

➤ As a result, storms are becoming more extreme both in and outside of the tropics and will cause greater damage

➤ The location and extent of the additional damage is difficult to predict, as experts and their studies differ in their conclusions

➤ Countries already exposed to tropical cyclones or immediately adjacent to cyclone belts should prepare for growing risks and damages, especially in coastal areas

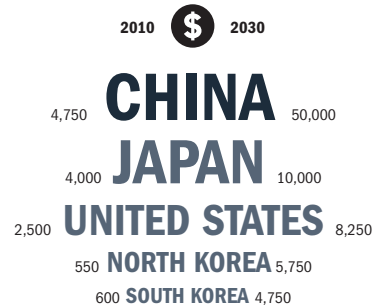
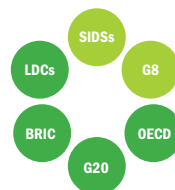
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



☠ Deaths \$ Economic Cost (2010 PPP non-discounted)
 🏠 Developing Country Low Emitters 🏭 Developed
 🏠 Developing Country High Emitters 🏠 Other Industrialized

☠ = Deaths per 10 million
 \$ = Losses per 10,000 USD of GDP
 ↗ Change in relation to overall global population and/or GDP

🎯 \$ = Millions of USD (2010 PPP non-discounted)

Whether or not specific events can be identified as “caused” by climate change, all weather is now affected by a global climate system that is warmer, more active, and wetter (Trenberth, 2012). As a result, it is evident that storms are generally becoming more extreme, particularly in terms of wind speeds and quantity of rainfall. Moreover, there is a pole-ward shift to the north and south of cyclone storm tracks, as parts of the world adjacent to the tropics are experiencing more “tropical” weather. Where vulnerabilities to more severe storms are accentuated by environmental and income-related factors—such as for high-risk urban slums in low-lying coastal areas—the dangers of these changes are much higher (IPCC, 2012a). Corresponding measures will need to offset the additional risk by reducing community vulnerabilities and, where possible, limiting exposure, to storm hazards (UNISDR, 2009 and 2011). Increased emergency assistance should also be foreseen in the coming years and decades.

CLIMATE MECHANISM

Climate change increases air and sea temperatures, boosting the

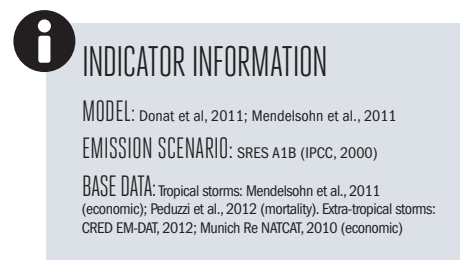
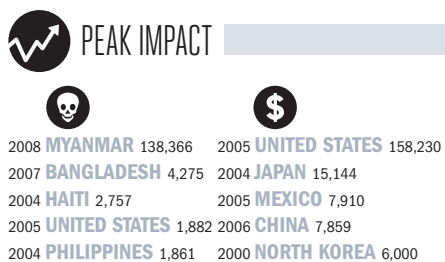
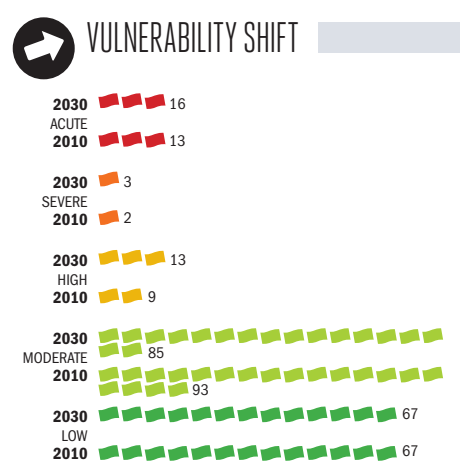
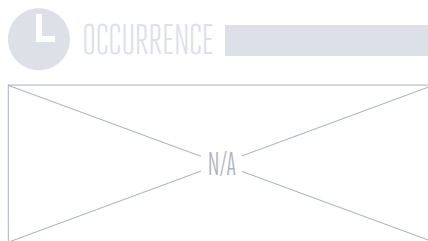
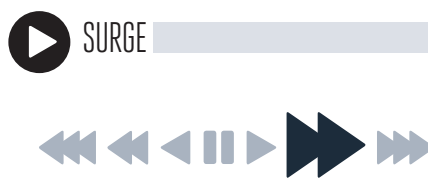
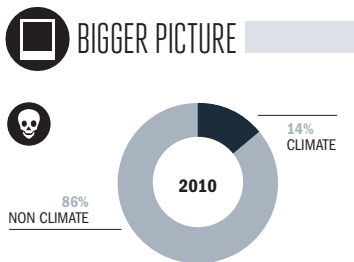
level of moisture in the atmosphere; this leads to acceleration of the planet’s hydrological system, heavier precipitation, higher maximum winds and a general tendency to more extreme weather (IPCC, 2007). These hallmarks have been recognized in storms, including cyclones (IPCC, 2012a). Whether or not there has been a change in the frequency or overall number of cyclones in recent years can side-track the focus on other important factors, such as wind speed changes (Knutson et al. in Chan et al. (eds.), 2010). Simply counting the change in the number of cyclones often leads to the conclusion that there is less cyclone activity, since there is generally understood to be a slight increase in the most extreme cyclones, such as categories 3 to 5, but an overall decrease in the total number of cyclones since the reduction in less severe storms is expected to be greater (Knutson et al., 2010). It is not surprising that an increase in the most extreme cyclones, as measured on the well-known Saffir-Simpson scale results in fewer cyclones overall, since the scale itself is static, measures overall power, and is a rough proxy for the size of storms (Dolan and David, 1992; Irish et al., 2008). Larger more powerful storms absorb and dissipate

considerably more energy than smaller ones, whose declining numbers have been attributed to an overall decline in cyclone frequency in recent times (IPCC, 2012a). Nor is the ultimate number of storms as important as the intensity or size of those storms: in the US, 85% of all cyclone damage is caused by the most extreme storms (Rudeva and Gulev, 2007; Pielke et al., 2008). A large share of the damage caused by cyclones is the result of storm surge, or inundations from rainfall, high winds, and freak waves caused by major storms, which have been worsened by heavier rainfall and sea-level rise, both of which are fuelled by climate change (Dasgupta et al., 2009).

IMPACTS

The impact of climate change on both tropical cyclones and major storms outside of the tropics (extra-tropical cyclones) is estimated to already cost 15 billion dollars and to be responsible for an average of almost 2,500 deaths each year, with around 1.5 million people affected and in need of emergency assistance. In global terms, the number of countries experiencing extreme effects is limited, particularly since the great majority

of losses relate to tropical cyclones, which are a serious concern for only 30 to 40 countries in the world’s cyclone belts. A dozen countries in Asia, Africa, the Pacific, and the Caribbean are estimated to suffer Acute or Severe vulnerability to climate change-aggravated storm effects. The countries most vulnerable cut across the socio-economic spectrum from Japan to major emerging economies, such as China, least developed countries such as Madagascar, or small island developing states, such as Haiti. Bangladesh is currently estimated to suffer the greatest human impact of these effects, with over 1,000 additional casualties due to climate change on an averaged yearly basis—major storms do not occur annually, but once in every 5 to 20 years. Myanmar and India are estimated to suffer the next greatest share of additional casualties. In overall economic terms, China, Japan, the US, North Korea, and South Korea experience the greatest estimated losses, incurring between 2 and 5 billion dollars a year in damages. A number of small island countries, such as Antigua and Barbuda, Dominica, Grenada, and Vanuatu are identified as experiencing the most severe economic and human loss



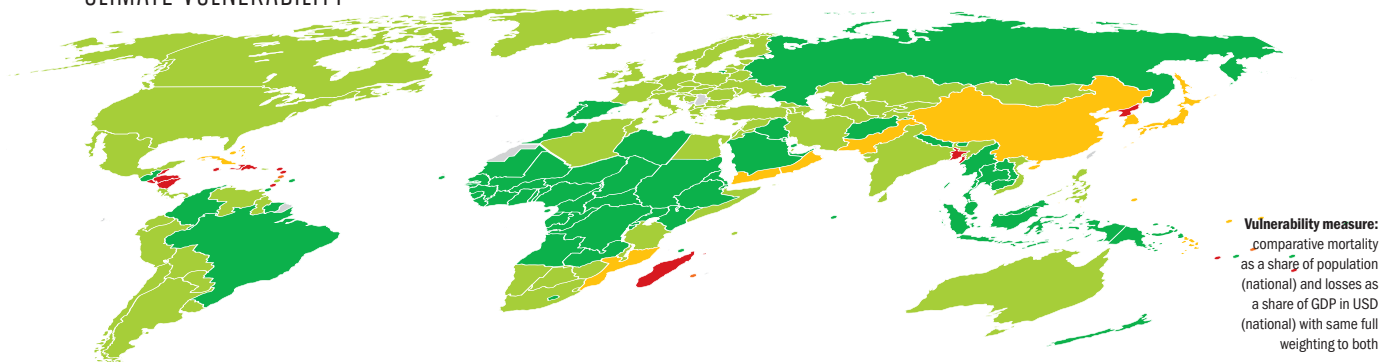
↑ = Millions of USD (historic)
 ● Acute ● Severe ● High ● Moderate ● Low

➡ = 5 countries (rounded)



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	☠		💰		👤		COUNTRY	☠		💰		👤	
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030
Romania			1	1			Brazil						
Saint Vincent			1	5	-150	-150	Brunei						
Seychelles				1			Burkina Faso						
Slovakia			1	5			Burundi						
Slovenia			1	5			Cambodia						
Somalia				1			Cameroon						
South Africa			5	20			Cape Verde						
Sri Lanka			5	35	2,500	60	Central African Republic						
Swaziland							Chad						
Sweden			5	10	10	15	Colombia						
Switzerland			5	15	65	100	Comoros						
Syria							Congo						
Tajikistan			1	15			Cote d'Ivoire						
Tanzania			15	90			DR Congo						
Tunisia							Equatorial Guinea						
Turkey							Eritrea						
Turkmenistan							Ethiopia						
Ukraine			1	5			Fiji	1	-1	-10	-75	5,250	-2,000
United Kingdom			20	60	55	150	Gabon						
United States	1	1	2,500	8,250	4,750	6,500	Gambia						
Uruguay				1			Ghana						
Uzbekistan							Guatemala	1	-1	-10	150	250	
Venezuela				1			Guinea						
Vietnam	10	10	-5	-75	15,000	15,000	Guinea-Bissau						
Zimbabwe	1	5			6,500	15,000	Indonesia			-50	-400		
LOW							Iraq						
Afghanistan							Kenya				-1		
Angola							Kiribati						
Bahrain			-5	-35			Laos	1	1	-5	-35	5,750	8,750
Barbados			1	-90	-250		Lesotho						
Berlin							Liberia						
Bhutan							Libya						
Malaysia					-1	-10							
Maldives					-1	5	15						
Mali													
Mauritania													
Morocco													
Nepal													
New Zealand			-5	-15	150	150							
Niger													
Nigeria													
Papua New Guinea													
Portugal													
Russia	-1	-5	1	10	-150	-300							
Rwanda													
Sao Tome and Principe													
Saudi Arabia			-30	-250									
Senegal													
Sierra Leone													
Singapore													
Spain			-1	-10									
Sudan/South Sudan													
Suriname													
Thailand			-5	-35	750	650							
Timor-Leste													
Togo					-1	-10							
Trinidad and Tobago			-1		-250	-1,250							
Tuvalu													
Uganda													
United Arab Emirates			-10	-85									
Zambia													

👤 Additional persons affected/in need of emergency assistance due to climate change - yearly average

WILDFIRES



ESTIMATES GLOBAL CLIMATE IMPACT

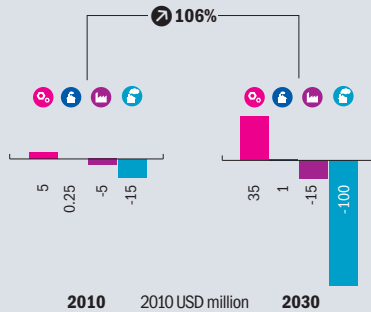
2010 EFFECT TODAY

\$ USD GAIN PER YEAR **15** MILLION

2030 EFFECT TOMORROW

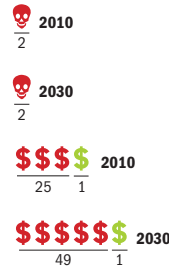
\$ USD GAIN PER YEAR **90** MILLION

\$ ECONOMIC IMPACT



- Global impact of climate change on wildfires may have a neutral effect as a warmer planet brings more rain, dampening fires
- Shifts in wildfire may occur where forested areas become drier and hotter, severely affecting populated parts of Russia, Mongolia, or Australia
- The marginal effect of climate change is difficult to predict because of wind and rain uncertainties and because good international data monitoring fire damages is lacking
- Wildfire occurrence has links to now more prevalent heat extremes and drought which increase the probability of fires

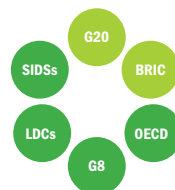
★ RELATIVE IMPACT



🎯 HOTSPOTS



🌐 GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **🏠** Developed
🏭 Developing Country High Emitters **🌐** Other Industrialized

★👤 = Deaths per 100 million
\$ = Losses per 10 million USD of GDP
 🔄 = Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Wildfires—the uncontrolled burning of forests, grasslands or brush—will generally become more frequent and damaging for drought-prone parts of the world. But it is certain that climate change will reduce disturbances from wildfires in some areas where rainfall is significantly increasing. The 2010 wildfires in Russia, as well as the recent fires in Australia, Greece, and the US, are clearly linked to warm, dry temperatures, if not drought (UNISDR, 2011). However, the additional losses incurred by those worst affected are likely to be offset on a global scale by a reduction in wildfire activity in other parts of the world. It is expected that Vietnam may see increased rainfall in some seasons, but declining rain and rising heat during the dry periods would favour wildfire onset, even if more rain overall falls in a given year (Vietnam MONRE, 2010). Tackling an additional burden of wildfire in affected areas will be great, since suppressing fires is costly: the US Forest Service spent 1 billion dollars on fire suppression in the year 2000 alone, with costs growing significantly over time—2.5 million dollars in losses were reported for that year. But expenditures were undoubtedly

warranted in most cases, since wildfires can be extremely deadly: in February 2009, one series of fires alone in Australia killed 180 people (WFLC, 2004; CRED/EM-DAT, 2012).

CLIMATE MECHANISM

Wildfires are affected by three key factors: 1) availability of vegetation to burn; 2) environmental conditions, such as temperature, wind, and humidity or rainfall but also topography and ecosystem type—tropical forests for example are more humid and burn less than temperate forests; and 3) varying ignition sources of fires (Krawchuk et al., 2009). Climate change affects all of these elements: it influences vegetation growth and health along with the expanse of different ecosystem areas (Gonzalez et al., 2010). In regions with less rain and more heat, the declining vegetation will offer less available material for burning and will ultimately reduce disturbances from wildfires. Heat is increasing relatively uniformly around the world due to climate change. Less predictable rainfall and vegetation changes add considerable uncertainty to whether or not fires ultimately retreat or advance with global warming. Climate change has also been shown

to potentially alter electrical activity in the atmosphere, giving rise to lightning, the principal initial trigger of wildfires (Reeve and Toumi, 1999).

IMPACTS

Drawing on recent research, the Monitor estimates the global impact of climate change on wildfire to be close to zero in 2010 and in 2030 (Krawchuk et al., 2009). Estimates of impact include around 3 million dollars of additional losses a year in 2010, and some 15 million dollars of additional losses in 2030. “Gains” of 25 and 150 million dollars a year in 2010 and 2030, respectively, outweigh considerably any losses incurred elsewhere in the world, but overall totals are small. “Gains” represent avoided wildfires that would have taken place without climate change. The largest negative effects in absolute terms are estimated to occur in Russia, Mongolia, Canada, Australia, and South Africa, while the US and Indonesia are expected to reap the most benefits overall. Within large countries like the US, it is possible that increased fire activity may well be experienced in certain areas but will be counterbalanced with decreased activity in other parts of the country.

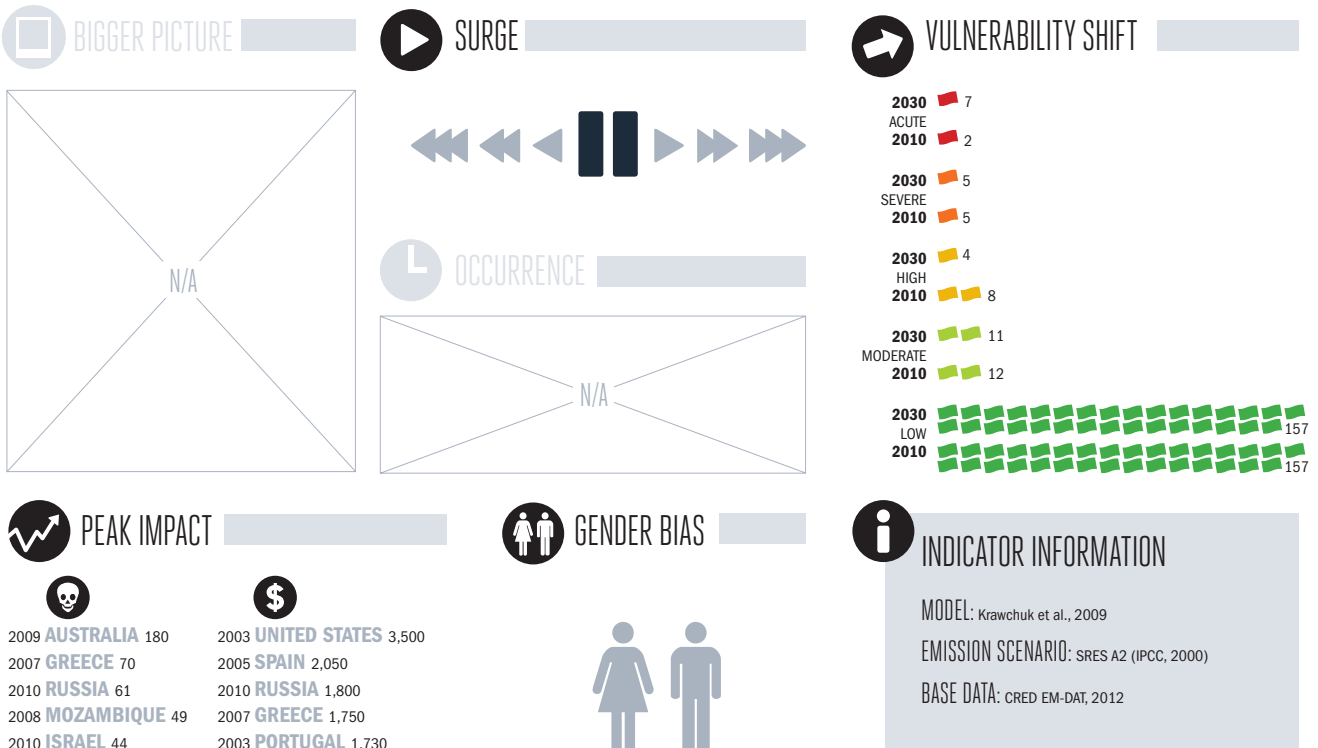
In general, wildfires mainly concern industrialized or developed countries.

THE BROADER CONTEXT

There has been a considerable increase in wildfire damage recorded in recent years (CRED/EM-DAT, 2012). However, improvements in the actual reporting systems themselves—advances in technology and information sharing—have allowed the reporting of increasing numbers of phenomena (UNISDR, 2009). However, satellite analysis has shown that the annual burned area has grown since the 1970s (UNEP, 2002). Several other factors, such as land usage change, could be contributing to increasing fire damage. As with other weather-related disasters, growing exposure to wildfires through economic development, population growth, and an expansion in infrastructure at risk should also increase damages.

VULNERABILITIES AND WIDER OUTCOMES

Countries with large areas of non-tropical vegetation and a propensity to drought are particularly vulnerable to the effects of climate change



📈 = Millions of USD (historic)
 ● Acute ● Severe ● High ● Moderate ● Low

➡ = 5 countries (rounded)

on wildfires. Coniferous forests are especially risky areas for fire outbreak during extended warm, dry periods (Cruz and Alexander, 2010).

The full extent of increased wildfires is difficult to estimate, but given the incredible potential for the rapid and uncontrolled spread of fires, growing fire dangers in some parts of the world could carry serious risks for public safety. The 2010 Russian wildfires, for example, burned some 4,000 hectares of land—contaminated, moreover, by radioactive material from the Chernobyl disaster—the full consequences of which are not yet known; the fires also threatened functioning nuclear power plants and research facilities (Munich Re, 2010).

RESPONSES

Responding to wildfires is extremely costly and requires highly sophisticated technology. Some early detection and warning systems are capable of identifying a fire within 5 minutes of its ignition (Bridge, 2010). Thus, such systems represent an investment that could significantly reduce overall expenditures on suppressing fires that would otherwise end up destroying thousands or millions of hectares. Fire safety and education programmes may



reduce the potential for fires set by human hands by up to 80% (UNEP, 2002). Of course, as is well known, not all wildfires are bad. Natural habitats have evolved to cope with wildfires over time and to support biodiversity and processes of regeneration (Parker et al., 2006). Therefore, many countries also practice what is called “prescribed burning,”

effectively a “let-burn” policy, in which human settlements are not endangered. But while such practices may lower fire prevention costs and help support ecosystems, if fires subsequently reach a large-scale and deviate to threaten settlements, the costs of fire suppression can rapidly and counter-productively escalate (UNEP, 2002).

THE INDICATOR

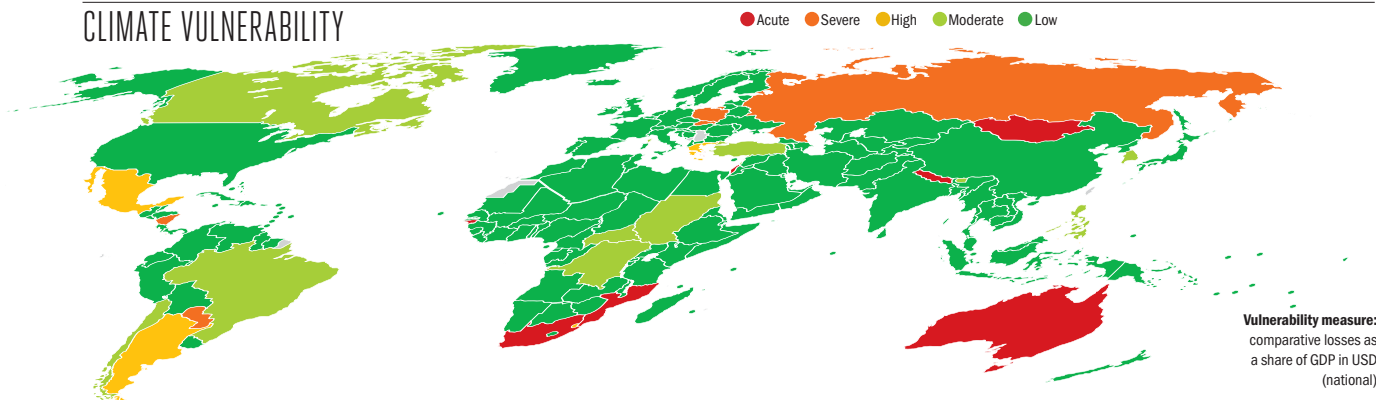
The indicator relies on a high-resolution global pyrogeography model for the effect of climate change on fire disturbances, used to estimate impact for populated areas (Krawchuk et al., 2009). Limitations relate to uncertain future rainfall and the restricted socio-economic base data set, which may underestimate costs (CRED/EM-DAT, 2012). Regarding base data, the major wildfires that affected Russia in 2010 are recorded in the reference database at 1.8 billion dollars in losses and 61 deaths. The major reinsurer, Munich Re, on the other hand estimates the total cost of the fires at 3.3 billion dollars and over 50,000 indirect deaths from both extreme heat and the significantly higher than normal air particle loads and their effect on chronic respiratory and cardiovascular disease sufferers (Munich Re, 2010). Historical base data would also give a misleading trend if fires spread to areas where damage in the past was unusual, underestimating future losses.

ESTIMATES COUNTRY-LEVEL IMPACT

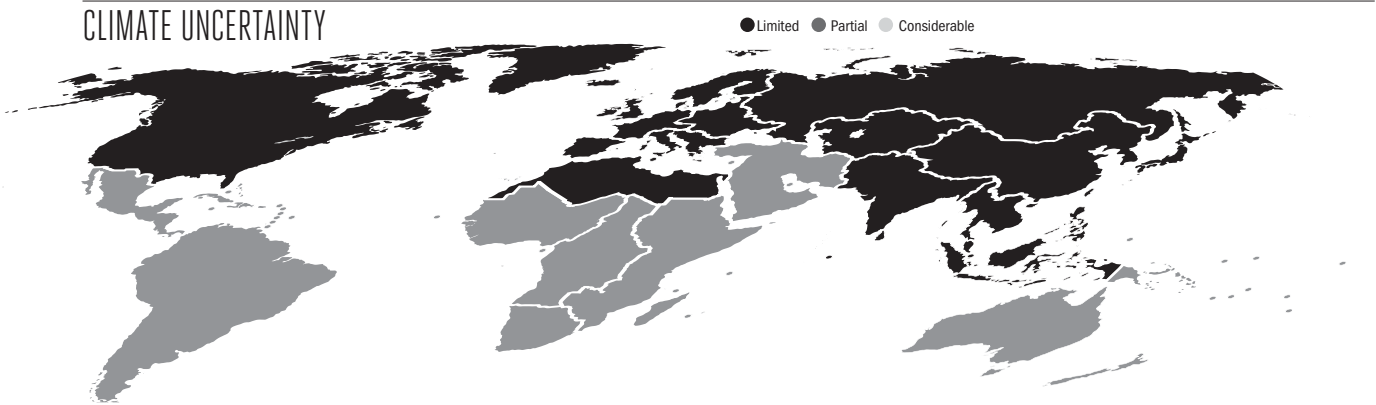
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$				
	2010	2030		2010	2030		2010	2030			
ACUTE											
Australia	0.25	0.50	LOW								
Guinea-Bissau			Afghanistan			Costa Rica					
Israel			Albania			Cote d'Ivoire					
Mongolia	1	15	Algeria			Croatia					
Mozambique			Angola			Cuba					
Nepal			Antigua and Barbuda			Cyprus					
South Africa	0.25	1	Armenia			Czech Republic					
SEVERE											
Nicaragua	0.25	1	Austria			Denmark					
Paraguay			Azerbaijan			Djibouti					
Poland			Bahamas			Dominica					
Russia	5	40	Bahrain			Dominican Republic					
Slovakia			Bangladesh			Ecuador					
HIGH											
Argentina			Barbados			Egypt					
Greece			Belarus			El Salvador					
Mexico			Belgium			Equatorial Guinea					
Swaziland			Belize			Eritrea					
MODERATE											
Bhutan			Benin			Estonia					
Brazil			Bolivia			Ethiopia					
Canada	0.50	1	Bosnia and Herzegovina			Fiji					
Central African Republic			Botswana			Finland					
Chile			Brunei			France					
DR Congo			Bulgaria	-0.25	-1	Gabon					
Lebanon			Burkina Faso			Gambia					
Philippines			Burundi			Georgia					
South Korea			Cambodia			Germany					
Sudan/South Sudan			Cameroon			Ghana					
Turkey			Cape Verde			Grenada					
			Chad			Guatemala					
			China			Guinea					
			Colombia			Guyana					
			Comoros			Haiti					
			Congo			Honduras					
						Hungary					



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Iceland			Micronesia			Somalia		
India			Moldova			Spain	-0.25	-1
Indonesia	-20	-150	Morocco			Sri Lanka		
Iran			Myanmar			Suriname		
Iraq			Namibia			Sweden		
Ireland			Netherlands			Switzerland		
Italy	-1	-1	New Zealand			Syria		
Jamaica			Niger			Tajikistan		
Japan			Nigeria			Tanzania		
Jordan			North Korea			Thailand		
Kazakhstan			Norway			Timor-Leste		
Kenya			Oman			Togo		
Kiribati			Pakistan			Tonga		
Kuwait			Palau			Trinidad and Tobago		
Kyrgyzstan			Panama			Tunisia		
Laos			Papua New Guinea			Turkmenistan		
Latvia			Peru			Tuvalu		
Lesotho			Portugal	-0.25	-1	Uganda		
Liberia			Qatar			Ukraine		
Libya			Romania			United Arab Emirates		
Lithuania			Rwanda			United Kingdom		
Luxembourg			Saint Lucia			United States	-5	-15
Macedonia			Saint Vincent			Uruguay		
Madagascar			Samoa			Uzbekistan		
Malawi			Sao Tome and Principe			Vanuatu		
Malaysia	-0.25	-1	Saudi Arabia			Venezuela		
Maldives			Senegal			Vietnam		
Mali			Seychelles			Yemen		
Malta			Sierra Leone			Zambia		
Marshall Islands			Singapore			Zimbabwe		
Mauritania			Slovenia					
Mauritius			Solomon Islands					



ENVIROMENTAL DISASTERS



DROUGHT



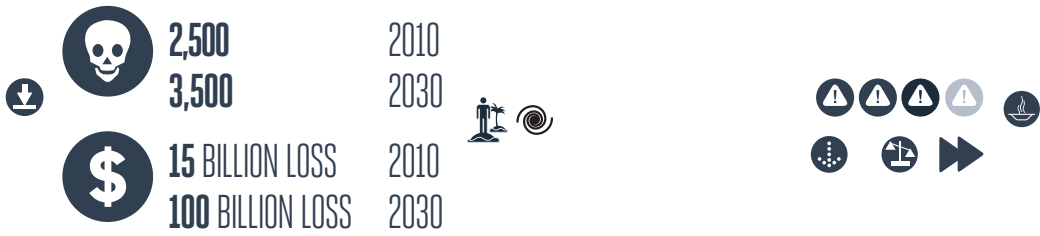
FLOODS & LANDSLIDES



STORMS



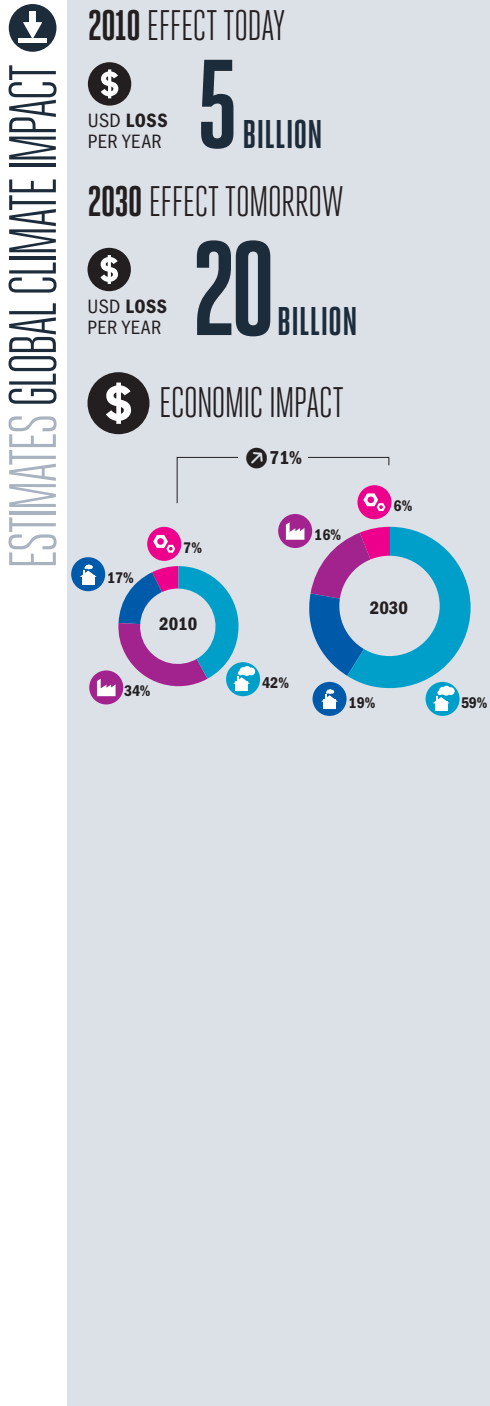
WILDFIRES



DROUGHT



ESTIMATES GLOBAL CLIMATE IMPACT

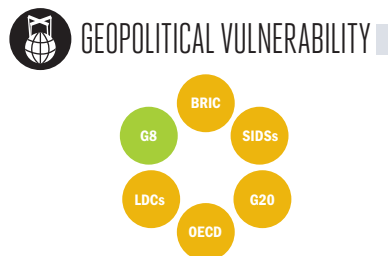
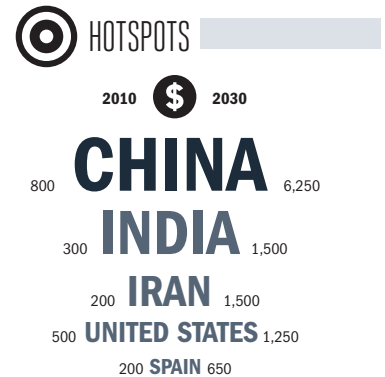
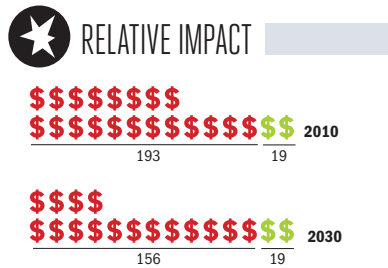


➤ As the planet's temperatures reach new highs drought will become more common and more severe

➤ Climate change also means more rain, but most of it is falling in the far north or far south where fewer people live, and much of this rain falls during the wet season while dry seasons tend to become drier

➤ When drought hits, agriculture comes under extreme pressure, crops may fail and livestock perish with important localized economic, health and social repercussions

➤ Catching and conserving water will be critical to ensure a resilient agricultural sector and food and water security during periods of extreme drought



💰 Economic Cost (2010 PPP non-discounted)
 ★ \$ = Losses per million USD of GDP
 🎯 \$ Millions of USD (2010 PPP non-discounted)

🏠 Developing Country Low Emitters
 🏭 Developed
 🏠 Developing Country High Emitters
 🏭 Other Industrialized

↗ Change in relation to overall global population and/or GDP

The increase in heat is already being experienced. It is virtually certain to increase in the coming years (IPCC, 2007). Parts of the world experiencing additional rainfall will also experience drought (Sheffield and Wood, 2008; Helm et al., 2010). Drought can diminish crop yields and kill livestock, generating serious economic losses for affected communities (Pandey et al. (eds.), 2007). Some of the world's major agriculturally productive regions, such as Brazil and Australia, are already affected (Saleska et al., 2011; LeBlanc et al., 2009). Deforestation and other forms of environmental degradation only worsen risk of drought (Turner II et al., 2007). Reducing losses and safeguarding communities will require the tackling of these problems as well as stimulating increased water availability through effective capture, storage and distribution measures and policies (McKinsey & Company, 2009). Displacing risks to the insurance industry would also alleviate the severity of losses to individuals and communities (Linnerooth-Bayer and Mechler, 2006).

CLIMATE MECHANISM

A hotter planet not unsurprisingly implies more drought (Sheffield and

Wood, 2008). This is qualified by the fact that because of climate change there will also be more moisture and rain in the atmosphere (Allen and Ingram, 2002; Huntington, 2006; Kharin et al., 2007). Additional rain however tends to fall far north or south, where it is not lacking, and less rain tends to fall in the tropical areas of the planet which are already near thermal maximums and where a majority of the world's population live (Helm et al., 2010; Sherwood and Huber, 2010). In parts of the tropics, clouds are gaining in altitude and failing to deposit their moisture on mountain ranges (Malhi et al., 2008). As evidenced in cities, even if more rain falls, provided heat rises faster, any additional water would evaporate and not benefit the soil and its vegetation (Schmidt in Hao et al. (eds.), 2009). Hence, global aridity has increased and is expected to continue increasing, including in areas like the US, which have largely escaped the most severe forms of drought to date (Dai, 2011). Even where rainfall is declining, it is becoming more concentrated generating longer dry spells (Trenberth, 2011). Moreover, country level analysis in Vietnam for instance shows how in regions prone to extreme heat rain will

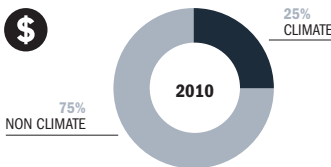
likely decline in dry seasons and only increase in wet seasons when there will be an overabundance (Vietnam MONRE, 2010). Extreme forms of heat experienced today, such as the European heat wave of 2003, the Russian heat wave of 2010, or the extreme summer temperatures of 2011 in Texas would have been extremely unlikely to occur in the absence of climate change (Hansen et al., 2012). When drought hits, plant productivity is directly affected and the mortality risk for livestock, such as cattle or birds, is greatly raised and indirectly can create vulnerabilities which invasive pests can exploit, further increasing damage (Chaves et al., 2009; Lesnoff et al., 2012; Wolf, 2009; Cherwin, 2009). Economic losses clearly result (Pandey et al. (eds.) 2007; Ding et al., 2011). Drought also damages buildings and infrastructure due to the shrinking and swelling of soil under extreme heat and aridity. This can lead to structural failure or accelerate asset depreciation (Corti et al., 2009).

IMPACTS

The global impact of climate change on drought is estimated to cause close to four billion dollars in damage a year in 2010, set to increase as a share of GDP to

2030 when average annual losses would reach close to 20 billion dollars a year. The impact is very widespread with some 160 countries experiencing high vulnerability to drought by 2030. There are many regions which are seriously affected, especially the wider Mediterranean basin and Black Sea, North Africa, the Middle East and southern and eastern Europe. In addition, parts of Central Asia and Southern Africa are also expected to experience severe effects. While mainly developing countries are affected, since developed nations in general are located geographically in the far north or south, a handful of major advanced economies are exposed to the most severe effects, in particular Spain, Portugal, Greece and Australia. Large numbers of least developed countries figure among those countries with Acute or Severe levels of vulnerability. The largest total impact is felt in China whose estimated losses in 2010 of 800 million dollars would surpass six billion dollars a year in damage by 2030. Other countries with particularly large-scale impacts include India, Iran, the US, Spain, Mexico, Brazil and Russia – several are estimated to experience impacts in excess of 1 billion dollars in annual losses by 2030.

BIGGER PICTURE



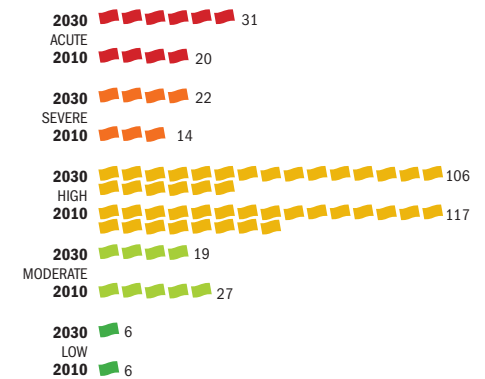
SURGE



OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT

2002 MALAWI 500	2011 UNITED STATES 8,000
2006 CHINA 134	2009 CHINA 3,600
2005 BURUNDI 120	2002 AUSTRALIA 2,000
2004 KENYA 80	2004 BRAZIL 1,650
2002 UGANDA 79	2010 RUSSIA 1,400

GENDER BIAS



INDICATOR INFORMATION

MODEL: Corti et al., 2009; Hoekstra et al., 2010; Rubel and Kottek, 2010; Sheffield and Wood, 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: Corti et al., 2009; CRED EM-DAT, 2012

📈 = Millions of USD (historic)

👤 = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

THE BROADER CONTEXT

Virtually all of the costliest drought years have occurred in the last two decades (CRED/EM-DAT, 2012). For statistical reasons it is still difficult to conclusively discern and pronounce on any global trends in drought losses; however the IPCC and insurance industry have reported increases in drought impact, and regional drought has become extreme in recent years (Quarantelli, 2001; IPCC, 2007; Bouwer, 2011). Major agricultural zones of Australia have experienced prolonged drought for a decade, not attenuated by a return to pre-drought levels of rainfall as the heat rises (LeBlanc et al., 2009). A 2010 drought in Brazil and across the Amazon regions was one of the worst ever (Saleska et al., 2011). The insurance industry is gauging growing losses as a result of drought-triggered soil subsidence and damage to buildings and infrastructure, estimated to cost €340 million per year in France alone (Swiss Re, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Geography is a prime vulnerability, since countries in the far north receive

considerably more rainfall (IPCC, 2007; Helm et al., 2010). Demand for water is another key determinant of vulnerability, since drought in the middle of the Sahara is of little consequence, while drought in the southern US, Europe or India is a major concern. Global water demand is expected to almost double by 2030, in particular due to increased water withdrawals in the agricultural sector – just as climate change will deprive many of the world's productive regions of water (McKinsey & Company, 2009; Sheffield and Wood, 2008). Land degradation from over-intensive agricultural exploitation or over-grazing and deforestation also greatly increase susceptibility to drought – another 30% loss of forest in the Amazon could push the entire region into permanent aridity (Malhi et al., 2008). A lack of adequate irrigation and water infrastructure exacerbates drought since water captured in other periods of the year cannot be drawn upon during periods of prolonged aridity. In general, water-deprived economies have been understood to be less prosperous (Brown and Lall, 2006). The human health consequences of drought are principally accounted for under the Hunger indicator of the Monitor.

RESPONSES

Any response to drought must face up to two key concerns: 1) increasing water availability, and 2) dealing with building and infrastructure damage due to sinking or destabilized land. Increasing water availability will be met at the market cost of supplying water, which varies from region to region depending on the degree of water scarcity currently prevailing locally (McKinsey & Company, 2009). Effective governments would anticipate any shortfall and stimulate action to meet any expected water demand shortfall in order to avoid economic losses and loss of tax revenues. Addressing soil subsidence through design could involve the retrofitting of buildings to withstand soil movements linked to drought. Both drought and soil subsidence impacts can be dealt with by displacing risks to the insurance (and micro-insurance) industry through policies enabling businesses and homeowners to safeguard against potential damages (Swiss Re, 2011; Churchill and Matul, 2012).

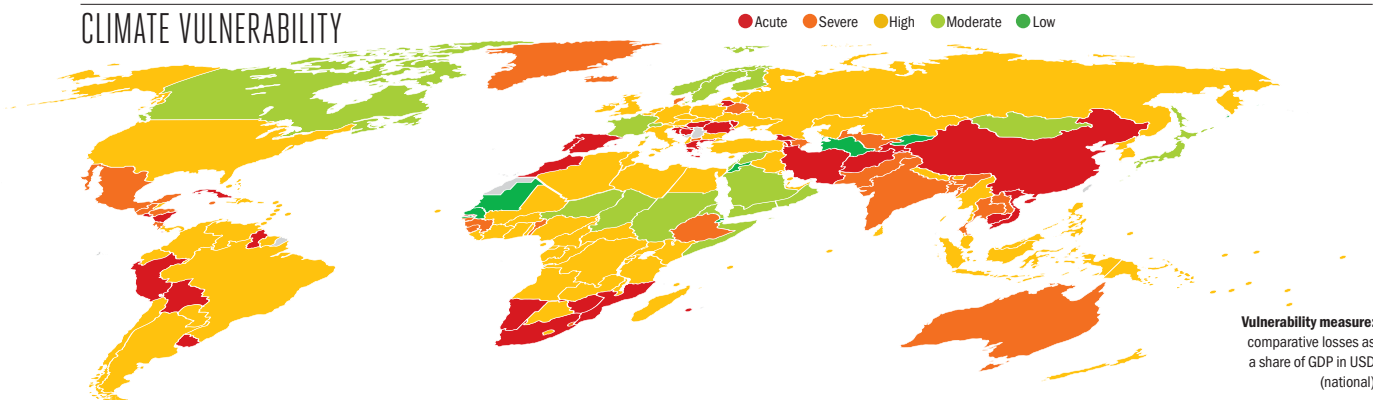
THE INDICATOR

The indicator measures the impact of climate change on drought, defined as a consecutive sequence of months with “anomalously low soil moisture”. It measures the change in both disaster damages and depreciation of property due to soil subsidence damages. The change in the number of droughts expected to occur is estimated using an ensemble of eight climate models (Sheffield and Wood, 2008). Baseline data for disaster damages is derived from the main international disaster database, but is known to be incomplete (CRED/EM-DAT, 2012). Accelerated depreciation of infrastructure due to soil subsidence uses a model based on France and extrapolated based on GDP per capita and population density, but excluding arid countries where the effect is considered less relevant (Corti et al., 2009; Hoekstra et al., 2010). Limitations and uncertainties relate to difficulties in estimating rainfall change for certain regions, the simplistic 1:1 damage assumption implied and to the extrapolation used for the soil subsidence indicator.

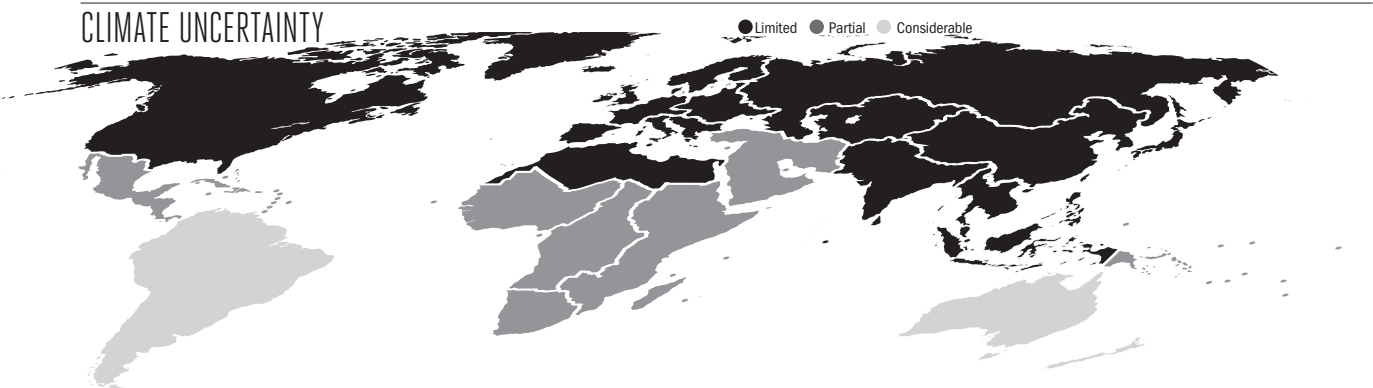
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			SEVERE					
Afghanistan	5	40	Australia	45	100	Barbados		1
Armenia	5	25	Azerbaijan	5	30	Belgium	10	15
Bolivia	5	45	Bangladesh	15	75	Belize		1
Bosnia and Herzegovina	15	100	Belarus	10	35	Bhutan		1
Cambodia	5	60	Benin	1	5	Botswana	1	5
China	800	6,250	Costa Rica	1	15	Brazil	95	550
Croatia	15	85	Denmark	10	25	Brunei	1	5
Cuba	10	65	Ethiopia	5	20	Bulgaria	5	20
El Salvador	10	70	Guatemala	5	20	Burkina Faso	1	1
Gambia		1	Guinea	1	1	Burundi		1
Georgia	10	50	Guinea-Bissau		1	Cameroon	1	5
Greece	35	95	Honduras	1	10	Cape Verde		
Guyana	1	15	India	300	1,500	Central African Republic		1
Hungary	15	90	Jamaica	1	5	Chile	15	70
Iran	200	1,500	Laos	1	5	Colombia	15	80
Lithuania	10	45	Macedonia	1	5	Comoros		
Mauritius	5	25	Mexico	95	600	Congo	1	1
Moldova	10	65	Pakistan	35	200	Cote d'Ivoire	1	5
Morocco	40	300	Sierra Leone		1	Cyprus	1	1
Mozambique	1	10	Swaziland		1	Czech Republic	10	40
Namibia	1	10	Thailand	40	200	Dominica		
Nicaragua	1	15	Uzbekistan	5	30	Dominican Republic	5	20
Peru	25	150	HIGH			DR Congo	1	5
Portugal	45	150	Albania	1	5	Ecuador	5	30
Romania	20	100	Algeria	5	30	Egypt	10	50
South Africa	50	250	Angola	5	15	Equatorial Guinea	1	5
Spain	200	650	Antigua and Barbuda			Estonia	1	5
Tajikistan	5	20	Argentina	25	150	Fiji		1
Uruguay	5	40	Austria	10	10	Gabon	1	5
Vietnam	40	350	Bahamas		1	Germany	70	100
Zimbabwe	1	10	Bahrain	1	5	Ghana	5	15
						Grenada		



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Haiti	1	1	Paraguay	1	5	Venezuela	10	45
Iceland		1	Philippines	20	85	Zambia	1	1
Indonesia	40	200	Poland	30	100	MODERATE		
Iraq	5	15	Qatar	5	20	Canada	25	45
Ireland	5	5	Russia	90	400	Chad		
Italy	55	150	Rwanda	1	1	Eritrea		
Kazakhstan	5	20	Saint Lucia		1	Finland	1	1
Kenya	1	5	Saint Vincent			France	45	75
Kiribati			Samoa			Israel	1	15
Kuwait	5	20	Sao Tome and Principe			Japan	90	150
Latvia	1	5	Seychelles		1	Luxembourg	1	1
Lebanon	1	10	Singapore	10	40	Mongolia		1
Lesotho		1	Slovakia	5	15	Niger		1
Liberia			Slovenia	1	10	Norway	1	5
Libya	1	10	Solomon Islands			Oman	1	5
Madagascar	1	5	South Korea	55	250	Saudi Arabia	1	10
Malawi	1	1	Sri Lanka	5	25	Somalia		
Malaysia	20	80	Suriname		1	Sudan/South Sudan	1	10
Maldives			Tanzania	5	15	Sweden	5	10
Mali	1	1	Timor-Leste		1	Switzerland	5	10
Malta		1	Togo		1	Syria	1	5
Marshall Islands			Tonga			Yemen	1	5
Micronesia			Trinidad and Tobago	1	5	LOW		
Myanmar	1	10	Tunisia	5	15	Djibouti		
Nepal	1	10	Turkey	35	65	Jordan		
Netherlands	15	25	Tuvalu			Kyrgyzstan		
New Zealand	5	5	Uganda	1	10	Mauritania		
Nigeria	15	70	Ukraine	20	75	Senegal		
North Korea	1	10	United Arab Emirates	5	25	Turkmenistan		
Palau			United Kingdom	55	90			
Panama	1	10	United States	500	1,250			
Papua New Guinea	1	1	Vanuatu					

FLOODS & LANDSLIDES



ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

DEATHS PER YEAR
2,750

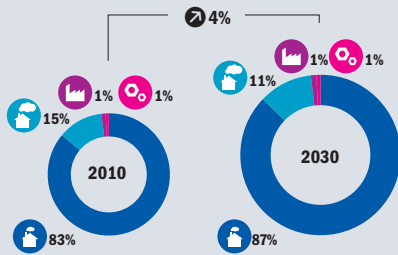
USD LOSS PER YEAR
10 BILLION

2030 EFFECT TOMORROW

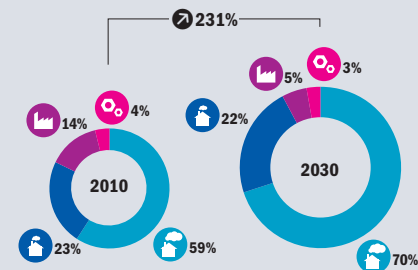
DEATHS PER YEAR
3,500

USD LOSS PER YEAR
95 BILLION

MORTALITY IMPACT



ECONOMIC IMPACT



SEVERITY



AFFECTED



INJUSTICE



PRIORITY

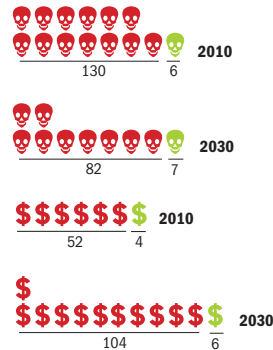


MDG EFFECT

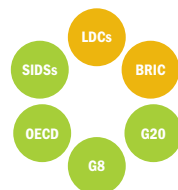


- Heavy rainfall, the main trigger of flooding and landslides, is on the rise
- Spring comes earlier and releases more water from mountains and glaciers which adds further to flood risks
- Future increases in these effects may coincide, generating more mega disasters of the scale of the 2010 Pakistan floods
- Comprehensive risk reduction efforts in implementation of the Hyogo Framework for Action are helping to reduce vulnerabilities, even as world population and exposed infrastructure expand
- Parallel efforts are not being made to deliberately adjust humanitarian relief systems to growing flood dangers implied by climate change

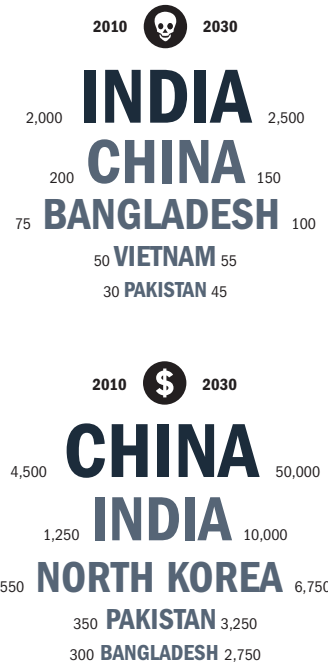
RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS



☠ Deaths \$ Economic Cost (2010 PPP non-discounted)
 🏠 Developing Country Low Emitters 🏭 Developed
 🏠 Developing Country High Emitters 🏠 Other Industrialized

☠ = Deaths per 100 million
 \$ = Losses per 100,000 USD of GDP
 ↗ Change in relation to overall global population and/or GDP

🎯 \$ = Millions of USD (2010 PPP non-discounted)

Flooding is a common natural hazard from increases in rainfall due to climate change. Floods are expected to worsen practically everywhere, even in areas facing declining annual rainfall, as heavy downpours become more common (IPCC, 2007). More floods mean more deaths and injuries, more damaged property and infrastructure, and growing disruption of economic activities. Where large countries like China, Pakistan, or the US are affected, the lives of millions of people may be disrupted and billions of dollars of economic damage inflicted (CRED/EM-DAT, 2012). However, the risk of death due to flooding is heavily concentrated in low-income countries, which face significant risks of setbacks in development gains, with women particularly vulnerable (UNISDR, 2011; Nelleman et al., 2011). Highly cost-effective including “low-regrets” measures to limit damages and speed recovery are also inaccessible to many for lack of the capacity and up-front resources to implement them (IPCC, 2012a). Social and political factors, including illiteracy and the over-exploitation of resources often exacerbate these problems (UNISDR, 2009).

CLIMATE MECHANISM

A warmer planet means a more active hydrological system, as water is evaporated faster from oceans and land, generating cloud and rainfall (Dore, 2005; Kharin et al., 2007). That means more rain overall and more energy in general in the global climate system as it heats up, leading to heavier downpours of rain, more variable or erratic rainfall, and more frequent heavy precipitation. Coupled with an earlier spring that discharges more water as glaciers continue to decline, the implications are that risk of flooding and landslides caused by weather, and not earthquakes or otherwise, are on an increase (Hidalgo et al., 2009; Radi and Hock, 2011; IPCC, 2007; Mirza et al., 2003; Jonkman et al., 2008; Bouwer et al., 2010). The evidence base for the flood trend is low, in particular due to inadequate gauge station records and confounding information linked to land use and engineering (IPCC, 2012a). The increase in heavy rainfall during short periods of time is assured and is not only the main trigger of flooding, but the main input variable to early warning tools to predict flooding (Prudhomme et al., 2002; Harris et al., 2007).

IMPACTS

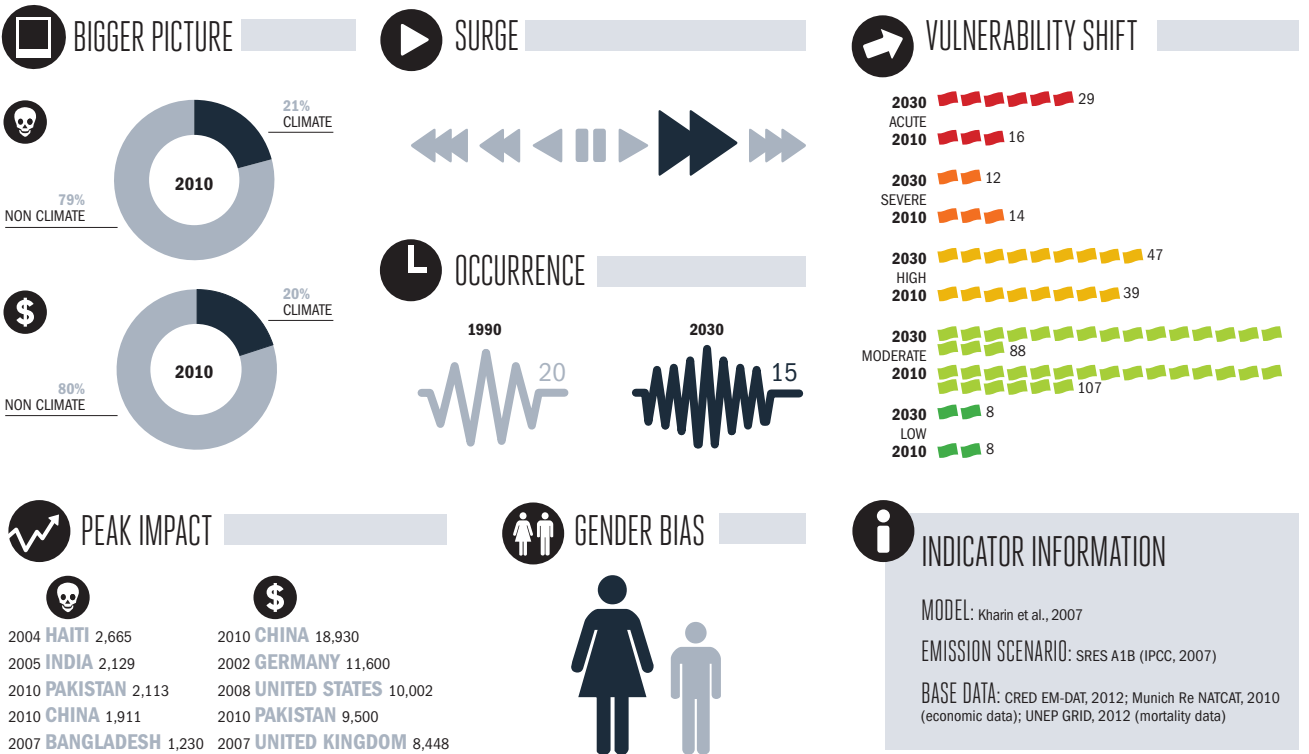
Globally, climate change is already estimated to be responsible for close to an average of 3,000 deaths per year and around 10 billion dollars in economic losses through flooding and landslides. For every death, there can be as many as 10,000 people in need of emergency assistance; each year, over 25 million more people are affected than in earlier periods when climate change was not so marked. Over the next 20 years, the climate-related flood death toll is expected to increase only modestly to 3,500 deaths per year with economic losses more than tripling as a share of global GDP, reaching 95 billion dollars per year by 2030. Approximately two-thirds of these losses are incurred in China and India alone. Populous emerging economies in Asia, such as Bangladesh, Pakistan, and Vietnam are particularly vulnerable, as are mountainous developing countries, such as Bhutan and Nepal. Effects are widely distributed around the world, with the number of countries labeled “Acute” doubling by 2030. Low-lying small island states, such as the Maldives, are unaffected by non-coastal flooding and landslides, whereas mountainous small islands, such as Haiti or Fiji are at high risk.

THE BROADER CONTEXT

The significance of socio-economic determinants of risk mean climate change is only one factor in the scale of damage generated by so-called natural disasters. Mortality risk due to extreme weather is known to fall over time with rising incomes (Pezuzzi et al., 2012). However, economic losses show increases in recent years (CRED/EM-DAT, 2012; Munich Re, 2012). These observations support the UN’s analysis that as socio-economic development improves, fewer people are killed, but infrastructure is at greater risk (UNISDR, 2009 and 2011).

VULNERABILITIES AND WIDER OUTCOMES

Vulnerability levels are often dictated by socio-economic development standing and the associated effectiveness of governments in putting in place measures that can limit dangers for populations. Poorly located, unprotected flood plain settlements are also at high risk, but sound governance should prevent or rationalize this type of development. Environmental degradation and unwise patterns of land



📈 = Millions of USD (historic)
 ● Acute ● Severe ● High ● Moderate ● Low

🕒 Estimated time between major weather events (years)

👤 = 5 countries (rounded)

usage, particularly deforestation, further exacerbate localized vulnerabilities, for example, by destabilizing hillsides and by increasing the flow of rainwater over land—effects especially significant in developing countries (Brashshaw et al., 2007). High rates of urbanization, common in most developing countries around the world today, often lead rural-urban migrants to settle in flood plain shanty towns adjacent to major urban centres, adding to the level of risk (Quarantelli, 2003). Flooding carries serious consequences for economic activity, especially for lower-income communities where insurance that otherwise speeds economic rebound is least prevalent (Dodman and Satterthwaite, 2008). Harm to poverty-reduction efforts has been shown to result more from widespread and regularly occurring small- to medium-scale disasters, since they repeatedly frustrate development progress, even though freak, high-profile, catastrophes typically receive more attention (Lavell, 2008). Flood damage—particularly ecological and social costs or diffuse disruptions to broad economic activities—is also difficult to fully quantify, and in extreme cases can persist for months (Messner and Meyer, 2005).

RESPONSES

Like other disasters, floods are considered to have three core components: hazard, exposure, and vulnerability. Hazard is a variable largely beyond immediate human control, so responses either aim to decrease vulnerability or exposure to hazard, or both. Measures such as rapid early warning systems, disaster education, building codes and their regulation, environmental protection against deforestation and land degradation, insurance for infrastructure or other economic assets, flood defences and storm drains, strengthening of local ecosystems, disaster volunteer programmes all reduce vulnerabilities, but may demand resources which many countries simply do not possess. Under pressure of economic and population growth, most increases in exposure are inevitable. But strategic municipal planning for infrastructure development can help minimize the extent of new exposure to risk. Urban centres with elevated population densities are also high-dividend opportunities for reducing possible disasters, provided urban authorities are willing and able to meet the needs of their residents

in managing risks (Dodman and Satterthwaite, 2008). The capacity of governments to develop and implement a range of risk-reduction measures is considered a fundamental determinant of the success of national disaster prevention and recovery strategies; this includes the ability to incorporate considerations of disaster risk into wide-ranging state agendas, from education to municipal planning and fiscal tools. Capacity to do so is also most deficient in highly vulnerable, low-income settings (Ahrens and Rudolph, 2006). A number of low-income countries, such as Bangladesh have nevertheless managed to reduce levels of vulnerability through cost-effective community and volunteer-based efforts, as alternatives to more resource-intensive measures (Khan, 2007). On the other hand, recent floods along the Mississippi and Missouri rivers in the US have shown how even the highly developed countries can be overwhelmed by large-scale events (Olson and Morton, 2012). New extremes and delays in policy changes to increase resilience mean that the world's humanitarian system should prepare for serious increases in flood response in the years ahead.

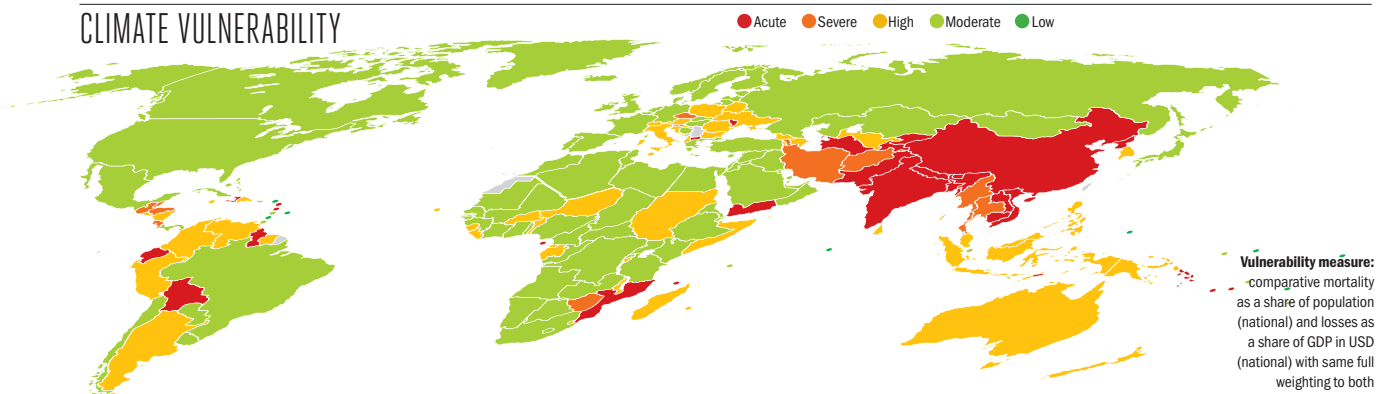
THE INDICATOR

The indicator combines exposure to floods and landslides with modeled mortality risk for estimations of deaths with socio-economic adjustments. For economic losses, a combination of 20 years of disaster data from different sources is relied upon as a baseline. The indicator then estimates how the change in, or increases in the occurrence of, heavy precipitation events would alter the current picture of flood and landslide risk. Uncertainty regarding precipitation change in some areas is an impediment to reliable national-level estimates of these changes. Likewise, country-specific variation in the effects of increased heavy rainfall is not accounted for, except through the worsening of the pre-existing topography of risk, as reflected in historic and modeled disaster data. Although records of floods are unreliable, models of the effects of climate change on heavy precipitation and observed rainfall changes do reveal the increasing trend (IPCC, 2007, IPCC, 2012a; Kharin et al.).

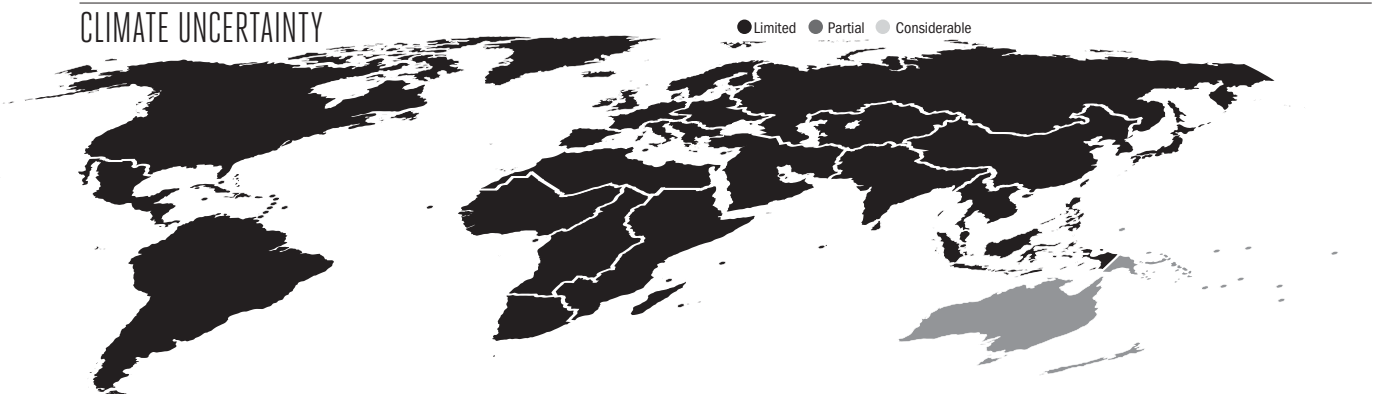
COUNTRY	👤		💰		👤		COUNTRY	👤		💰		👤		COUNTRY	👤		💰		👤		
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030	
ACUTE							ACUTE					ACUTE					ACUTE				
Bangladesh	75	100	300	3,000	600,000	900,000	Armenia	1	1	1	20,000	25,000	Italy	1	1	150	500	5,500	7,000		
Bhutan	1	1	1	15,000	25,000	Belize			1	1,500	2,000	Jamaica	1	1	1	20	3,500	4,000			
Bolivia	1	1	30	300	10,000	15,000	Costa Rica	1	1	5	55	6,500	10,000	Liberia	1	1	1	5,500	15,000		
Cambodia	10	10	20	200	65,000	85,000	Czech Republic			55	350	2,000	1,500	Madagascar	5	5	1	15	30,000	55,000	
China	200	150	4,500	50,000	2,000,000	1,500,000	Guatemala	5	10	5	60	45,000	90,000	Malawi	1	1	1	5	15,000	25,000	
Comoros	5	10			45,000	85,000	Honduras	1	1	5	70	15,000	20,000	Malaysia	5	5	20	200	15,000	15,000	
Dominica	1	1			2,500	3,000	Iran	10	10	200	1,500	40,000	50,000	Malta			1	1	200	300	
Ecuador	1	5	30	300	25,000	30,000	Myanmar	35	45	5	40	250,000	350,000	Mauritius			1		1,500	1,500	
Fiji	1	1	1	10	4,000	3,500	Slovenia			15	95	2,000	1,500	New Zealand	1	1	5	15	4,500	9,500	
Guyana			10	100	2,000	1,500	Thailand	15	10	100	1,000	150,000	100,000	Nicaragua	1	5	1	5	20,000	40,000	
Haiti	5	5	5	35	30,000	40,000	Zimbabwe	1	1	5	25	15,000	25,000	Niger	1	5	1	10	10,000	25,000	
India	2,000	2,500	1,000	10,000	20,000,000	25,000,000	HIGH						Papua New Guinea	1	5	1	5	30,000	40,000		
Kyrgyzstan	1	1	5	35	9,500	15,000	Albania	1	1	1	10	5,000	6,500	Peru	5	5	15	150	15,000	20,000	
Laos	5	10	1	15	55,000	70,000	Argentina	5	5	70	700	15,000	20,000	Philippines	25	25	30	300	200,000	250,000	
Macedonia			5	50	1,500	1,000	Australia	1	1	65	200	2,500	5,500	Poland	1	1	85	600	5,500	4,000	
Moldova	1	1	15	100	5,500	5,000	Austria	1	1	30	90	5,000	6,500	Romania	1	1	40	300	8,500	6,000	
Mozambique	1	5	10	85	20,000	30,000	Azerbaijan	1	1	5	30	10,000	10,000	Sierra Leone	1	5		1	15,000	30,000	
Nepal	10	15	15	150	85,000	100,000	Belarus	1	1	5	35	6,500	5,500	Somalia	1	5	1	1	20,000	45,000	
North Korea	10	10	550	6,500	100,000	85,000	Benin	1	1	1	5	7,500	15,000	South Korea	5	5	95	800	25,000	20,000	
Pakistan	30	45	350	3,000	300,000	450,000	Brunei					1,500	1,500	Sri Lanka	5	5	15	150	45,000	40,000	
Saint Lucia	1	1			6,000	6,000	Bulgaria	1	1	10	70	3,000	1,500	Sudan/South Sudan	5	5	5	40	40,000	55,000	
Sao Tome and Principe	1	1			15,000	25,000	Burkina Faso	1	1	1	15	3,000	7,500	Suriname					550	650	
Solomon Islands	1	1			5,000	9,000	Burundi	1	1			10,000	20,000	Swaziland			1		3,000	4,000	
Tajikistan	5	5	40	300	30,000	45,000	Cape Verde					1,500	2,000	Switzerland	1	1	25	75	2,000	3,000	
Timor-Leste	1	1			25,000	25,000	Colombia	10	10	50	450	35,000	45,000	Ukraine	1	1	40	300	25,000	15,000	
Turkmenistan	5	10	5	25	55,000	80,000	Croatia	1	1	10	85	4,000	3,000	Uzbekistan	10	15		1	95,000	150,000	
Vanuatu			1	1	2,500	4,000	Dominican Republic	1	1	1	25	7,500	8,000	Venezuela	5	5	30	300	15,000	15,000	
Vietnam	50	55	150	2,000	500,000	500,000	El Salvador	1	5			20,000	30,000	MODERATE							
Yemen	1	1	35	250	7,500	25,000	Equatorial Guinea			1		2,000	3,500	Algeria	5	5	5	60	15,000	20,000	
SEVERE							Gabon	1	1			1,500	3,000	Angola	1	5		1	20,000	45,000	
Afghanistan	5	10	5	35	55,000	90,000	Georgia	1	1	1	10	30,000	20,000	Bahamas							
							Indonesia	25	30	75	650	250,000	250,000	Bahrain					1	650	850



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	👤		💰		👤		COUNTRY	👤		💰		👤	
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030
Belgium		1	1	5	1,500	2,000	Israel		1	1	5	1,500	2,000
Bosnia and Herzegovina	1	1	1	5	3,000	2,000	Japan	5	5	150	400	20,000	35,000
Botswana			1	650	700	Jordan			1	2,000	3,000		
Brazil	5	10	20	200	30,000	30,000	Kazakhstan	1	5	5	30	10,000	15,000
Cameroon	5	5	1	35,000	50,000	Kenya	5	5	1	10	40,000	50,000	
Canada	1	5	30	100	9,000	20,000	Kuwait				150	200	
Central African Republic	1	1		6,000	9,500	Latvia				1,000	750		
Chad	1	1	1	9,500	20,000	Lebanon	1	1		3,000	3,000		
Chile	1	1	5	50	4,000	Lesotho				3,500	3,500		
Congo	1	1		7,000	15,000	Libya			1	5	650	850	
Cote d'Ivoire	1	1		20,000	30,000	Lithuania				1,000	900		
Cuba	1	1	1	20	2,500	Luxembourg			1	200	500		
Cyprus				750	1,500	Mali	1	1		10,000	20,000		
Denmark			1	250	350	Mauritania		1	1	2,000	4,500		
Djibouti				200	250	Mexico	10	10	55	500	40,000	40,000	
DR Congo	10	25	1	90,000	200,000	Micronesia							
Egypt	5	10	5	30	65,000	80,000	Mongolia	1		1	4,500	3,500	
Eritrea	1	1		4,500	7,500	Morocco	1	1	5	30	15,000	20,000	
Estonia				750	450	Namibia				1	1,000	1,500	
Ethiopia	10	15	1	5	75,000	150,000	Netherlands	1	1	15	40	2,000	3,500
Finland				1		Nigeria	10	15	1	20	85,000	150,000	
France	1	1	60	200	9,000	15,000	Norway			1	5	700	1,000
Gambia				1,000	1,500	Oman		1	1	1,500	3,000		
Germany	1	1	100	350	4,500	6,500	Panama	1	1	1	5	2,000	2,000
Ghana	1	1	1	5	6,500	10,000	Paraguay	1	1	1	10,000	20,000	
Greece	1	1	10	30	2,000	3,000	Portugal	1	1	10	30	2,000	3,000
Guinea	1	5	1	15,000	25,000	Qatar				300	350		
Guinea-Bissau				950	1,500	Russia	10	5	75	550	35,000	25,000	
Hungary			10	65	1,500	900	Rwanda	1	1		15,000	25,000	
Iceland				1	150	250	Saint Vincent						
Iraq	5	5		35,000	60,000	Samoa							
Ireland		1	5	15	1,000	2,500	Saudi Arabia	1	10	90	1,500	3,000	
Senegal	1	1	1	5	9,500	15,000							
Seychelles													
Singapore				1	5								
Slovakia	1		5	30	2,500	2,000							
South Africa	1	1	5	35	5,500	4,500							
Spain	1	1	10	35	4,000	5,500							
Sweden				1	400	600							
Syria	1	5			30,000	45,000							
Tanzania	1	5	1	10	20,000	30,000							
Togo	1	1	1	5,000	9,000								
Tonga													
Trinidad and Tobago				1	650	600							
Tunisia		1	5	45	3,500	4,000							
Turkey	5	10	30	100	15,000	35,000							
Uganda	1	5	1	15,000	35,000								
United Arab Emirates	1	1	1	20	2,500	3,000							
United Kingdom	1	1	100	350	3,500	5,500							
United States	5	5	600	2,000	15,000	35,000							
Uruguay	1	1	1	5	1,500	1,500							
Zambia	1	1	1	10,000	20,000								
LOW													
Antigua and Barbuda													
Barbados													
Grenada													
Kiribati													
Maldives													
Marshall Islands													
Palau													
Tuvalu													

👤 Additional persons affected/in need of emergency assistance due to climate change - yearly average

STORMS



ESTIMATES GLOBAL CLIMATE IMPACT



2010 EFFECT TODAY

DEATHS PER YEAR
2,500

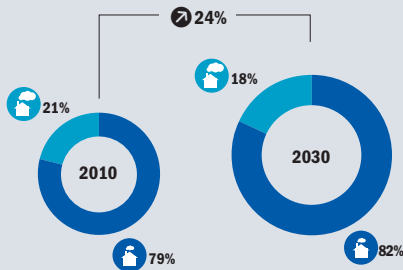
USD LOSS PER YEAR
15 BILLION

2030 EFFECT TOMORROW

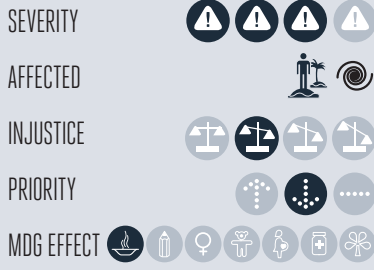
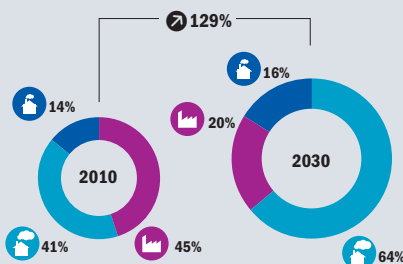
DEATHS PER YEAR
3,500

USD LOSS PER YEAR
100 BILLION

MORTALITY IMPACT



ECONOMIC IMPACT



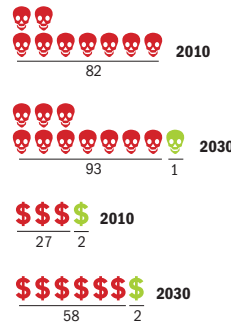
➤ All weather is affected by climate change because the Earth's atmosphere is warmer, moister, and more active today than in the recent past

➤ As a result, storms are becoming more extreme both in and outside of the tropics and will cause greater damage

➤ The location and extent of the additional damage is difficult to predict, as experts and their studies differ in their conclusions

➤ Countries already exposed to tropical cyclones or immediately adjacent to cyclone belts should prepare for growing risks and damages, especially in coastal areas

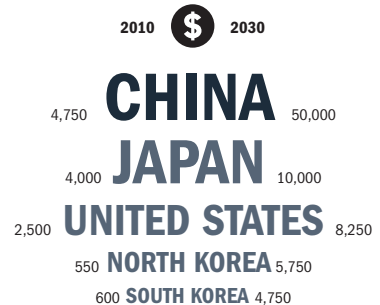
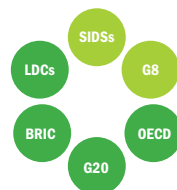
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



☠ Deaths \$ Economic Cost (2010 PPP non-discounted)
 🏠 Developing Country Low Emitters 🏭 Developed
 🏠 Developing Country High Emitters 🏠 Other Industrialized

☠ = Deaths per 10 million
 \$ = Losses per 10,000 USD of GDP
 ↗ Change in relation to overall global population and/or GDP

🎯 \$ = Millions of USD (2010 PPP non-discounted)

Whether or not specific events can be identified as “caused” by climate change, all weather is now affected by a global climate system that is warmer, more active, and wetter (Trenberth, 2012). As a result, it is evident that storms are generally becoming more extreme, particularly in terms of wind speeds and quantity of rainfall. Moreover, there is a pole-ward shift to the north and south of cyclone storm tracks, as parts of the world adjacent to the tropics are experiencing more “tropical” weather. Where vulnerabilities to more severe storms are accentuated by environmental and income-related factors—such as for high-risk urban slums in low-lying coastal areas—the dangers of these changes are much higher (IPCC, 2012a). Corresponding measures will need to offset the additional risk by reducing community vulnerabilities and, where possible, limiting exposure, to storm hazards (UNISDR, 2009 and 2011). Increased emergency assistance should also be foreseen in the coming years and decades.

CLIMATE MECHANISM

Climate change increases air and sea temperatures, boosting the

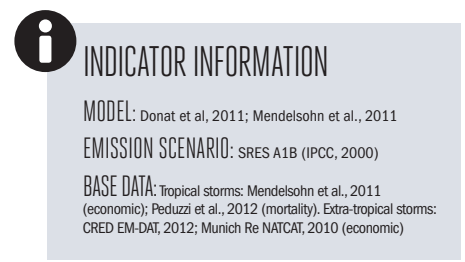
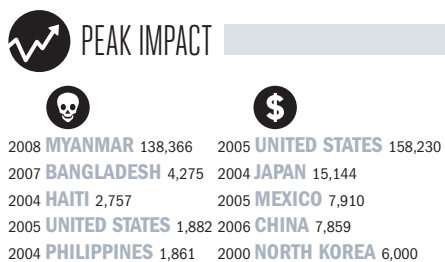
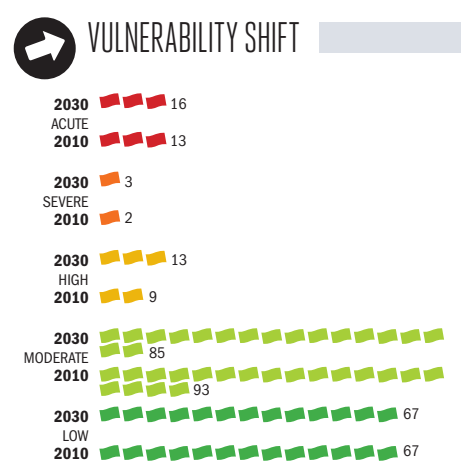
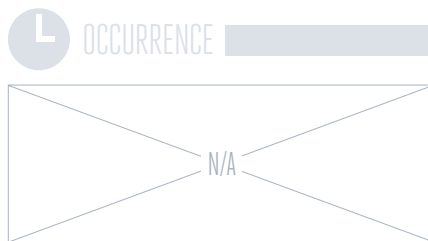
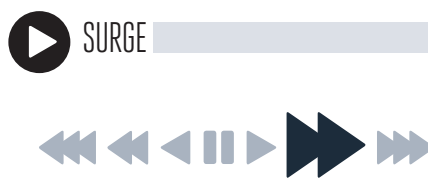
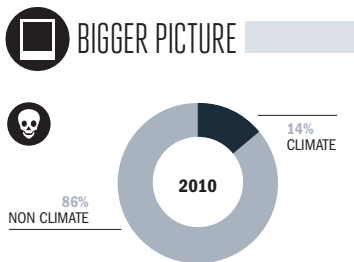
level of moisture in the atmosphere; this leads to acceleration of the planet’s hydrological system, heavier precipitation, higher maximum winds and a general tendency to more extreme weather (IPCC, 2007). These hallmarks have been recognized in storms, including cyclones (IPCC, 2012a). Whether or not there has been a change in the frequency or overall number of cyclones in recent years can side-track the focus on other important factors, such as wind speed changes (Knutson et al. in Chan et al. (eds.), 2010). Simply counting the change in the number of cyclones often leads to the conclusion that there is less cyclone activity, since there is generally understood to be a slight increase in the most extreme cyclones, such as categories 3 to 5, but an overall decrease in the total number of cyclones since the reduction in less severe storms is expected to be greater (Knutson et al., 2010). It is not surprising that an increase in the most extreme cyclones, as measured on the well-known Saffir-Simpson scale results in fewer cyclones overall, since the scale itself is static, measures overall power, and is a rough proxy for the size of storms (Dolan and David, 1992; Irish et al., 2008). Larger more powerful storms absorb and dissipate

considerably more energy than smaller ones, whose declining numbers have been attributed to an overall decline in cyclone frequency in recent times (IPCC, 2012a). Nor is the ultimate number of storms as important as the intensity or size of those storms: in the US, 85% of all cyclone damage is caused by the most extreme storms (Rudeva and Gulev, 2007; Pielke et al., 2008). A large share of the damage caused by cyclones is the result of storm surge, or inundations from rainfall, high winds, and freak waves caused by major storms, which have been worsened by heavier rainfall and sea-level rise, both of which are fuelled by climate change (Dasgupta et al., 2009).

IMPACTS

The impact of climate change on both tropical cyclones and major storms outside of the tropics (extra-tropical cyclones) is estimated to already cost 15 billion dollars and to be responsible for an average of almost 2,500 deaths each year, with around 1.5 million people affected and in need of emergency assistance. In global terms, the number of countries experiencing extreme effects is limited, particularly since the great majority

of losses relate to tropical cyclones, which are a serious concern for only 30 to 40 countries in the world’s cyclone belts. A dozen countries in Asia, Africa, the Pacific, and the Caribbean are estimated to suffer Acute or Severe vulnerability to climate change-aggravated storm effects. The countries most vulnerable cut across the socio-economic spectrum from Japan to major emerging economies, such as China, least developed countries such as Madagascar, or small island developing states, such as Haiti. Bangladesh is currently estimated to suffer the greatest human impact of these effects, with over 1,000 additional casualties due to climate change on an averaged yearly basis—major storms do not occur annually, but once in every 5 to 20 years. Myanmar and India are estimated to suffer the next greatest share of additional casualties. In overall economic terms, China, Japan, the US, North Korea, and South Korea experience the greatest estimated losses, incurring between 2 and 5 billion dollars a year in damages. A number of small island countries, such as Antigua and Barbuda, Dominica, Grenada, and Vanuatu are identified as experiencing the most severe economic and human loss



↑ = Millions of USD (historic)
 ● Acute ● Severe ● High ● Moderate ● Low

➡ = 5 countries (rounded)

relative to size. Several countries located on the Central American isthmus, such as Belize, El Salvador, and Honduras are exposed to tropical cyclones originating in both the Caribbean/Atlantic and Pacific Oceans, and are estimated to suffer extreme effects.

THE BROADER CONTEXT

As with other weather-related disasters, two key trends provide the context for the changes in extreme weather hazards which researchers increasingly attribute to climate change: 1) reductions in vulnerability due to continued economic growth especially in developing countries; and 2) an increase in the number of people and the amount of infrastructure exposed to extreme weather, due to the combined effects of population growth, urbanization, and economic development (UNISDR, 2011; Peduzzi et al., 2012). Correcting for these developments and other inconsistencies, evolution in reporting systems and biases in the statistical record have led to mixed interpretations of whether the scale of impacts due to climate change are increasing or decreasing (Mendelsohn et al., 2011; Pielke et al., 2008). The insurance industry has been registering greater

and greater losses from weather-related catastrophes, including storms, over the past several years (Swiss Re, 2010, 2011, and 2012).

VULNERABILITIES AND WIDER OUTCOMES

Particularly noteworthy in terms of environmental vulnerabilities to storms are low-lying coastal communities which will bear the brunt of the increasing effects of climate change on heavy rainfall, wave height, and storm surge during cyclones (Füssel in Edenhofer et al. (eds.), 2012). Significantly altering the risk profile of countries are existing protection levels and capacities embodied in infrastructure, early warning systems, social and community response, support networks and levels of awareness about disasters. Likewise, government capacity to manage risks, as well as land use and environmental planning and protection can all affect the level of vulnerability, e.g., inappropriate urbanization or the clearing of coastal mangrove forests, which otherwise provide protection against winds and storm surges (UNISDR, 2009 and 2011; IPCC, 2012a). Migration patterns are fuelling rapid and inappropriate urbanization, leading to

growing settlements in high-risk coastal flood zones, which themselves are seeing a depletion in natural protection, as from the destruction of mangrove forests (Donner and Rodriguez, 2008; Füssel in Edenhofer et al. (eds.), 2012).

Where insurance coverage is low, the ability of affected communities to rebound from disasters is greatly inhibited (Dodman and Satterthwaite, 2008). This is especially a concern among developing and lower-income countries, such as small island developing states, where the scale of impact can also generate important setbacks for development (Pelling and Uitto, 2001).

RESPONSES

Numerous preventive measures can be taken to reduce key vulnerabilities and minimize naturally increasing exposures to disaster. Possible efforts include education and communication programmes, promotion of community volunteer emergency organizations, supporting governments to develop and implement action plans to manage risks through sensible municipal planning, constructing protective infrastructure, reinforcing environmental protection to limit risk-multiplication, and promoting access to insurance products. Better

THE INDICATOR

Although the increasing severity of weather including tropical and extra-tropical cyclones is well established, the indicator is considered speculative because there is considerable disagreement among the models predicting change in cyclone intensity for different regions of the world. With the exception of the North Atlantic, where evidence of an increase in extreme weather is strongest, predictions of changes in cyclone activity in the Indian and Pacific oceans differ widely (Mendelsohn et al., 2011; IPCC, 2012a).

management of urbanization and urban-rural migration flows would also help lower risks for coastal mega-cities (de Sherbinin et al., 2007). Progress in human development and poverty reduction will inevitably enhance capacities to withstand serious storms and limit the damage to the highest risk groups, requiring integrated strategies regarding climate change, disaster risk, and development strategies (Schipper and Pelling, 2006).

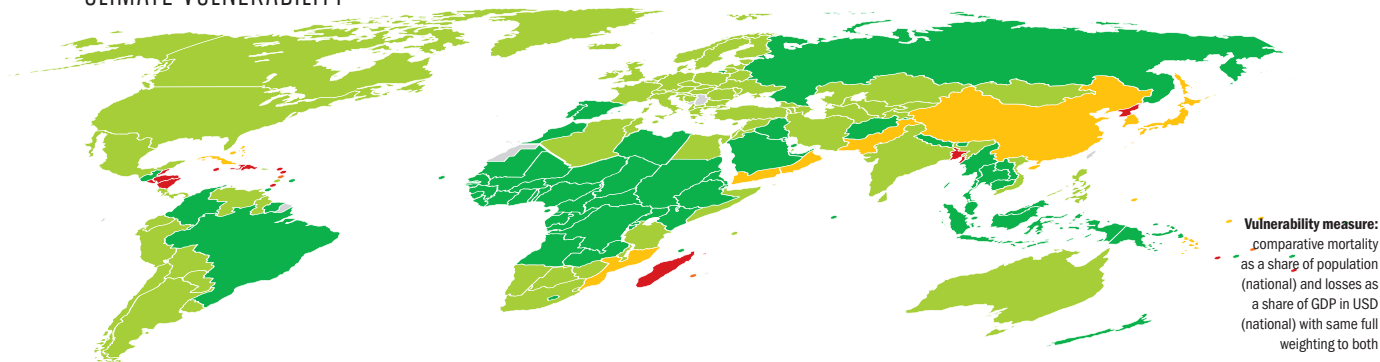
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	2010		2030		2010	2030		COUNTRY	2010		2030		2010	2030		COUNTRY	2010		2030								
	2010	2030	2010	2030		2010	2030		2010	2030	2010	2030		2010	2030		2010	2030	2010	2030							
ACUTE																											
Antigua and Barbuda			30	250	700	650	Solomon Islands	1	1			8,500	20,000	Greece			1	5									
Bangladesh	1,750	2,500	150	1,250	400,000	600,000	South Korea			-1	600	4,750	-25	-200	Guyana				1								
Belize			30	250	550	700	Yemen					25	200	Hungary					1								
Dominica			15	150	-90	-100	MODERATE																				
Dominican Republic	10	10	200	1,750	20,000	20,000	Albania								150	150	550	4,250	300,000	350,000							
El Salvador			250	1,750	5	15	Algeria					1		Iran			250	1,750									
Grenada				25	200	-35	-60	Argentina				1	10	Ireland				1	1								
Haiti	15	20	25	200	5,750	8,500	Armenia							Israel				1	10								
Honduras	1	1	200	1,500	200	350	Australia	1	1	-1	-1	100,000	150,000	Italy				1	5								
Jamaica			1	100	800	1,000	Austria					5	10	Jordan					1								
Madagascar	50	100	40	250	150,000	300,000	Azerbaijan							Kazakhstan													
Myanmar	500	600	1	20	10,000	15,000	Belarus							Kuwait				1	15								
Nicaragua	1	1	50	350	250	550	Belgium				1	10	1	1	Kyrgyzstan												
North Korea				550	5,750	2,250	Bolivia							Latvia				1	10	400	750						
Tonga				1		-3,750	20,000	Bosnia and Herzegovina						Lebanon				1	5								
Vanuatu	5	10		-1	7,250	15,000	Botswana							Lithuania					1	250	500						
SEVERE																											
Mauritius	1	1	25	150	500	400	Bulgaria							Luxembourg					1	1							
Saint Lucia				1	20	15	10	Canada				1	5	Macedonia													
Samoa			1		-1	750	5,750	Chile					1	10	Malawi					1							
HIGH																											
Bahamas			1			400	450	Costa Rica				1	10	950	1,250	Malta											
China	1	-5	4,750	50,000	100,000	-250,000	Croatia									10	15	150	1,250	70,000	85,000						
Cuba	-1	-1	100	850	-75,000	-200,000	Cyprus											1	5								
Japan	-10	-20	4,000	10,000	-10,000	-30,000	Czech Republic				1	5	550	1,000	Moldova												
Marshall Islands					55	650	Denmark				5	15	10	20	Mongolia												
Micronesia					1	25	Djibouti								Namibia					1	5	90	200				
Mozambique	15	25	1	15	150,000	200,000	Ecuador							Netherlands					1	5							
Oman				75	550		Egypt							Norway													
Pakistan	5	5	250	2,250	4,500	8,750	Estonia				1	1		Panama						25	30						
Palau					200	450	Finland							Paraguay													
							France				1	40	95	3,250	6,000	Peru					1	10					
							Georgia								Philippines	45	60	15	100	200,000	250,000						
							Germany				100	350	25	50	Poland					1	10	1	1				
														Qatar							1	10					



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure: comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	☠		💰		👤		COUNTRY	☠		💰		👤	
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030
Romania			1	1			Brazil						
Saint Vincent			1	5	-150	-150	Brunei						
Seychelles				1			Burkina Faso						
Slovakia			1	5			Burundi						
Slovenia			1	5			Cambodia						
Somalia				1			Cameroon						
South Africa			5	20			Cape Verde						
Sri Lanka			5	35	2,500	60	Central African Republic						
Swaziland							Chad						
Sweden			5	10	10	15	Colombia						
Switzerland			5	15	65	100	Comoros						
Syria							Congo						
Tajikistan			1	15			Cote d'Ivoire						
Tanzania			15	90			DR Congo						
Tunisia							Equatorial Guinea						
Turkey							Eritrea						
Turkmenistan							Ethiopia						
Ukraine			1	5			Fiji	1	-1	-10	-75	5,250	-2,000
United Kingdom			20	60	55	150	Gabon						
United States	1	1	2,500	8,250	4,750	6,500	Gambia						
Uruguay				1			Ghana						
Uzbekistan							Guatemala	1	-1	-10	150	250	
Venezuela				1			Guinea						
Vietnam	10	10	-5	-75	15,000	15,000	Guinea-Bissau						
Zimbabwe	1	5			6,500	15,000	Indonesia			-50	-400		
LOW							Iraq						
Afghanistan							Kenya				-1		
Angola							Kiribati						
Bahrain			-5	-35			Laos	1	1	-5	-35	5,750	8,750
Barbados			1		-90	-250	Lesotho						
Berlin							Liberia						
Bhutan							Libya						
Malaysia					-1	-10							
Maldives					-1	5	15						
Mali													
Mauritania													
Morocco													
Nepal													
New Zealand			-5	-15	150	150							
Niger													
Nigeria													
Papua New Guinea													
Portugal													
Russia	-1	-5	1	10	-150	-300							
Rwanda													
Sao Tome and Principe													
Saudi Arabia			-30	-250									
Senegal													
Sierra Leone													
Singapore													
Spain			-1	-10									
Sudan/South Sudan													
Suriname													
Thailand			-5	-35	750	650							
Timor-Leste													
Togo					-1	-10							
Trinidad and Tobago			-1		-250	-1,250							
Tuvalu													
Uganda													
United Arab Emirates			-10	-85									
Zambia													

👤 Additional persons affected/in need of emergency assistance due to climate change - yearly average

WILDFIRES



ESTIMATES GLOBAL CLIMATE IMPACT

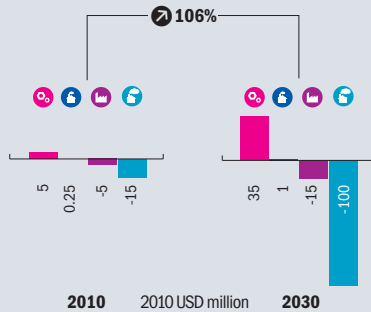
2010 EFFECT TODAY

\$ USD GAIN PER YEAR **15** MILLION

2030 EFFECT TOMORROW

\$ USD GAIN PER YEAR **90** MILLION

\$ ECONOMIC IMPACT



CONFIDENCE INDICATIVE

- Person icon
- Home icon
- Cloud icon
- Document icon

SEVERITY

AFFECTED

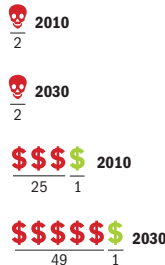
INJUSTICE

PRIORITY

MDG EFFECT

- The global impact of climate change on wildfires may have a neutral effect as a warmer planet brings more rain, dampening fires
- Shifts in wildfire may occur where forested areas become drier and hotter, severely affecting populated parts of Russia, Mongolia, or Australia
- The marginal effect of climate change is difficult to predict because of wind and rain uncertainties and because good international data monitoring fire damages is lacking
- Wildfire occurrence has links to now more prevalent heat extremes and drought which increase the probability of fires

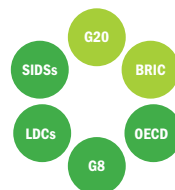
★ RELATIVE IMPACT



🎯 HOTSPOTS



🌐 GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **🏠** Developed
🏡 Developing Country High Emitters **🏭** Other Industrialized

★👤 = Deaths per 100 million
\$ = Losses per 10 million USD of GDP
 🔄 = Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Wildfires—the uncontrolled burning of forests, grasslands or brush—will generally become more frequent and damaging for drought-prone parts of the world. But it is certain that climate change will reduce disturbances from wildfires in some areas where rainfall is significantly increasing. The 2010 wildfires in Russia, as well as the recent fires in Australia, Greece, and the US, are clearly linked to warm, dry temperatures, if not drought (UNISDR, 2011). However, the additional losses incurred by those worst affected are likely to be offset on a global scale by a reduction in wildfire activity in other parts of the world. It is expected that Vietnam may see increased rainfall in some seasons, but declining rain and rising heat during the dry periods would favour wildfire onset, even if more rain overall falls in a given year (Vietnam MONRE, 2010). Tackling an additional burden of wildfire in affected areas will be great, since suppressing fires is costly: the US Forest Service spent 1 billion dollars on fire suppression in the year 2000 alone, with costs growing significantly over time—2.5 million dollars in losses were reported for that year. But expenditures were undoubtedly

warranted in most cases, since wildfires can be extremely deadly: in February 2009, one series of fires alone in Australia killed 180 people (WFLC, 2004; CRED/EM-DAT, 2012).

CLIMATE MECHANISM

Wildfires are affected by three key factors: 1) availability of vegetation to burn; 2) environmental conditions, such as temperature, wind, and humidity or rainfall but also topography and ecosystem type—tropical forests for example are more humid and burn less than temperate forests; and 3) varying ignition sources of fires (Krawchuk et al., 2009). Climate change affects all of these elements: it influences vegetation growth and health along with the expanse of different ecosystem areas (Gonzalez et al., 2010). In regions with less rain and more heat, the declining vegetation will offer less available material for burning and will ultimately reduce disturbances from wildfires. Heat is increasing relatively uniformly around the world due to climate change. Less predictable rainfall and vegetation changes add considerable uncertainty to whether or not fires ultimately retreat or advance with global warming. Climate change has also been shown

to potentially alter electrical activity in the atmosphere, giving rise to lightning, the principal initial trigger of wildfires (Reeve and Toumi, 1999).

IMPACTS

Drawing on recent research, the Monitor estimates the global impact of climate change on wildfire to be close to zero in 2010 and in 2030 (Krawchuk et al., 2009). Estimates of impact include around 3 million dollars of additional losses a year in 2010, and some 15 million dollars of additional losses in 2030. “Gains” of 25 and 150 million dollars a year in 2010 and 2030, respectively, outweigh considerably any losses incurred elsewhere in the world, but overall totals are small. “Gains” represent avoided wildfires that would have taken place without climate change. The largest negative effects in absolute terms are estimated to occur in Russia, Mongolia, Canada, Australia, and South Africa, while the US and Indonesia are expected to reap the most benefits overall. Within large countries like the US, it is possible that increased fire activity may well be experienced in certain areas but will be counterbalanced with decreased activity in other parts of the country.

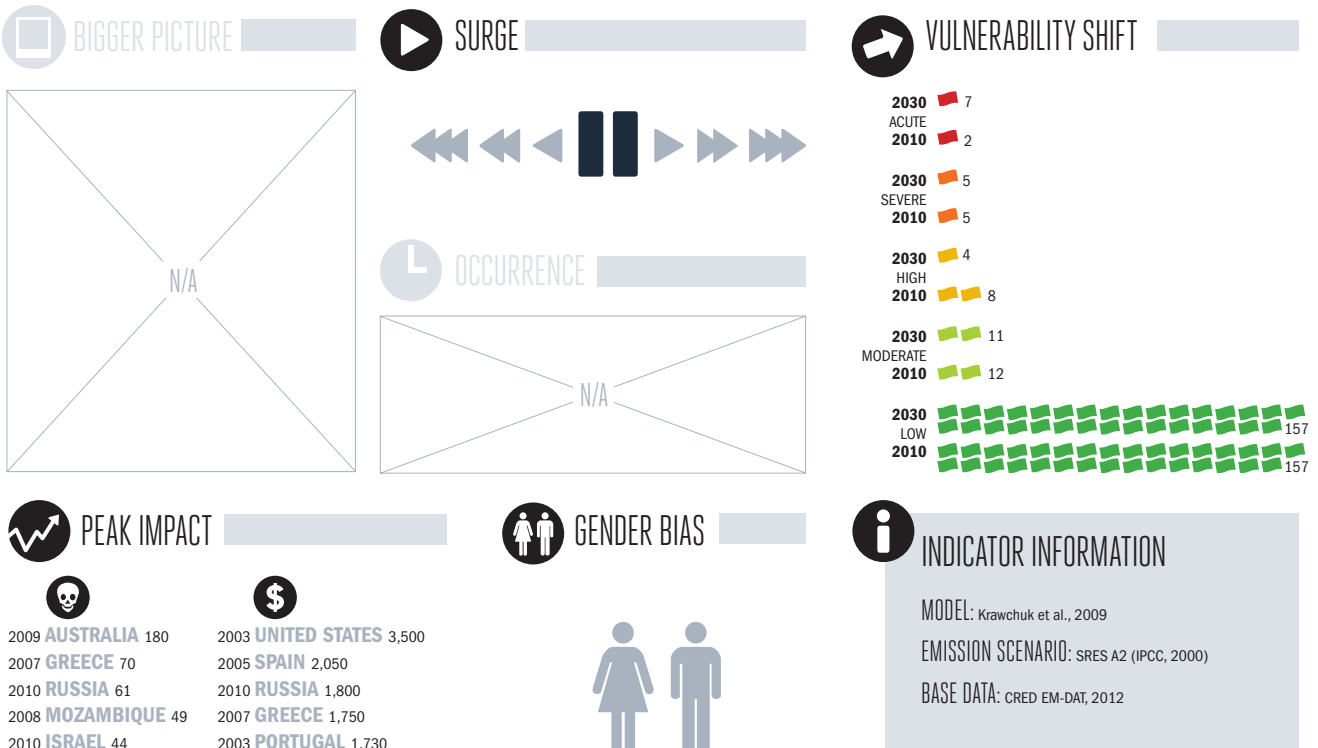
In general, wildfires mainly concern industrialized or developed countries.

THE BROADER CONTEXT

There has been a considerable increase in wildfire damage recorded in recent years (CRED/EM-DAT, 2012). However, improvements in the actual reporting systems themselves—advances in technology and information sharing—have allowed the reporting of increasing numbers of phenomena (UNISDR, 2009). However, satellite analysis has shown that the annual burned area has grown since the 1970s (UNEP, 2002). Several other factors, such as land usage change, could be contributing to increasing fire damage. As with other weather-related disasters, growing exposure to wildfires through economic development, population growth, and an expansion in infrastructure at risk should also increase damages.

VULNERABILITIES AND WIDER OUTCOMES

Countries with large areas of non-tropical vegetation and a propensity to drought are particularly vulnerable to the effects of climate change



📈 = Millions of USD (historic)
 ● Acute ● Severe ● High ● Moderate ● Low

➡ = 5 countries (rounded)

on wildfires. Coniferous forests are especially risky areas for fire outbreak during extended warm, dry periods (Cruz and Alexander, 2010).

The full extent of increased wildfires is difficult to estimate, but given the incredible potential for the rapid and uncontrolled spread of fires, growing fire dangers in some parts of the world could carry serious risks for public safety. The 2010 Russian wildfires, for example, burned some 4,000 hectares of land—contaminated, moreover, by radioactive material from the Chernobyl disaster—the full consequences of which are not yet known; the fires also threatened functioning nuclear power plants and research facilities (Munich Re, 2010).

RESPONSES

Responding to wildfires is extremely costly and requires highly sophisticated technology. Some early detection and warning systems are capable of identifying a fire within 5 minutes of its ignition (Bridge, 2010). Thus, such systems represent an investment that could significantly reduce overall expenditures on suppressing fires that would otherwise end up destroying thousands or millions of hectares. Fire safety and education programmes may



reduce the potential for fires set by human hands by up to 80% (UNEP, 2002). Of course, as is well known, not all wildfires are bad. Natural habitats have evolved to cope with wildfires over time and to support biodiversity and processes of regeneration (Parker et al., 2006). Therefore, many countries also practice what is called “prescribed burning,”

effectively a “let-burn” policy, in which human settlements are not endangered. But while such practices may lower fire prevention costs and help support ecosystems, if fires subsequently reach a large-scale and deviate to threaten settlements, the costs of fire suppression can rapidly and counter-productively escalate (UNEP, 2002).

THE INDICATOR

The indicator relies on a high-resolution global pyrogeography model for the effect of climate change on fire disturbances, used to estimate impact for populated areas (Krawchuk et al., 2009). Limitations relate to uncertain future rainfall and the restricted socio-economic base data set, which may underestimate costs (CRED/EM-DAT, 2012). Regarding base data, the major wildfires that affected Russia in 2010 are recorded in the reference database at 1.8 billion dollars in losses and 61 deaths. The major reinsurer, Munich Re, on the other hand estimates the total cost of the fires at 3.3 billion dollars and over 50,000 indirect deaths from both extreme heat and the significantly higher than normal air particle loads and their effect on chronic respiratory and cardiovascular disease sufferers (Munich Re, 2010). Historical base data would also give a misleading trend if fires spread to areas where damage in the past was unusual, underestimating future losses.

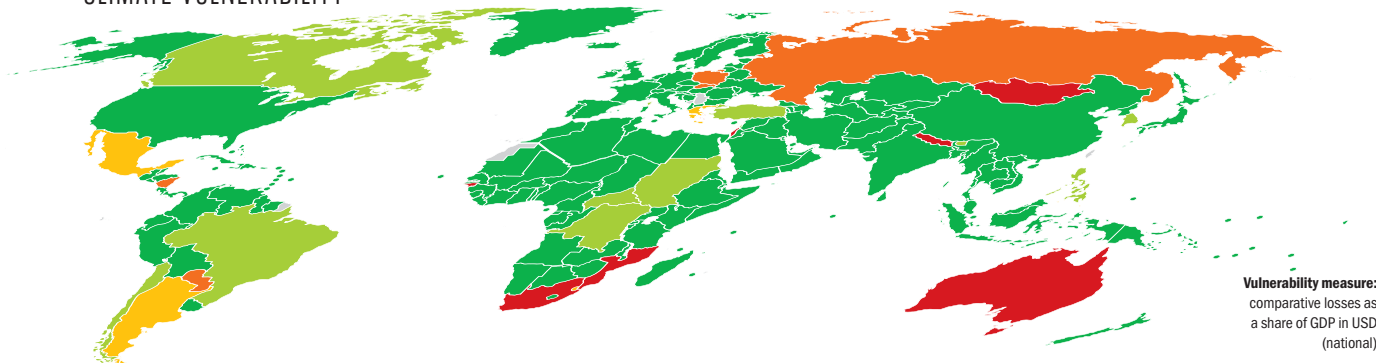
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$				
	2010	2030		2010	2030		2010	2030			
ACUTE											
Australia	0.25	0.50	LOW								
Guinea-Bissau			Afghanistan			Costa Rica					
Israel			Albania			Cote d'Ivoire					
Mongolia	1	15	Algeria			Croatia					
Mozambique			Angola			Cuba					
Nepal			Antigua and Barbuda			Cyprus					
South Africa	0.25	1	Armenia			Czech Republic					
SEVERE											
Nicaragua	0.25	1	Austria			Denmark					
Paraguay			Azerbaijan			Djibouti					
Poland			Bahamas			Dominica					
Russia	5	40	Bahrain			Dominican Republic					
Slovakia			Bangladesh			Ecuador					
HIGH											
Argentina			Barbados			Egypt					
Greece			Belarus			El Salvador					
Mexico			Belgium			Equatorial Guinea					
Swaziland			Belize			Eritrea					
MODERATE											
Bhutan			Benin			Estonia					
Brazil			Bolivia			Ethiopia					
Canada	0.50	1	Bosnia and Herzegovina			Fiji					
Central African Republic			Botswana			Finland					
Chile			Brunei			France					
DR Congo			Bulgaria	-0.25	-1	Gabon					
Lebanon			Burkina Faso			Gambia					
Philippines			Burundi			Georgia					
South Korea			Cambodia			Germany					
Sudan/South Sudan			Cameroon			Ghana					
Turkey			Cape Verde			Grenada					
			Chad			Guatemala					
			China			Guinea					
			Colombia			Guyana					
			Comoros			Haiti					
			Congo			Honduras					
						Hungary					



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Iceland			Micronesia			Somalia		
India			Moldova			Spain	-0.25	-1
Indonesia	-20	-150	Morocco			Sri Lanka		
Iran			Myanmar			Suriname		
Iraq			Namibia			Sweden		
Ireland			Netherlands			Switzerland		
Italy	-1	-1	New Zealand			Syria		
Jamaica			Niger			Tajikistan		
Japan			Nigeria			Tanzania		
Jordan			North Korea			Thailand		
Kazakhstan			Norway			Timor-Leste		
Kenya			Oman			Togo		
Kiribati			Pakistan			Tonga		
Kuwait			Palau			Trinidad and Tobago		
Kyrgyzstan			Panama			Tunisia		
Laos			Papua New Guinea			Turkmenistan		
Latvia			Peru			Tuvalu		
Lesotho			Portugal	-0.25	-1	Uganda		
Liberia			Qatar			Ukraine		
Libya			Romania			United Arab Emirates		
Lithuania			Rwanda			United Kingdom		
Luxembourg			Saint Lucia			United States	-5	-15
Macedonia			Saint Vincent			Uruguay		
Madagascar			Samoa			Uzbekistan		
Malawi			Sao Tome and Principe			Vanuatu		
Malaysia	-0.25	-1	Saudi Arabia			Venezuela		
Maldives			Senegal			Vietnam		
Mali			Seychelles			Yemen		
Malta			Sierra Leone			Zambia		
Marshall Islands			Singapore			Zimbabwe		
Mauritania			Slovenia					
Mauritius			Solomon Islands					



HABITAT CHANGE



BIODIVERSITY



DESERTIFICATION



HEATING & COOLING



LABOUR PRODUCTIVITY



PERMAFROST



SEA-LEVEL RISE



WATER

↓ **\$** 80 BILLION LOSS 2010
400 BILLION LOSS 2030



↓ **\$** 5 BILLION LOSS 2010
20 BILLION LOSS 2030



↓ **\$** 35 BILLION GAIN 2010
75 BILLION GAIN 2030



↓ **\$** 300 BILLION LOSS 2010
2.5 TRILLION LOSS 2030



↓ **\$** 30 BILLION LOSS 2010
150 BILLION LOSS 2030



↓ **\$** 85 BILLION LOSS 2010
550 BILLION LOSS 2030



↓ **\$** 15 BILLION LOSS 2010
15 BILLION LOSS 2030



BIODIVERSITY



ESTIMATES GLOBAL CLIMATE IMPACT

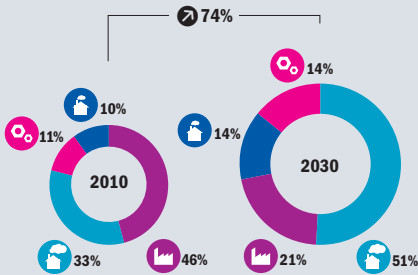
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **80** BILLION

2030 EFFECT TOMORROW

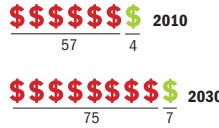
\$ USD LOSS PER YEAR **400** BILLION

ECONOMIC IMPACT

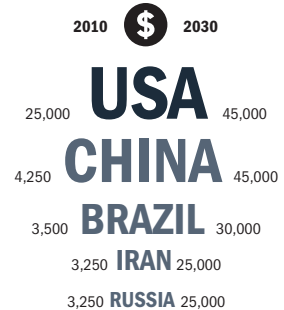


- Richness of life in the world's ecosystems is currently in full decline as human activities from toxic pollution to deforestation and destruction of natural habitats for agricultural land persist
- Climate change forces biological zones to face weather conditions that are unsuitable for their plant, animal, insect, and other species, hastening decline and extinction
- Biodiversity loss has significant market value and on a large scale will slow the world's economic growth
- Limiting non-climate dangers to biodiversity, such as deforestation, will be the basis of an effective response to the impact of climate change

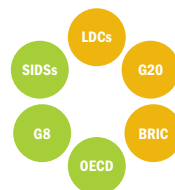
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **f** Developed
H Developing Country High Emitters **o** Other Industrialized

★ **\$** = Losses per 10,000 USD of GDP
↗ Change in relation to overall global population and/or GDP

◎ **\$** = Millions of USD (2010 PPP non-discounted)

The international definition of biodiversity is “variability among living organisms” (CBD, 1992). Biodiversity has both market and non-market value—such as aesthetic and other non-traded values—principally through the integral role of biodiversity in sustaining ecosystems (Boyd and Banzhaf, 2007). The agricultural sector is particularly dependent on ecosystem services, such as water, pollination, and pest control. If removed, they will incur predictable market-based costs, since compensating measures must be taken at market cost. Experts have estimated that a 30% species loss can generate some 10% of lost plant production affecting agricultural outputs (Hooper et al., 2012). Global biodiversity loss has become not only a conservation issue, but a large-scale and serious macroeconomic problem. UNEP estimates current global environmental damages at over 6 trillion dollars (Garfunkel ed., 2010). As one of the costliest impacts of climate change assessed here, losses can only worsen unless comprehensive solutions are found (IPCC, 2007; Bellard et al., 2012).

CLIMATE MECHANISM

The world’s main biological zones, or biomes, from tropical woodlands, to grass steppes, and temperate deciduous forests, have taken thousands of years to establish rich habitats for an unimaginable variety of natural species. These zones are distinguished one from another by precise climate and geographical characteristics (Sala et al., 2000). The planet is warming at rates faster than in much of the Earth’s recent past and the growing human presence in the environment limits the scope for biomes and their inhabitants to shift to new areas or adapt to changing climates (IPCC, 2007; Pereira et al., 2010). Some species will become invasive, establishing themselves in new areas where others are in decline (Vilà et al. in Canadell et al. (eds.), 2007; Hellmann et al., 2008). As climates become unsuitable, endemic species of all kinds which have evolved to thrive in a specific habitat will be locked into declining biological zones with reduced geographic range. As that area shrinks, species decline at a predictable rate, reducing biodiversity (Thomas et al., 2004). Climate change could conceivably also bring some biodiversity benefits in isolated cases, but on a global scale

the impacts are clearly understood by experts to be negative (Bellard et al., 2012). Valuing the market worth of ecosystems and their so-called “services” is difficult, not least since it involves putting a price tag on ecological life (Farber et al., 2002). But in a surrogate market—in which consumers would be charged for the benefits many now enjoy without cost—around half of the losses estimated here might be considered to have value (Sutton and Constanza, 2002; Curtis, 2004).

IMPACTS

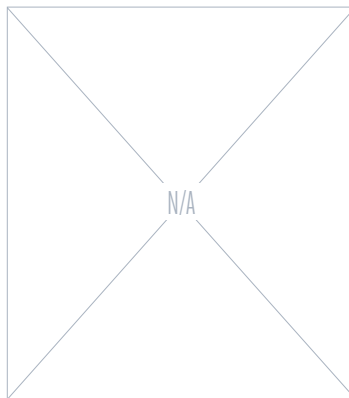
The scale of the estimated impact on biodiversity from climate change are substantial: around 80 billion dollars a year at present. By 2030, that estimate will nearly double as a share of global GDP, approaching 400 billion dollars a year in losses. Although the impact is estimated to affect developing countries more severely, biodiversity loss will occur in virtually every region, since the world’s entire climate is in rapid shift. However, lower-income countries are more dependent on ecosystem services, increasing the damage potential for populations lower on the socio-economic scale.

Large countries incur the most damages, especially the US, China, Brazil, Iran, and Russia. The US is estimated to incur one quarter of all losses today, at over 20 billion US dollars a year. Impacts are most severe as a share of GDP for countries in Africa and Central Asia, many of which could experience losses equivalent to more than 1% of GDP by 2030.

THE BROADER CONTEXT

The long-term decline of biodiversity is well established and continues as a clear trend. For example, since the 1970s, the fall in the abundance of vertebrate species has been almost one third. The World Conservation Union’s (IUCN) “Red List” of endangered species reveals some 20,000 species of animals and plants at high risk for extinction. Decline of natural habitats due to human activities is also a continuing trend around the world, although destruction of tropical forests and mangroves has shown signs of slowing in some areas (SCBD, 2010). Deforestation is still a major global concern and threatens biodiversity (Busch et al., 2011). High demand for food and biofuels, driven by population and economic growth is an important driver of land change and degradation

BIGGER PICTURE



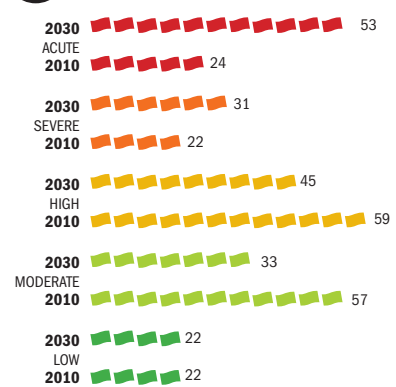
SURGE



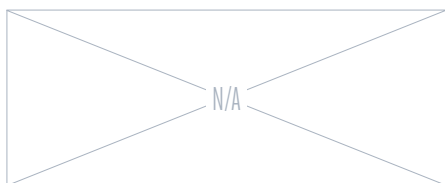
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Baumgartner et al., 2012; Thomas et al., 2004
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: Costanza et al., 1997; Mace et al., 2003; US Forest Service (2010)

➡ = 5 countries (rounded)

DESERTIFICATION



ESTIMATES GLOBAL CLIMATE IMPACT

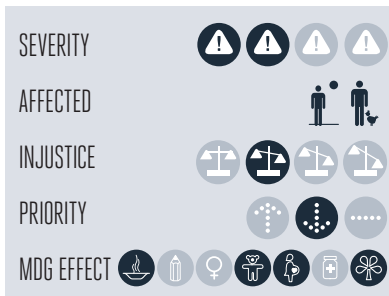
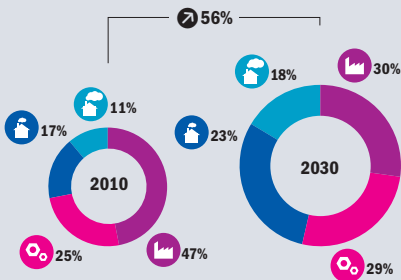
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

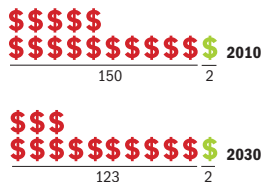
\$ USD LOSS PER YEAR **20 BILLION**

\$ ECONOMIC IMPACT



- Desertification will worsen already dry areas as heat rises and rainfall declines
- Although global climate change brings more rain, most of it will fall in the far north and south, while rainfall in the tropical zones, home to much of the world's drylands, is likely to decline as heat rises
- Millions of hectares of agricultural land in these areas are experiencing an increase in aridity, compounding other degradation taking place
- Climate change in the world's drylands will further impede human development progress for some of the world's poorest groups
- Sustainable land management strategies can help prevent desertification, but restoration of already degraded lands is difficult and costly

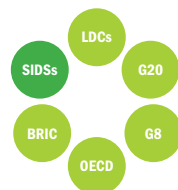
★ RELATIVE IMPACT



🎯 HOTSPOTS



🌐 GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **f** Developed
H Developing Country High Emitters **o** Other Industrialized

★ **\$** = Losses per 100,000 USD of GDP
 ↗ Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Desertification is degradation of drylands. The UN has defined “drylands” broadly as areas of land with an aridity index—a measure of rainfall versus evaporation—below a certain low-end threshold (UN, 2011). More than half the planet’s productive land is considered drylands. Covering around 40% of the earth’s land surface, drylands are home to some 2 billion people, nearly all in developing countries, and are responsible for more than 40% of global food production (UNCCD, 2011). As climate change intensifies heat and limits rainfall in drylands, already rampant land degradation in these areas will worsen (Evans and Geerken, 2004; Adeel et al., 2005; Zika and Erb, 2009). The UN and Christian Aid have estimated that anywhere between 25 and 700 million people could be displaced due to expected water stress and environmental degradation, including 50 million people affected by desertification over the next decade (Christian Aid, 2007; WWAP, 2009; UNCCD, 2010). Such groups have been campaigning for greater application of sustainable land and water resource management in order to combat this alarming development.

CLIMATE MECHANISM

A range of socio-economic and environmental processes are involved in land degradation in dry areas, including declining water availability, soil erosion and nutrient depletion, among others (Geist and Lambin, 2004). Climate observations and models indicate that many of the world’s dry regions are becoming hotter and drier as global warming intensifies (Hansen et al., 2007; McCluney et al., 2011). A loss in net moisture or rainfall is a key factor in the degradation of dry land (Evans and Geerken, 2004). As a result, many non-arid lands will become arid, while affected arid lands will become even drier. On the other hand, where there are substantial increases in rainfall on existing drylands, such zones will improve and become more humid. Overall, the changes will be negative, since rainfall change is more likely to degrade the world’s existing dryland, especially in Africa (IPCC, 2007 and 2007b; Helm et al., 2010). Where lands degrade, agricultural productivity and livelihoods will be severely affected (Fraser et al., 2011).

IMPACTS

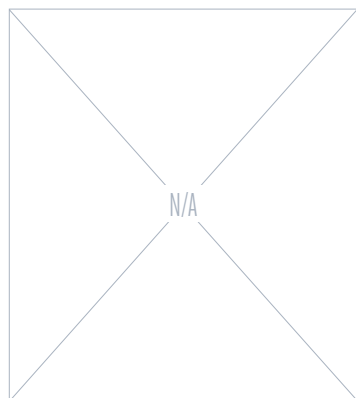
The impact of climate change on desertification is expected to be widespread, affecting around 40 countries by 2030. The economic impact of land degradation is estimated at 5 billion dollars a year today, increasing to some 20 billion dollars annually and a larger share of global GDP by 2030. Climate change-driven desertification is already estimated to affect some 5 million people worldwide, doubling to 10 million by 2030. The range of worst affected countries is varied, with West Africa particularly hard hit. Countries such as Benin, Burkina Faso, Gambia, Guinea-Bissau, Mali, Niger, and Senegal top the list of those suffering the most extreme effects. A number of developed and industrialized countries are also affected from Australia to the Mediterranean, and Black Sea countries such as Bosnia and Herzegovina, Croatia, Russia and the Ukraine. The bulk of global costs will occur in Organization for Economic Co-operation and Development (OECD) countries, including Italy, Spain and Turkey. However, Mexico is the country with the greatest total losses, reaching an estimated 5

billion dollars a year by 2030. Countries acutely vulnerable to climate change include a large number of least developed and landlocked developing countries (LDCs and LLDCs), a particular cause for concern from a poverty/development perspective.

THE BROADER CONTEXT

Desertification itself is a serious global concern. The Secretariat of the UN Convention to Combat Desertification has been sounding the alarm on highly damaging changes underway in many of the world’s drylands. They call attention, for instance, to 12 million hectares, including 75 billion tons of fertile soil, a principal global resource, lost each year as a result of desertification and drought (UNCCD, 2010). The extent to which climate change is rendering these regions hotter and drier (or wetter) will be its main, primarily negative, contribution to an already large-scale and multifaceted concern. Aside from climate change, the most widely cited causes of desertification include land-use issues such as deforestation, overcultivation, overgrazing, and unsustainable irrigation practices (Adeel et al, 2005). Natural variability in weather regimes can also result in

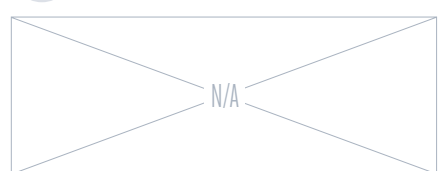
BIGGER PICTURE



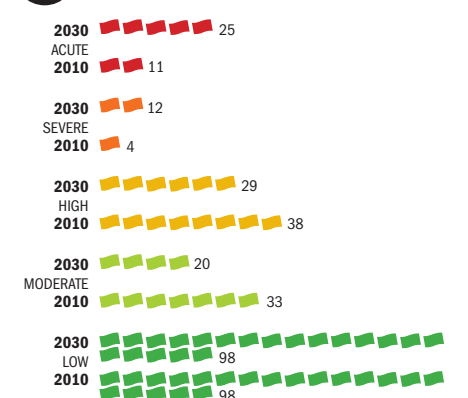
SURGE



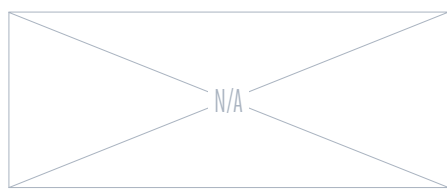
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Hansen et al., 2007
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: FAOSTAT (land investments and gross crops production); Hoekstra et al., 2010; Kindermann et al., 2006; Portmann et al., 2010

= 5 countries (rounded)

large-scale short-term fluctuations in the primary productivity of drylands, both positive and negative (Hughes and Diaz, 2008).

Vulnerabilities and Wider Outcomes Drylands exist around the world. Where they have been well managed, as in parts of southern Europe, they are fertile and productive. Where drylands are poorly managed, the opposite situation can develop as their susceptibility to degradation increases (Oygaard et al., 1999). Given the overwhelming share of populated dryland areas within developing countries and LDCs or LLDCs, the capacity to promote and regulate sound policies can be an important factor in successful management (Esikuri et al., 1999). Poverty can be viewed as a driver of desertification, when communities become locked in a vicious cycle that exacerbates deforestation for lack of alternative livelihoods. It can also be viewed as an outcome of desertification when, for example, households suffer losses of land, soil, or crop productivity due to desertification. As productive possibilities decline and populations in dryland areas continue to grow, these regions will likely expand as suppliers of seasonal and/or permanent migration (Johnson et al. (eds.), 2006). Poverty



and health indicators for populations living in dryland areas are low, compared to other climatic zones (Adeel et al., 2005; Verstraete et al., 2009).

RESPONSES

Supporting dryland communities to adapt will require offsetting the additional heat and/or loss of rainfall brought about by climate change. Degradation prevention is preferable to costly restoration projects that seek to return vegetation and environmental integrity to degraded lands, often with limited results (Puigdefabregas, 1998). Desertification control measures have had little success

and have led experts to propose developmental approaches that foster technology uptake, investment, best practice land management replication, and boosting and diversifying incomes of dryland populations to better cope with change (Mortimore, 2003). Water capture, conservation and storage, increasing vegetation through reforestation, and the control of deforestation, and prevention of overgrazing and other soil-damaging processes can all contribute to enhanced resilience of drylands and their communities (Adeel et al., 2005). Improved monitoring of drylands would also facilitate better macro policy analysis and development (Reynolds et al., 2011).

THE INDICATOR

The indicator measures the value loss (or gain) in rapidly degraded (or improving) dryland agricultural zones resulting from an increase (or decrease) in aridity, due to temperature and rainfall changes brought about through global warming (Hansen et al., 2007). It is broadly indicative of how desertification is likely to unfold as a result of climate change. The amount of new agricultural lands accruing from deforestation is also accounted for. While projections of the key variable of rainfall are uncertain, there scientists are virtually unanimous about the direction of change (wet or dry) for a number of the world's key dryland regions, such as the Mediterranean basin.

ESTIMATES COUNTRY-LEVEL IMPACT

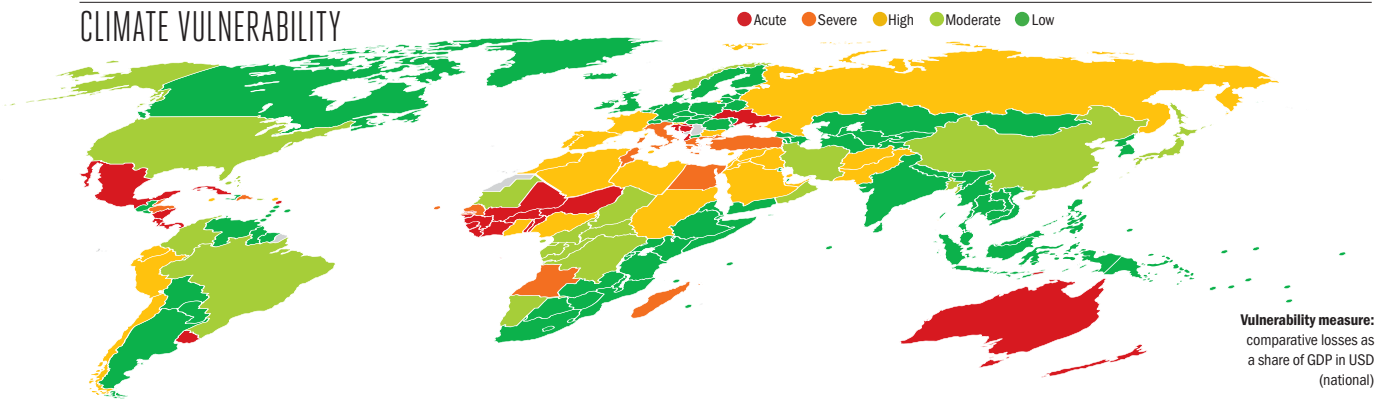
COUNTRY	💰		🌳		👤	
	2010	2030	2010	2030	2010	2030
ACUTE						
Albania ²⁰	100	300	600	35,000	80,000	
Australia	500	1,500	7,000	15,000	20,000	45,000
Benin	15	100	1,500	3,000	100,000	350,000
Bosnia and Herzegovina ⁶⁵	450	1,750	3,250	100,000	250,000	
Burkina Faso	10	50				
Costa Rica	25	200	550	1,250	50,000	150,000
Cote d'Ivoire	15	95				
Croatia	100	800	2,000	3,750	150,000	300,000
Cuba	65	450	1,250	2,500	150,000	250,000
Dominica	1	10	20	35	1,750	3,750
Gambia	1	10				
Guinea	5	30				
Guinea-Bissau	1	5				
Liberia	1	5				
Mali	5	45				
Mexico	600	4,500	10,000	20,000	600,000	1,500,000
New Zealand	150	500	2,750	5,750	45,000	100,000
Nicaragua	15	100	550	1,000	25,000	65,000
Niger	5	30				
Panama	90	700	1,500	3,250	75,000	200,000
Sierra Leone	1	10				
Timor-Leste	25	200	650	1,250	50,000	100,000
Togo	10	45	1,250	2,500	150,000	400,000
Ukraine	450	2,750	9,000	20,000	700,000	1,000,000
Uruguay	20	150	400	800	7,750	15,000
SEVERE						
Angola						

COUNTRY	💰		🌳		👤	
	2010	2030	2010	2030	2010	2030
HIGH						
Afghanistan	5	30	500	1,000	25,000	80,000
Algeria	45	350				
Antigua and Barbuda	1	5	5	750	1,750	
Bahrain	5	25				
Bulgaria	10	80	150	350	10,000	20,000
Chile	40	300	700	1,500	15,000	40,000
Cyprus	5	10	40	85	5,000	10,000
Ecuador	20	150	400	850	25,000	60,000
France	400	1,250	5,250	10,000	600,000	1,500,000
Ghana	10	65	750	1,500	75,000	200,000
Iraq	15	100				
Israel	25	200				
Jamaica	1	20	65	150	15,000	40,000
Jordan	5	30				
Lebanon	5	50				
Libya	15	100				
Malta	1	5	15	30	20,000	45,000
Morocco	30	200	1,250	2,500	85,000	200,000
Nigeria	60	350	4,250	8,500	750,000	2,000,000
Pakistan	70	400	1,500	3,250	350,000	1,000,000
Peru	55	400	1,250	2,250	25,000	65,000
Portugal	30	90	450	900	55,000	100,000
Russia	200	1,250	3,250	6,250	25,000	50,000
Saudi Arabia	75	550				

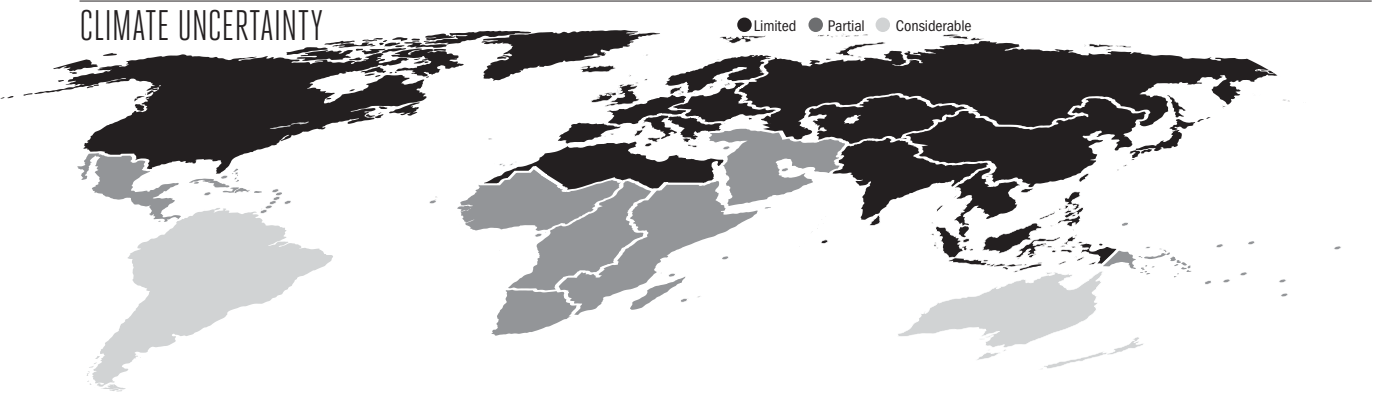
COUNTRY	💰		🌳		👤	
	2010	2030	2010	2030	2010	2030
MODERATE						
Bahamas		1	1	5	70	150
Bangladesh	5	20	150	300	150,000	400,000
Brazil	70	550	2,250	4,500	50,000	100,000
Cameroon	1	10				
Central African Republic	1					
Chad	1	5				
China	75	750	2,000	4,000	300,000	600,000
Colombia	1	10	35	75	1,500	3,750
Congo	1	5				
DR Congo	1	5				
Equatorial Guinea	1	5				
Gabon	1	5				
Iran	1	20	35	70	1,500	4,000
Japan	40	100	500	950	150,000	300,000
Mauritania	1	25	50	85	85	250
Namibia	1	15	25	35	35	95
Norway	1	1	10	20	150	350
Oman						1
Sao Tome and Principe						
United States	200	700	1,750	3,500	55,000	150,000
LOW						
Argentina	-250	-2,000	-3,750	-7,500	-55,000	-150,000
Armenia						
Austria						
Azerbaijan		-1	-5	-10	-600	-1,500
Barbados						



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		€		👤		COUNTRY	\$		€		👤		COUNTRY	\$		€		👤				
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030			
Belarus							Kiribati							Samoa									
Belgium							Kuwait							Seychelles		-1							
Bhutan							Kyrgyzstan							Singapore									
Bolivia							Laos		-1	-15	-30	-400	-1,000	Slovakia									
Botswana		-5		-25			Latvia							Solomon Islands									
Brunei							Lesotho		-1	-15	-30	-1,000	-2,000	Somalia			-1	-5	-20	-75			
Burundi		-1		-1			Lithuania							South Africa		-5	-25	-90	-200	-3,750	-7,000		
Cambodia							Luxembourg							South Korea		-250	-1,750	-2,000	-4,000	-1,000,000	-2,000,000		
Canada		-5		-10		-35	-70	-100	-250					Sri Lanka									
Comoros			-1		-75	-150	-30,000	-90,000						Suriname									
Czech Republic							Malawi		-1		-10			Swaziland		-5	-20	-150	-300	-10,000	-25,000		
Denmark							Malaysia							Sweden									
Djibouti				-1			Maldives							Switzerland									
El Salvador							Marshall Islands							Switzerland									
Eritrea		-1		-1			Mauritius		-5	-40	-90	-200	-55,000	-150,000	Tajikistan								
Estonia							Micronesia								Tanzania			-1	-5	-150	-400		
Ethiopia		-10		-65			Moldova							Thailand		-80	-650	-2,000	-4,000	-250,000	-600,000		
Fiji							Mongolia				-5	-10	-150	-350	Tonga								
Finland		-40		-300		-1,750	-3,500	-650,000	-1,500,000					Trinidad and Tobago									
Georgia							Mozambique					-5	-10	-150	-350	Turkmenistan				-1	-1	-10	
Germany							Myanmar		-5	-35	-650	-1,250	-50,000	-100,000	Tuvalu								
Grenada							Nepal								Uganda		-5		-30				
Guatemala							Netherlands								United Kingdom								
Guyana							North Korea		-1	-10	-100	-200	-20,000	-45,000	Uzbekistan								
Haiti							Palau								Vanuatu								
Hungary							Papua New Guinea								Venezuela								
Iceland							Paraguay								Vietnam		-80	-850	-3,500	-7,250	-950,000	-2,000,000	
India		-40		-300		-1,750	-3,500	-650,000	-1,500,000					Yemen		-1	-1	-30	-55	-1,250	-5,250		
Indonesia		-5		-50		-400	-750	-50,000	-100,000					Zambia		-1		-15					
Ireland							Romania								Zimbabwe		-1		-10				
Kazakhstan		-5		-45		-150	-300	-950	-2,000														
Kenya		-10		-50			Rwanda		-1		-10												
							Saint Lucia																
							Saint Vincent																

👤 Additional persons affected due to climate change - yearly average

HEATING & COOLING

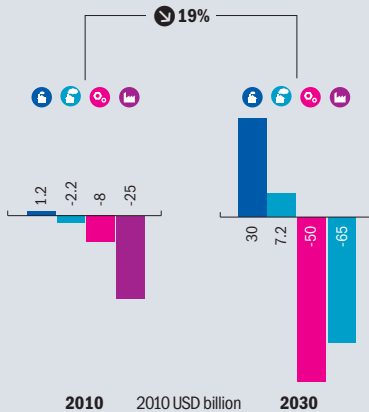


ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY
 USD GAIN PER YEAR
35 BILLION

2030 EFFECT TOMORROW
 USD GAIN PER YEAR
75 BILLION

ECONOMIC IMPACT



CONFIDENCE ROBUST

SEVERITY

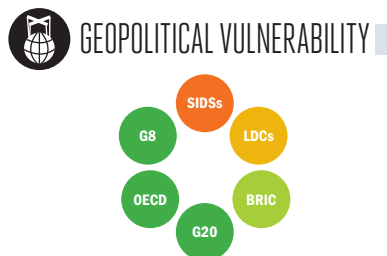
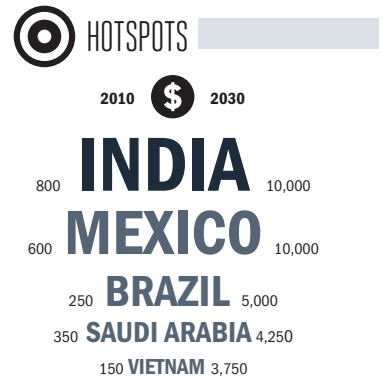
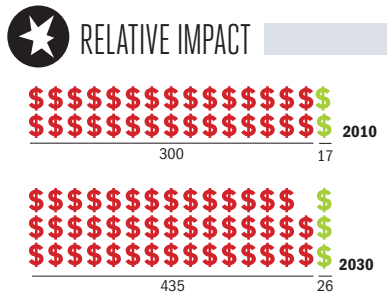
AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

- The most certain outcome of global warming is rising heat
- As heat goes up, heating costs decrease and air conditioning costs rise
- In the cooler north, heating especially is mandatory and widespread, but in tropical zones, artificial cooling is not always a necessity
- Currently, the impact of rising heat on indoor space conditioning is a positive effect of climate change globally, as cost reductions in cooler countries outweigh cost increases in hotter countries
- Tropical countries still incur serious losses, and in the longer term, if climate change is not controlled, high cooling costs will overtake reductions in heating costs



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **ii** Developed
iii Developing Country High Emitters **iv** Other Industrialized

★ \$ = Losses per 100,000 USD of GDP
↻ Change in relation to overall global population and/or GDP

◎ \$ = Millions of USD (2010 PPP non-discounted)

The heating and cooling of residential and non-residential indoor spaces are among the largest energy consumers globally (WRI, 2009). Energy demand for heating is currently ten times higher than for cooling (Isaac and van Vuuren, 2008). As a result, temperature rise is presently generating a net economic benefit for the world economy, since the lowering of heating costs due to milder winters or fewer cold days is more significant than any increase in air conditioning costs (Hansen et al., 2012). However, if climate change continues to the end of the century, rising heat and increased air conditioning demand in developing countries would generate net losses for the world (Isaac and van Vuuren, 2009). Today, the increasing costs faced by middle and lower income countries in tropical regions can represent a significant negative economic impact at a national level. As a result, cooler countries are seeing declining emissions or less growth in emissions at national levels, enabling them to better meet GHG reduction targets. In hotter countries, however, GHG emissions will be artificially inflated, making it more difficult to reduce them. In fact,

meeting the rapidly growing demand for air-conditioning as incomes expand in developing countries is a significant challenge without climate change. Not meeting the challenge, including with climate change, will curtail the economic development and welfare of many lower and middle-income countries, for example through reduced productivity and greater exposure to heat related health risks (Kjellstrom et al., 2009; Akpınar-Ferrand and Singh, 2010).

CLIMATE MECHANISM

The planet's warming is virtually certain, resulting in more hot and fewer cold days and nights (IPCC, 2007). On average, winters are becoming shorter and milder, summers longer and hotter. Areas that rely on heating indoor space to maintain comfortable temperature levels will increasingly need less energy in a year as the cold wanes. On the other hand, areas that can benefit from year-round or seasonal air-conditioning to bring down indoor temperatures to comfortable levels will increasingly need more energy to maintain these levels as temperatures climb. Many industrialized countries will see benefits from reduced winter

heating needs, however many of those same countries will also experience increased cooling needs (Miller et al., 2008). In the sub-tropics and tropics where most of the world's population resides, greater cooling costs far outweigh any heating fluctuations (Isaac and van Vuuren, 2008).

IMPACTS

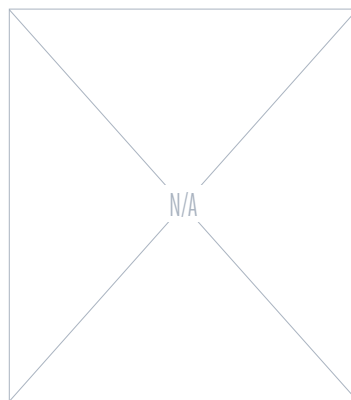
The global impact of climate change on heating and cooling is currently estimated to benefit the global economy by more than 30 billion dollars each year. By 2030, the costs of heating and cooling are estimated to decline slightly as a share of global GDP, but reach over 70 billion dollars. This is a signal of what lies ahead, as increased demand for cooling will gradually overtake any benefits from lower heating costs. In 2010, national losses amounted to some 5 billion dollars a year in additional costs, whereas gains in countries benefitting from lower heating costs amounted to 40 billion dollars a year. By 2030, annual losses are estimated to be over 70 billion dollars and gains at 150 billion dollars. Countries with the largest losses in 2030 are India and Mexico, each

with over 10 billion in annual costs. The largest gains are in the United Kingdom, Russia, China, and Germany, with benefits ranging from 10 to 20 billion dollars or more each year. Least developed and lower-income countries in Africa, Central America, the Caribbean, and the Pacific are particularly negatively impacted, with losses reaching from 0.5-1% of GDP by 2030.

THE BROADER CONTEXT

Energy demand for both heating and cooling is growing almost everywhere. Global demand for heating is expected to peak around 2030, while demand for cooling will continue to expand throughout the 21st century as incomes grow in tropical and sub-tropical developing countries (Isaac and van Vuuren, 2008). These increases and decreases would occur without climate change, since energy efficiencies are being realized in cooler countries where markets for heating and cooling equipment are saturated and population growth is slow or declining (UNECE, 2012). In developing countries air conditioning demand is far from saturated and is expected to increase rapidly as incomes rise and

BIGGER PICTURE



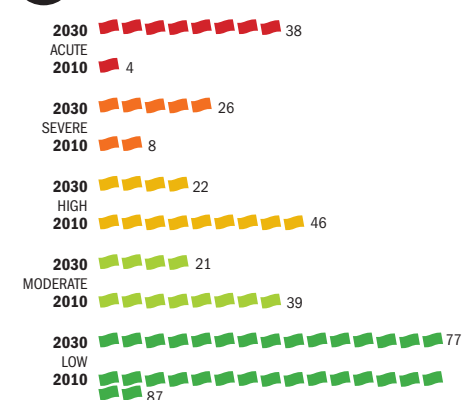
SURGE



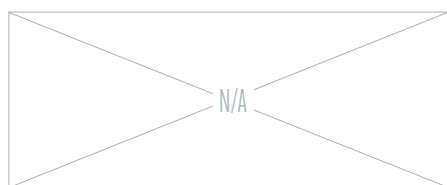
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Isaac et al., 2008
 EMISSION SCENARIO: TIMER/IMAGE reference scenario for the ADAM project (Isaac et al., 2008)
 BASE DATA: Baumert et al., 2003; Electricity price EIA 2010; Perez-Lombard et al., 2007; UNECE (2012); Zmeureanu and Renaud, 2009

➡ = 5 countries (rounded)

populations grow. Urban heat islands, growing in many places as a concern parallel to these other factors, are also exacerbating energy requirements (Kolokotroni et al., 2010; Memon et al., 2011).

VULNERABILITIES AND WIDER OUTCOMES

The world's hottest countries are most vulnerable to the impacts of climate change, since they already rely heavily on air-conditioning. Africa, Asia and the equatorial zones are particularly exposed since large populations and significant amounts of economic activity are located in warm zones.

If rising heat is not compensated by additional cooling that maintains at least the same level and progress in indoor climate control, economic productivity will fall more or less predictably (Kjellstrom et al., 2009a). Human welfare will be significantly affected through additional, serious impacts to human health from cardiovascular and chronic respiratory illnesses over and above what is already noted in the Health Impact section of this report (McMichael et al., 2006). As is highlighted in this report's Ghana

country study, people in the lowest-income communities are more likely to sleep outdoors on the hottest nights, increasing exposure to mosquito bites during peak vector activity periods (dusk and dawn) and promoting higher transmission rates of malaria. Heat stress also affects cognitive performance, mental stress, and depression among other psychological effects (Hancock et al., 2003; Hansen et al., 2008).

RESPONSES

Increases in heat are often offset by increased energy consumption on the part of those who can afford it, but at an additional energy cost. For those who cannot, social and economic welfare will be compromised by productivity and health effects, although it is unclear how the economic costs of lost productivity might compare with extra cooling costs (Yardley et al., 2011; Kjellstrom et al., 2009b). Since solutions for indoor space cooling are technically possible in many cases, international responses could focus on ensuring adequate indoor cooling for lower-income communities unable to do so at will, particularly in areas with high risk for malaria and vector-borne

disease. Improving building insulation and energy efficiency in the tropics (not only in cold countries) to protect against heat (not only cold) would be an important, lower-emission option for adapting to the growing heat (Akpınar-Ferrand and Singh, 2010). Heating and cooling is a clear example of a dual-focus adaptation-mitigation response area. Any mitigation project that ensures provision of cooling-related technologies to affected communities would also constitute an adaptation action. In terms of practical steps, increasing local shade-tree cover can have a positive effect on cooling buildings (Donovan and Butry, 2009). Cities could take greater advantage of the geothermal energy created as a result of the heat island effect to supply energy for cooling, since cities also heat the ground below, not only the air above. The potential energy supply has been estimated to exceed cooling demand requirements in several major cities (Zhu et al., 2010).

THE INDICATOR

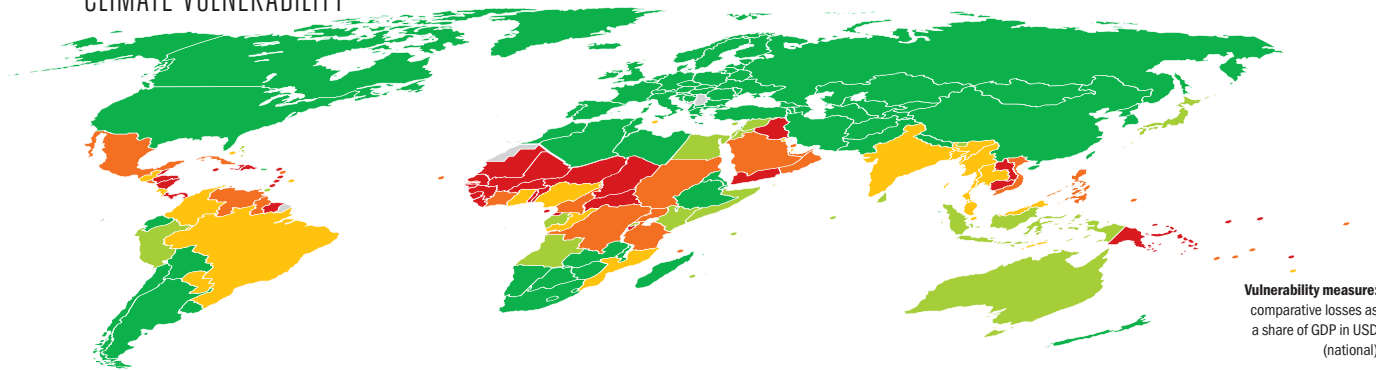
The indicator maps residential/non-residential heating demand changes. It is considered robust, given the certainty of the climate science community and model convergence on the main parameter of increasing heat, although humidity levels are also important (Wang et al., 2010). High quality energy consumption data gives a reasonable indication of the phenomenon's scale, but relies on the concept of heating and cooling degree-days, which are not fully accurate in terms of all demands, since wind, cloud cover, and humidity strongly influence heating and cooling behaviour (Baumert and Selman, 2003). While the same optimal temperature is assumed for different countries, it is argued that the optimal temperature varies by region, climate, and other conditions (Dear and Brager, 1998). Though the Indicator considers several dynamic variables, floor space size changes over time are not, though are understood to have a significant impact on future energy requirement estimates (Isaac et al., 2008; Clune et al., 2012).

COUNTRY	2010		2030		COUNTRY	2010		2030		COUNTRY	2010		2030	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
ACUTE					SEVERE					HIGH				
Antigua and Barbuda	1	25	15	65	Senegal	30	250	200	550	Venezuela	200	3,000	1,500	6,250
Belize	1	30	15	55	Sierra Leone	10	75	65	150	Vietnam	150	3,750	1,500	6,000
Benin	15	150	100	300	Solomon Islands	1	25	15	65					
Burkina Faso	45	400	250	600	Suriname	5	50	25	100	Bahamas	1	30	20	80
Burundi	5	55	60	150	Togo	10	85	70	200	Bangladesh	45	650	950	3,500
Cambodia	25	500	200	850	Tuvalu			1	1	Barbados	1	30	20	80
Central African Republic	5	55	40	100	Yemen	200	2,250	1,500	4,750	Brazil	250	5,000	1,500	7,500
Chad	45	350	150	350				1,000	3,250	Brunei	5	50	25	100
Dominican Republic	65	950	450	1,750	SEVERE					Colombia	-40	1,250	-300	2,500
Equatorial Guinea	25	200	150	400	Bahrain	15	200	100	400	Congo	5	60	50	100
Grenada	1	15	10	40	Cameroon	35	300	250	650	Costa Rica	10	150	100	400
Guinea	15	100	95	250	Cape Verde	1	10	5	15	Ghana	30	250	350	900
Guinea-Bissau	1	20	15	45	Comoros	1	5	5	20	Guatemala	5	150	30	300
Haiti	35	500	250	950	Cote d'Ivoire	35	300	300	750	India	800	10,000	15,000	65,000
Honduras	25	400	200	750	Cuba	55	850	550	2,250	Kuwait	55	650	400	1,500
Iraq	100	1,500	750	3,000	Dominica	1	10	5	25	Malaysia	65	1,000	550	2,250
Jamaica	20	300	200	750	DR Congo	15	150	400	1,000	Malta	1	10	15	30
Laos	10	250	100	400	El Salvador	20	300	150	600	Mozambique	10	90	150	400
Liberia	5	50	40	100	Fiji	1	35	20	90	Nigeria	85	700	2,500	6,250
Mali	30	250	200	550	Gambia	5	25	20	60	Paraguay	5	150	90	500
Marshall Islands		5	1	10	Guyana	5	50	25	100	Qatar	40	500	300	1,000
Mauritania	10	70	60	150	Kiribati		5	5	15	Singapore	60	1,000	300	1,250
Micronesia	1	5	5	15	Mexico	600	10,000	6,250	30,000	Thailand	200	3,000	2,000	8,500
Myanmar	75	1,250	650	2,750	Oman	45	550	350	1,250	Timor-Leste	1	10	5	20
Nicaragua	30	500	200	750	Palau		1	1	5					
Niger	30	250	200	550	Philippines	200	3,000	1,500	6,500	MODERATE				
Panama	30	500	200	750	Samoa	1	10	5	25	Angola	15	150	95	350
Papua New Guinea	20	350	200	900	Saudi Arabia	350	4,250	2,500	9,000	Australia	150	550	1,750	4,000
Saint Lucia	1	25	15	65	Sudan/South Sudan	80	750	750	2,000	Bhutan		1	-1	15
Saint Vincent	1	15	10	35	Tanzania	40	350	450	1,250	Cyprus	1	15	5	65
Sao Tome and Principe	1	1	5	1	Uganda	40	300	150	450	Djibouti	-1	1	-5	1
					United Arab Emirates	150	2,000	1,250	4,250	Egypt	-150	200	-1,250	550
					Vanuatu	1	10	5	25					



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as a share of GDP in USD (national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	\$		⚡		🌍		COUNTRY	\$		⚡		🌍		COUNTRY	\$		⚡		🌍	
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030
Gabon	5	35	30	70	5	15	Croatia	-75	-450	-700	-1,250	-250	-400	Nepal	-15	-80	-250	-450	-1	-1
Indonesia	150	1,750	2,250	7,000	1,750	5,750	Czech Republic	-700	-4,250	-3,500	-6,500	-2,500	-4,750	Netherlands	-1,250	-3,500	-5,250	-9,500	-2,500	-4,500
Israel	5	150	55	400	45	300	Denmark	-900	-2,500	-2,250	-4,000	-1,250	-2,500	New Zealand	-65	-200	-400	-750	-65	-150
Japan	250	750	1,250	2,500	550	1,000	Ecuador	-30	-10	-350	-20	-95	-5	North Korea	-150	-1,250	-1,250	-2,250	-650	-1,250
Jordan	-5	45	-50	95	-30	55	Eritrea	-20	-100	-150	-300	-100	-200	Norway	-350	-1,000	-2,250	-4,250	-35	-65
Kenya	-10	15	-60	35	-25	15	Estonia	-40	-250	-150	-300	-150	-300	Pakistan	-65	-75	-1,500	-400	-700	-200
Maldives		5	-1	25	-1	20	Ethiopia	-35	-200	-900	-1,500	-100	-150	Poland	-1,250	-8,250	-6,750	-10,000	-7,000	-15,000
Mauritius	1	20	20	45	10	30	Finland	-550	-1,500	-3,000	-5,500	-1,000	-1,750	Portugal	-150	-400	-700	-1,250	-300	-550
Peru	5	450	35	900	10	200	France	-2,250	-6,250	-15,000	-25,000	-1,250	-2,000	Romania	-200	-1,250	-1,750	-3,250	-1,000	-2,000
Rwanda	-1	5	-15	10	-5	1	Georgia	-1	-5	-5	-10	-1	-1	Russia	-2,250	-15,000	-20,000	-45,000	-15,000	-25,000
Seychelles		1	5	10	1	5	Germany	-8,000	-20,000	-30,000	-55,000	-15,000	-30,000	Slovakia	-300	-1,750	-1,250	-2,500	-400	-750
Somalia	-1	1	-10	5	-5	1	Greece	-25	-45	-250	-250	-200	-200	Slovenia	-100	-650	-550	-1,000	-200	-400
Sri Lanka	5	100	150	600	70	300	Hungary	-350	-2,250	-1,500	-2,750	-750	-1,250	South Africa	-200	-1,000	-3,250	-5,500	-3,000	-5,250
Syria	-25	55	-200	100	-100	70	Iceland	-40	-100	-150	-300			South Korea	-150	-1,250	-1,750	-3,500	-950	-2,000
Trinidad and Tobago	1	40	100	400	75	300	Iran	-100	-350	-2,000	-2,000	-1,250	-1,250	Spain	-500	-1,250	-2,500	-4,000	-800	-1,250
LOW							Ireland	-300	-850	-1,250	-2,000	-500	-900	Swaziland	-1	-15	-30	-50	-1	-1
Afghanistan	-30	-150	-650	-800	-150	-200	Italy	-2,000	-5,250	-6,500	-10,000	-3,250	-5,750	Sweden	-1,250	-3,250	-5,000	-9,000	-150	-300
Albania	-20	-100	-95	-150	-1	-1	Kazakhstan	-150	-850	-2,500	-4,750	-2,500	-5,000	Switzerland	-400	-1,250	-2,750	-5,000	-20	-30
Algeria	-300	-1,750	-3,000	-4,500	-1,750	-2,750	Kyrgyzstan	-10	-75	-250	-400	-20	-40	Tajikistan	-5	-15	-95	-90	-1	-1
Argentina	-65	-350	-3,000	-3,750	-1,000	-1,500	Latvia	-150	-950	-600	-1,000	-100	-200	Tunisia	-100	-550	-1,000	-1,500	-600	-850
Armenia	-25	-150	-200	-300	-20	-40	Lebanon	-10	-15	-85	-30	-65	-20	Turkey	-550	-1,250	-3,250	-5,250	-1,750	-2,750
Austria	-500	-1,500	-2,500	-4,750	-450	-850	Lesotho	-1	-10	-20	-35			Turkmenistan	-5	-25	-100	-150	-100	-100
Azerbaijan	-35	-200	-250	-400	-150	-250	Libya	-55	-200	-500	-450	-500	-450	Ukraine	-1,250	-8,000	-6,250	-15,000	-3,000	-5,750
Belarus	-350	-2,250	-1,750	-3,500	-1,500	-2,750	Lithuania	-300	-1,750	-1,250	-2,000	-950	-1,750	United Kingdom	-4,250	-10,000	-20,000	-35,000	-9,000	-15,000
Belgium	-600	-1,750	-3,000	-5,250	-700	-1,250	Luxembourg	-35	-100	-150	-300	-70	-150	United States	-650	-1,000	-5,750	-5,750	-3,500	-3,500
Bolivia	-100	-800	-900	-1,750	-350	-650	Macedonia	-40	-250	-200	-350	-200	-300	Uruguay	-40	-200	-250	-300	-60	-85
Bosnia and Herzegovina	-85	-500	-450	-800	-350	-600	Madagascar	-40	-150	-150	-200	-50	-60	Uzbekistan	-40	-150	-750	-850	-500	-550
Botswana	-5	-30	-70	-100	-90	-150	Malawi	-1	-10	-80	-100	-10	-10	Zambia	-1	-5	-55	-45		
Bulgaria	-250	-1,500	-1,250	-2,250	-800	-1,500	Moldova	-65	-450	-350	-650	-250	-500	Zimbabwe	-30	-150	-250	-400	-150	-250
Canada	-550	-1,500	-6,750	-15,000	-1,250	-2,250	Mongolia	-40	-450	-350	-750	-500	-1,000							
Chile	-400	-2,750	-2,000	-3,750	-850	-1,500	Morocco	-200	-1,000	-1,750	-2,500	-1,250	-1,750							
China	-2,750	-20,000	-60,000	-80,000	-50,000	-65,000	Namibia	-15	-70	-100	-200	-25	-40							

LABOUR PRODUCTIVITY

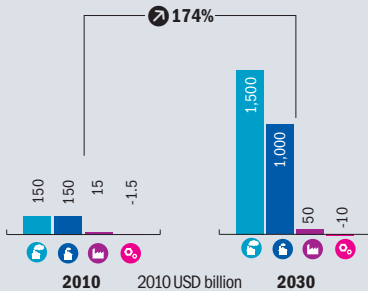


ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY
 USD LOSS PER YEAR **300** BILLION

2030 EFFECT TOMORROW
 USD LOSS PER YEAR **2.5** TRILLION

ECONOMIC IMPACT



- People work less productively in hot conditions
- As the workplace warms, occupational heat exposure standards defined by the International Organization for Standardization (ISO) and other bodies are being breached
- Heat stress affects employees working outdoors or in non-cooled environments, except for the coldest and highest-altitude areas
- Effects are most serious for subsistence farmers in developing countries who cannot avoid daytime outdoor work
- Adapting to these changes can be cost-effective, such as through sun protection measures, but the full extent of adaptation is not well studied and could be extremely limited, especially for outdoor workers
- For indoor situations, air conditioning or insulation would need to be increased, but equally incur a cost

★ RELATIVE IMPACT



🎯 HOTSPOTS



🌐 GEOPOLITICAL VULNERABILITY



💰 Economic Cost (2010 PPP non-discounted)
 🇨🇳 Developing Country Low Emitters 🇺🇸 Developed
 🇨🇳 Developing Country High Emitters 🇨🇳 Other Industrialized

★ 💰 = Losses per 10,000 USD of GDP
 🎯 💰 = Billions of USD (2010 PPP non-discounted)
 🔄 Change in relation to overall global population and/or GDP

🎯 💰 = Billions of USD (2010 PPP non-discounted)

Labour productivity is one of the principal factors in contemporary economics, and a generalized loss of productivity results in economic loss (Samuelson and Nordhaus, 1948; Solow, 1956). Workers are less efficient and less productive when subjected to excess heat both outdoors and in inadequately climate-controlled working conditions (Ramsey, 1995; Pilcher et al., 2002; Niemelä et al., 2002; Hancock et al., 2007; Su et al., 2009). International ergonomic standards define highly specific thermal conditions for differing degrees of occupational exertion and stipulate clear threshold limits (ISO, 1989). Similar national standards are effective since the mid-1980s (NIOSH, 1986). Precise directives for personnel heat stress management are also imbedded in military operational guidelines, since it may affect combat outcomes (USDAAF, 2003). Science is more certain about the warming of the planet than any other aspect of climate change (IPCC, 2007). As the increase in hot days and hot nights continues, worker heat stress has the potential to become a significant drain on the world economy (Hansen et al., 2012; Kjellstrom et al., 2009a). Adapting to

labour productivity impacts is costly, but not doing so will result in further costs through deteriorating health, cooling costs, or slower gains in competitiveness (Hanna et al., 2011a; CDC, 2008; Kjellstrom et al., 2009). Thus, incentives to adapt are high, but may be out of reach for three-quarters of the world's developing poor, who live in rural areas with few options (Kjellstrom et al., 2009b; Ravallion et al., 2007).

CLIMATE MECHANISM

As the planet warms, thresholds regulated in international and national occupational standards are increasingly surpassed. Unless measures are taken, more hours of work will be needed to accomplish the same tasks, or more workers to achieve the same output (Kjellstrom et al., 2009a-b). Thermally optimal working conditions increase productivity (Fisk, 2000). Incremental increases in temperature are well understood, with business-as-usual economic development set to raise the average temperature by 3°C (5°F) above today's levels in 50–60 years (Betts et al., 2009). An additional 4°C (7°F) above that level—not ruled out for this

century—would make outdoor activities of any kind impossible in large tropical areas of human habitation (Sokolov et al., 2009; Sherwood and Huber, 2010).

IMPACTS

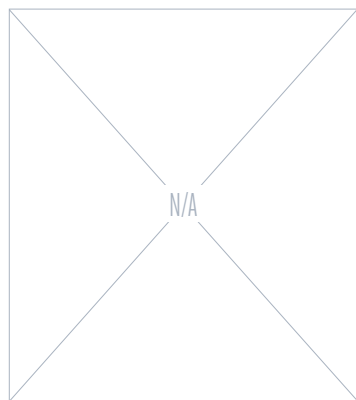
The global impact of climate change on labour productivity is already estimated to cost the world economy 300 billion dollars a year—around 0.5% of global GDP. It is overwhelmingly the single most significant negative impact included in this assessment. Hot and humid tropical and sub-tropical countries of Africa, Asia, Latin America, and the Pacific are already severely affected. The greatest total losses affect the world's major emerging economies: China, India, Indonesia, and Mexico, whose development due to labour productivity set-backs alone could be impeded by more than 200 billion dollars a year by 2030, when China and India's annual losses could approach half a trillion dollars each. Approximately 0.6°C (1°F) of heat absorbed by the world's oceans will be released back into the atmosphere in the coming decades, effectively committing the world to a labour productivity loss estimated to reach

2.5 trillion dollars a year by 2030, stunting global GDP by over 1% (Hansen et al., 2005). Parts of West and Central Africa may even have 6% lower levels of GDP by 2030. Comparatively few people in colder zones of the planet, such as Australia and the United States, are expected to reap a modest gain in productivity: 3 billion dollars in 2010 and 18 billion dollars in 2030. The skewed workforce structure of developed economies, heavily reliant on low-exertion indoor work reduces vulnerability. However, numerous studies also indicate concern for exposed workers in developed countries (Graff Zivan and Neidell, 2011; Hanna et al., 2011a; Hübler et al., 2007).

THE BROADER CONTEXT

Labour productivity drives profitability and higher living standards (Ingene et al., 2010). Labour productivity is surging almost everywhere, even in the world's wealthiest and slowest growing economies (Jorgenson and Vu, 2011; OECD, 2012). Comparisons of labour productivity growth between the US (faster) and Europe (slower) have shown the importance of information technology (IT) as a positive driver (Ark

BIGGER PICTURE



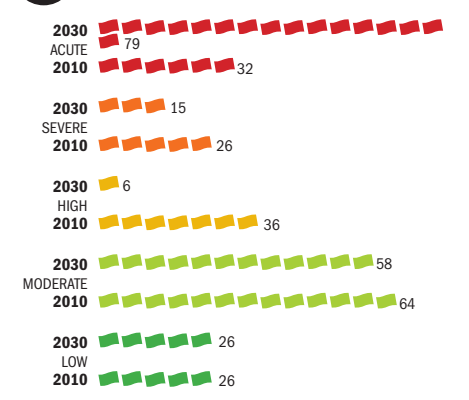
SURGE



OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Euskirchen, 2006; Kjellstrom et al., 2009
 EMISSION SCENARIO: SRES A2 (IPCC, 2000)
 BASE DATA: Kjellstrom et al., 2009

➡ = 5 countries (rounded)

et al., 2008; Holman et al., 2008). Above all, climate change is limiting the productivity potential otherwise achievable by developing countries, as they make structural shifts in workforce employment towards higher productivity economic sectors (Kjellstrom et al., 2009a; McMillan and Rodrik, 2012).

VULNERABILITIES AND WIDER OUTCOMES

Geographical and structural vulnerabilities are determined by levels of income or human development. Geography is important since only the coldest zones experience gains, while the hottest ones approach the limits of physiological habitability (Sherwood and Huber, 2010). Structurally, economies with mostly outdoor workers are particularly vulnerable, as are economies with slower industrialization rates and few climate controlled workspaces—middle and low-income countries (Kjellstrom et al., 2009d). Some evidence indicates that women are less resistant to heat stress, while men are more exposed, due to the proportion of men in heavy, outdoor work (Luecke, 2006; ILO, 2011). Subsistence farmers typically

inhabit geographically vulnerable regions and would need to commit to higher levels of activity in order to deliver equal output; however, since they need to see the land, displacing their working shifts into the cooler night hours is impossible (Kjellstrom et al., 2009). This raises food security concerns. Nutrition can compound matters by contributing to, or detracting from, labour productivity (Maturu, 1979).

RESPONSES

Six key strategy and measurement areas for adapting to growing thermal stress on the workforce follow:

1. Education and awareness campaigns directed at behavioural change of employees and workers to drink water (hydrate) and minimize sun exposure; e.g., municipal initiatives to increase tree cover and shade, or movable screens (McKinnon and Utley, 2005);
2. Strengthened labour institutions, guidelines, protection, regulations, and labour market policies for workers (Crowe et al. 2010; ILO, 2011);
3. Climate control to increase use of air conditioning or building insulation systems, assisting some indoor

workers; not all indoor workplaces can be adequately cooled;

4. Gaining productivity by expanding use of IT, improving capital equipment, or modernizing agricultural technology (Storm and Naastepad, 2009; Wacker et al., 2006; Restuccia et al., 2004);
5. Fiscal and regulatory intervention to stimulate a faster structural transition of the economy away from outdoor labour; e.g., coordinating industrial systems or transitioning from natural resource-intensive growth plans that detract from macroeconomic productivity gains (Storm and Naastepad, 2009; McMillan and Rodrik, 2012);
6. Promotion of individual health to improve body thermal responses (Chan et al., 2012).

THE INDICATOR

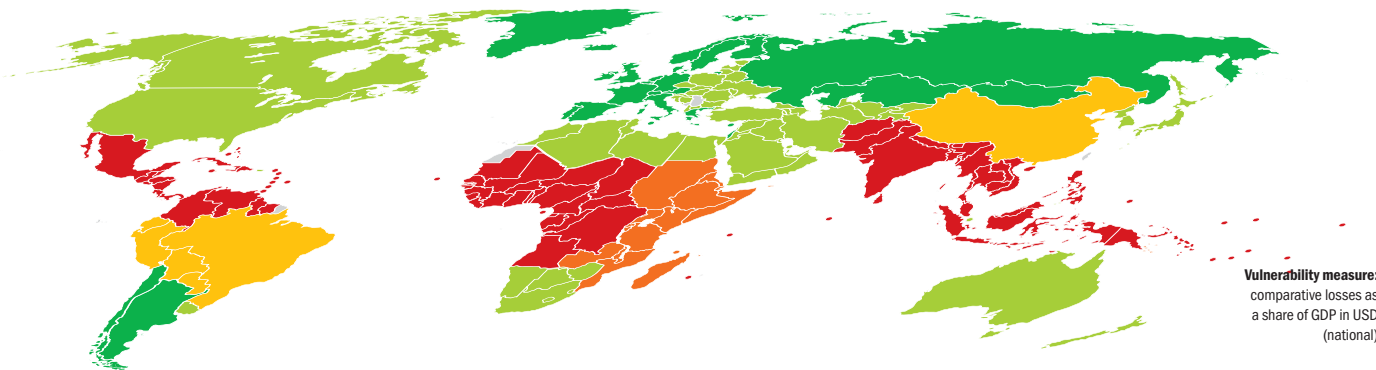
Certainty about increasing temperature, the main climate variable at play, contributes to the robustness of the indicator, although humidity levels are another important determinant of thermal stress and are less certain (Wang et al., 2010). The indicator relies on a global/sub-regional scale model for estimating the loss of labour productivity, based on international labour standards and estimates of wet bulb globe temperature (WBGT) change for populations assumed to be acclimatized (Kjellstrom et al., 2009a). It takes into account both the productivity of outdoor and indoor workers, although the heaviest forms of labour are not considered. The changing structure of the workforce over time, in particular, the industrial shift of developing countries away from outdoor agriculture is also factored in. Productivity gains to countries in high latitudes that will experience a reduction in extreme cold were also accounted for, over and above the base model (Euskirchen et al., 2006).

COUNTRY	\$		👤		COUNTRY	\$		👤		COUNTRY	\$		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
ACUTE					Guinea	350	2,000	57%	47%	Sao Tome and Principe	10	60	58%	47%
Afghanistan	350	3,000	29%	23%	Guinea-Bissau	55	350	55%	45%	Senegal	700	4,750	57%	48%
Angola	2,500	15,000	52%	43%	Guyana	80	600	37%	29%	Seychelles	60	400	45%	35%
Antigua and Barbuda	25	200	49%	38%	Haiti	150	1,250	41%	32%	Sierra Leone	150	900	54%	44%
Bahamas	150	1,250	44%	35%	Honduras	750	5,750	40%	31%	Solomon Islands	30	250	30%	21%
Bangladesh	3,500	30,000	44%	34%	India	55,000	450,000	35%	27%	Sri Lanka	3,000	25,000	33%	26%
Barbados	90	700	45%	35%	Indonesia	30,000	250,000	40%	31%	Suriname	70	500	33%	25%
Belize	40	300	41%	32%	Jamaica	350	2,500	39%	30%	Thailand	15,000	150,000	45%	35%
Benin	400	2,750	59%	48%	Kiribati	10	90	33%	23%	Timor-Leste	90	750	35%	27%
Bhutan	55	400	44%	34%	Laos	450	4,750	49%	38%	Togo	200	1,250	61%	50%
Burkina Faso	600	4,000	67%	54%	Liberia	50	350	48%	39%	Tonga	15	100	33%	23%
Cambodia	900	9,250	52%	40%	Malaysia	10,000	95,000	37%	29%	Trinidad and Tobago	400	3,000	43%	34%
Cameroon	1,250	8,750	55%	45%	Maldives	75	550	37%	28%	Tuvalu	1	5	33%	23%
Cape Verde	60	400	50%	41%	Mali	500	3,250	40%	32%	Vanuatu	20	150	33%	23%
Central African Republic	75	500	59%	48%	Marshall Islands	5	45	33%	23%	Venezuela	8,000	60,000	41%	32%
Chad	550	3,750	55%	45%	Mauritania	200	1,250	30%	24%	Vietnam	8,000	85,000	48%	37%
Colombia	9,750	75,000	40%	31%	Mauritius	550	3,500	35%	27%	SEVERE				
Congo	350	2,500	53%	43%	Mexico	35,000	250,000	39%	30%	Burundi	35	250	61%	50%
Costa Rica	1,250	9,000	40%	31%	Micronesia	10	90	33%	23%	Comoros	10	55	43%	35%
Cote d'Ivoire	1,000	7,250	53%	43%	Myanmar	2,250	15,000	48%	37%	Djibouti	20	150	56%	46%
Cuba	1,750	15,000	38%	30%	Nepal	500	3,750	53%	41%	Eritrea	40	250	62%	51%
Dominica	15	100	49%	38%	Nicaragua	400	3,000	40%	31%	Ethiopia	950	6,000	64%	52%
Dominican Republic	1,250	9,500	38%	30%	Niger	350	2,250	50%	41%	Kenya	700	4,750	48%	39%
DR Congo	500	3,250	54%	44%	Nigeria	10,000	75,000	42%	34%	Madagascar	200	1,250	67%	55%
El Salvador	950	7,500	38%	30%	Pakistan	6,500	50,000	33%	25%	Malawi	150	900	61%	50%
Equatorial Guinea	500	3,250	65%	53%	Palau	5	25	33%	23%	Mozambique	250	1,500	63%	51%
Fiji	75	600	27%	18%	Panama	1,000	7,750	41%	32%	Rwanda	150	850	68%	55%
Gabon	500	3,250	41%	33%	Papua New Guinea	300	2,250	33%	23%	Somalia	65	400	42%	34%
Gambia	100	700	59%	48%	Philippines	10,000	85,000	38%	29%	Sudan/South Sudan	1,000	7,500	39%	32%
Ghana	2,000	15,000	55%	45%	Saint Lucia	30	250	49%	38%	Tanzania	650	4,000	63%	51%
Grenada	20	150	49%	38%	Saint Vincent	20	150	49%	38%	Uganda	450	3,000	60%	48%
Guatemala	1,500	10,000	44%	34%	Samoa	20	150	33%	23%	Zambia	200	1,500	54%	43%



CLIMATE VULNERABILITY

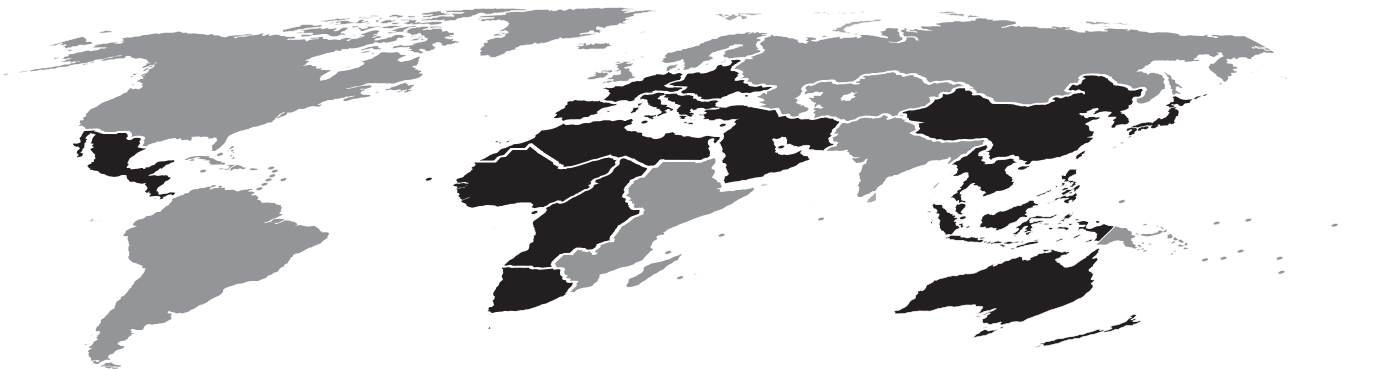
● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	\$		i		COUNTRY	\$		i		COUNTRY	\$		i	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
HIGH					Latvia	5	25	5%	5%	Yemen	20	150	20%	13%
Bolivia	200	1,750	46%	36%	Lebanon	25	150	20%	13%	Zimbabwe	25	150	69%	56%
Brazil	6,000	45,000	43%	34%	Lesotho	5	50	39%	32%	LOW				
China	40,000	450,000	36%	25%	Libya	40	250	23%	16%	Argentina				
Ecuador	500	4,000	43%	33%	Lithuania	5	45	5%	5%					
Paraguay	90	700	46%	36%	Macedonia	1	5	4%	4%					
Peru	1,250	9,500	48%	37%	Moldova	1	10	4%	4%					
MODERATE					Morocco	65	450	21%	14%					
Albania	1	5	5%	5%	Namibia	30	200	33%	27%					
Algeria	100	750	18%	12%	New Zealand	5	15	6%	6%					
Armenia	5	40	25%	19%	North Korea	90	900	37%	26%					
Australia	45	100	6%	6%	Oman	25	150	26%	18%					
Azerbaijan	35	200	36%	27%	Poland	15	100	5%	5%					
Bahrain	10	60	31%	21%	Qatar	65	450	40%	27%					
Belarus	15	95	5%	5%	Romania	5	40	5%	5%					
Bosnia and Herzegovina	1	5	4%	4%	Saudi Arabia	200	1,250	22%	15%					
Botswana	60	400	53%	43%	Singapore	25	200	6%	6%					
Brunei	1	15	6%	6%	Slovakia	1	20	5%	5%					
Bulgaria	1	15	5%	5%	Slovenia	1	10	5%	5%					
Canada	300	950	7%	7%	South Africa	1,250	7,250	32%	27%					
Croatia	1	15	5%	5%	South Korea	150	1,000	6%	6%					
Czech Republic	5	40	5%	5%	Swaziland	15	85	36%	30%					
Egypt	200	1,000	21%	14%	Syria	35	200	18%	12%					
Estonia	5	20	5%	5%	Tajikistan	5	25	35%	26%					
Georgia	10	60	32%	24%	Tunisia	40	250	19%	13%					
Hungary	5	30	5%	5%	Turkey	400	1,250	20%	14%					
Iran	400	2,750	19%	13%	Turkmenistan	15	90	32%	24%					
Iraq	30	250	16%	11%	Ukraine	30	200	5%	5%					
Japan	400	1,000	6%	6%	United Arab Emirates	95	600	36%	24%					
Jordan	10	70	17%	12%	United States	15,000	50,000	6%	6%					
Kuwait	55	350	31%	21%	Uruguay	10	75	41%	32%					
Kyrgyzstan	5	25	36%	27%	Uzbekistan	25	150	32%	24%					

i Share of workforce particularly affected by climate change (%) - yearly average

PERMAFROST



ESTIMATES GLOBAL CLIMATE IMPACT

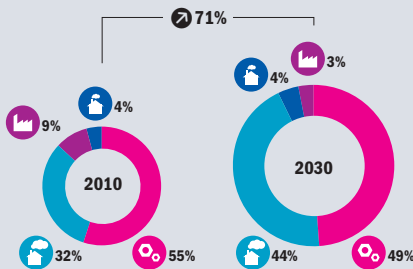
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **30** BILLION

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **150** BILLION

ECONOMIC IMPACT



- One-quarter of the northern hemisphere's land is permanently frozen or frozen for extended periods
- The planet's warming has been most rapid in the far north, where rising heat simply melts permanently frozen land
- Infrastructure of every kind, from buildings, roads, and railways, to pipelines, airports, and power lines come under stress or are damaged when the rate of melting is accelerated
- The entire infrastructure of the far north and the world's coldest zones is affected
- Overall, the effect is estimated to accelerate by around 10-20% the rate of wear and tear on all exposed infrastructure in the near term

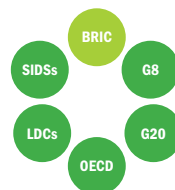
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)

🏠 Developing Country Low Emitters **🏭** Developed

🏠 Developing Country High Emitters **🏭** Other Industrialized

★ **\$** = Losses per 10,000 USD of GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

➤ Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Permafrost thawing is one impact of climate change that does not spare some of the world's most advanced and industrialized countries. In some places rising heat is causing dry lands to degrade into desert. In the coldest parts of the world, the heat is instead causing land to melt and sink, damaging infrastructure as it subsides (Larsen and Goldsmith, 2007). Every conceivable type of infrastructure is at risk as permafrost melts, including buildings, roads, railways, and oil pipelines (Xu et al., 2010; Lin, 2011M; Feng and Liu, 2012). Preserving this infrastructure as growing heat adds to the stress is a major challenge for engineers and a serious cost for local communities (McGuire, 2009). In Alaska, for instance, two-thirds of the state roads budget is spent on permafrost repair alone (Stidger, 2001). In worst case scenarios, it is estimated that extreme permafrost thaw could force the relocation of entire communities (Romanovsky et al., 2010). Permafrost thawing through accelerated infrastructure replacement and repair will impose significant cost burdens on the world's coldest communities.

CLIMATE MECHANISM

As temperatures rise, regions nearer the poles are heating up the fastest (IPCC, 2007). Much of the land within the Arctic Circle is frozen on a permanent basis, or for more than 1–2 years. The permafrost region currently covers about one-quarter of earth's land area (Nelson et al., 2002); however, it is home to only a fraction of the world's population (Hoekstra et al., 2010). One-quarter of the land area of the northern hemisphere has a subterranean layer of ice built up under the soil which can melt when temperatures rise (Anisimov, 2009). The warming planet thaws otherwise permanently frozen land, destabilizes it, alters its ecosystem, and compromises the structural integrity of any buildings or infrastructure that have been constructed in these zones (Romanovsky et al., 2010). In this way, climate change is already accelerating the process by which key infrastructure in these areas requires repair or replacement (Larsen and Goldsmith, 2007).

IMPACTS

The impact of climate change on infrastructure in affected permafrost

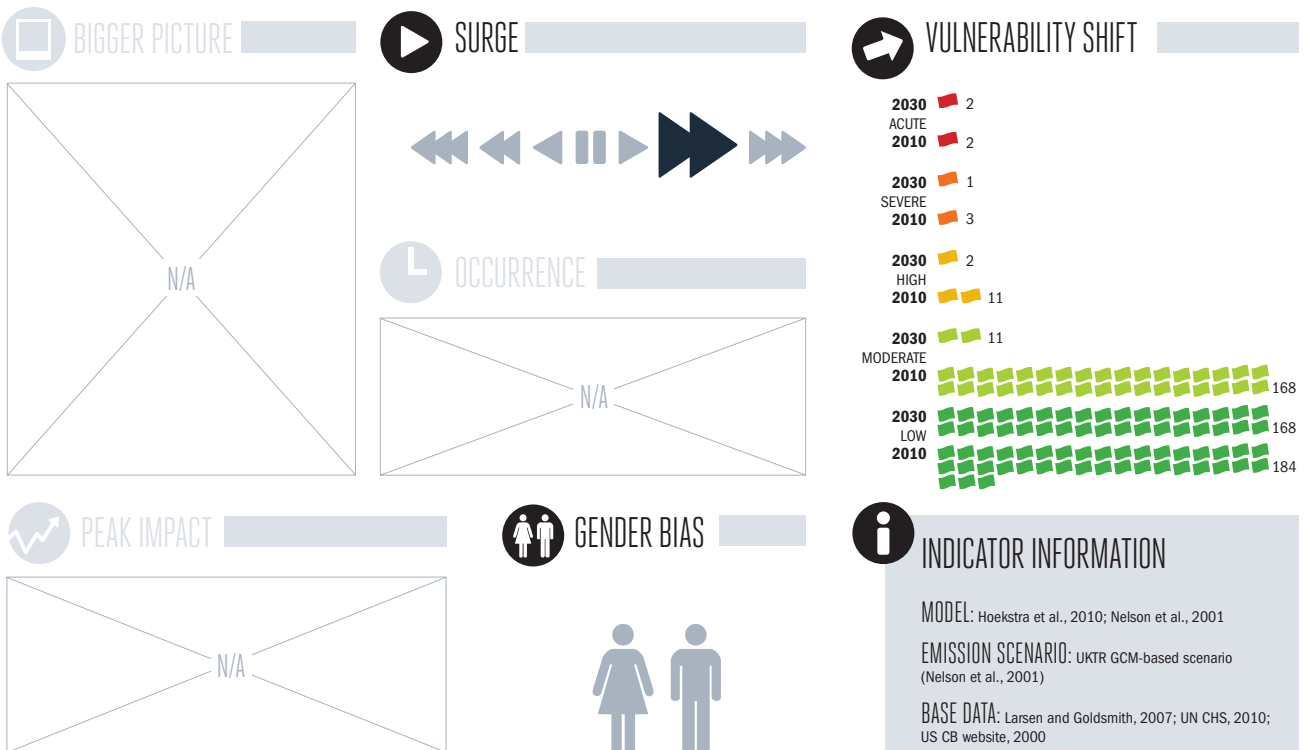
zones is estimated globally at 30 billion dollars a year in 2010. With the expected increase in temperatures through to 2030, losses associated with permafrost thawing are estimated to grow as a share of global GDP, amounting to approximately 150 billion dollars a year. Countries worst affected include the US (because of Alaska), Canada, China (because of Tibet), Mongolia, Russia, and a number of Central Asian states (because of the Himalayas). As climate change intensifies, the same group of countries continues to be affected. The largest total losses are incurred in Russia, China, Mongolia, and Canada. Losses for Russia and China are currently estimated at around 20 and 10 billion dollars respectively, and should grow to over 60 billion dollars each year by 2030. Mongolia, Kyrgyzstan, and Bhutan are estimated to suffer the most severe effects as a share of GDP, with Mongolia and Kyrgyzstan's losses at over 4% of GDP by 2030, and Bhutan's in excess of 1% of GDP. Some 10 million people are estimated to be affected by the impact of climate change on permafrost globally, a number that will more than double to nearly 25 million by 2030.

THE BROADER CONTEXT

Dealing with some degree of oscillation in permanently frozen land in the coldest zones of the planet is normal (Wei et al., 2009). It is the acceleration in these processes that incurs additional costs as temperatures rise. While the northernmost or coldest regions of the planet are sparsely inhabited, oil and gas exploitation has grown in permafrost regions in and around the Arctic Circle. Planned or constructed high value infrastructure in these regions will face growing risks (Pavlenko and Glukhareva, 2010). The same is true for the multi-billion dollar China-Tibet railway, built over partially unstable land across the Tibetan ranges and plateaux (Yang and Zhu, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Communities and governments maintaining expensive public infrastructure in lower-middle income countries, such as Kyrgyzstan in Central Asia, will face a major development challenge in tackling accelerated infrastructure erosion. There is a lack of clarity on the extent to which insurance



➡ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

policies are valid for permafrost erosion damage (Mills, 2005; Williams, 2011). Insurance coverage is growing, as incomes of developing countries expand, suggesting that for many of the worst affected areas, including Tibet, Mongolia, and Kyrgyzstan, a lack of insurance will heighten the impact of these changes (Kharas, 2010). Permanently frozen land also stores around half of the potential soil-derived emissions of greenhouse gases (GHGs), mostly in the form of methane, a highly potent GHG. As such, there is mounting concern that, as they thaw, the permafrost regions could become a major unmanageable driver of global climate change (Tarnocai et al., 2009).

RESPONSES

Adaptation to the thawing of permafrost is a challenge. Future planning might make non-essential infrastructure projects in transition zones less of a priority. For all existing infrastructure, there is a predictable accelerated depreciation and replacement cost that must be faced (Larsen and Goldsmith, 2007). Unlike sea-level rise, changes are likely to come faster, and no wall can prevent the retreat of frozen land which, as it thaws, will decimate



any built infrastructure in affected areas. However, for certain types of infrastructure, such as pipelines or railways, measures can be taken to mitigate the extent of destabilising effects, especially when designing new infrastructure (Xu et al., 2010; Wei et al., 2009). Public resources may be considered,

for instance, to subsidise or back insurance schemes which allow risk to be managed in a more long-term framework, buffering communities from abrupt losses and enhancing the resilience of highly exposed groups (Verheyen, 2005). In worst cases, community relocation may be necessary (Romanovsky, 2010).

THE INDICATOR

The indicator is understood to be moderately robust. This is because clarity on the climate signal in one of the fastest warming regions of the world is pronounced, and the IPCC's stance on the possibility of extensive damage stemming from permafrost erosion is firm (IPCC, 2007). However, permafrost damage is for now a niche research area at best, and the indicator's robustness is compromised by being based on only one study and model from Alaska (Larsen and Goldsmith, 2007). Further uncertainties relate to the extrapolation of the damage estimations through income (GDP) metrics and population-weighted adjustments in order to simulate the damage effects in the other countries. Assumptions were also made by proxy for non-public infrastructure based on capital values of private infrastructure at risk, which could be an area for further improvement. Given the potential scale of the damage, the topic remains a clear research priority for additional enquiry in all respects.

ESTIMATES COUNTRY-LEVEL IMPACT

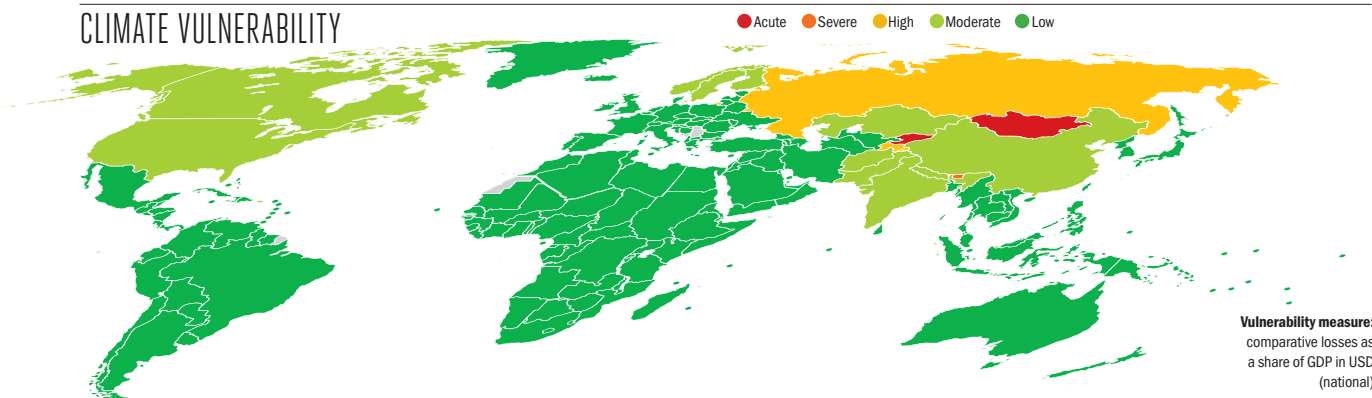
COUNTRY	\$		👤	
	2010	2030	2010	2030
ACUTE				
Kyrgyzstan	400	1,750	450,000	850,000
Mongolia	600	4,000	550,000	1,000,000
SEVERE				
Bhutan	45	250	20,000	40,000
HIGH				
Russia	15,000	75,000	4,500,000	9,500,000
Tajikistan	100	500	150,000	250,000
MODERATE				
Afghanistan	20	100	90,000	200,000
Canada	1,750	3,500	350,000	700,000
China	9,250	65,000	4,500,000	9,500,000
Finland	15	30	3,750	7,750
India	100	550	85,000	150,000
Kazakhstan	200	800	75,000	150,000
Nepal	65	300	150,000	300,000
Norway	100	200	20,000	40,000
Pakistan	400	2,000	350,000	750,000
Sweden	85	150	20,000	40,000
United States	650	1,250	90,000	200,000
LOW				
Albania				
Algeria				
Angola				
Antigua and Barbuda				
Argentina				
Armenia				
Australia				
Austria				
Azerbaijan				
Bahamas				
Bahrain				

COUNTRY	\$		👤	
	2010	2030	2010	2030
Bangladesh				
Barbados				
Belarus				
Belgium				
Belize				
Benin				
Bolivia				
Bosnia and Herzegovina				
Botswana				
Brazil				
Brunei				
Bulgaria				
Burkina Faso				
Burundi				
Cambodia				
Cameroon				
Cape Verde				
Central African Republic				
Chad				
Chile				
Colombia				
Comoros				
Congo				
Costa Rica				
Cote d'Ivoire				
Croatia				
Cuba				
Cyprus				
Czech Republic				
Denmark				
Djibouti				
Dominica				

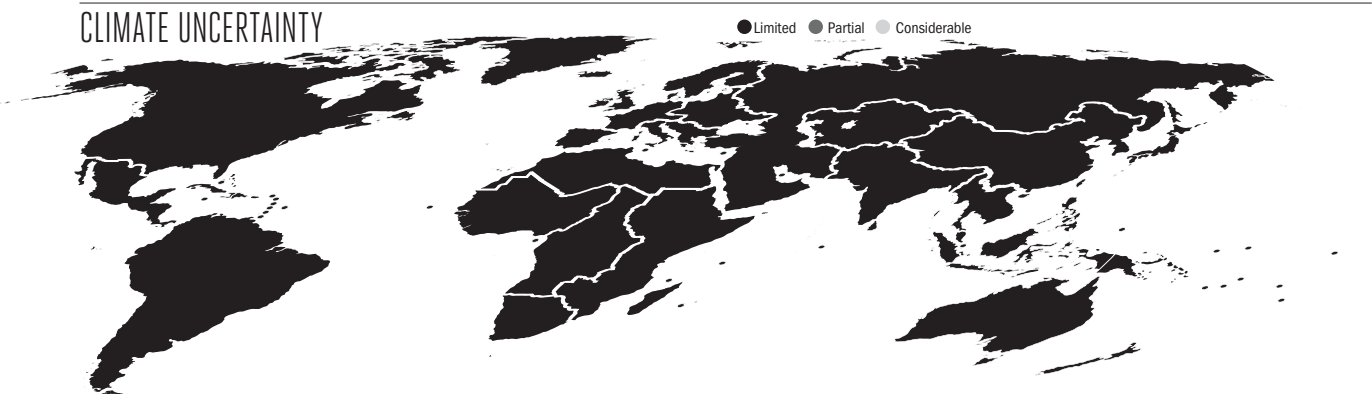
COUNTRY	\$		👤	
	2010	2030	2010	2030
Dominican Republic				
DR Congo				
Ecuador				
Egypt				
El Salvador				
Equatorial Guinea				
Eritrea				
Estonia				
Ethiopia				
Fiji				
France				
Gabon				
Gambia				
Georgia				
Germany				
Ghana				
Greece				
Grenada				
Guatemala				
Guinea				
Guinea-Bissau				
Guyana				
Haiti				
Honduras				
Hungary				
Iceland				
Indonesia				
Iran				
Iraq				
Ireland				
Israel				
Italy				



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		i		COUNTRY	\$		i		COUNTRY	\$		i	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Jamaica					New Zealand					Spain				
Japan					Nicaragua					Sri Lanka				
Jordan					Niger					Sudan/South Sudan				
Kenya					Nigeria					Suriname				
Kiribati					North Korea					Swaziland				
Kuwait					Oman					Switzerland				
Laos					Palau					Syria				
Latvia					Panama					Tanzania				
Lebanon					Papua New Guinea					Thailand				
Lesotho					Paraguay					Timor-Leste				
Liberia					Peru					Togo				
Libya					Philippines					Tonga				
Lithuania					Poland					Trinidad and Tobago				
Luxembourg					Portugal					Tunisia				
Macedonia					Qatar					Turkey				
Madagascar					Romania					Turkmenistan				
Malawi					Rwanda					Tuvalu				
Malaysia					Saint Lucia					Uganda				
Maldives					Saint Vincent					Ukraine				
Mali					Samoa					United Arab Emirates				
Malta					Sao Tome and Principe					United Kingdom				
Marshall Islands					Saudi Arabia					Uruguay				
Mauritania					Senegal					Uzbekistan				
Mauritius					Seychelles					Vanuatu				
Mexico					Sierra Leone					Venezuela				
Micronesia					Singapore					Vietnam				
Moldova					Slovakia					Yemen				
Morocco					Slovenia					Zambia				
Mozambique					Solomon Islands					Zimbabwe				
Myanmar					Somalia									
Namibia					South Africa									
Netherlands					South Korea									

SEA-LEVEL RISE



ESTIMATES GLOBAL CLIMATE IMPACT

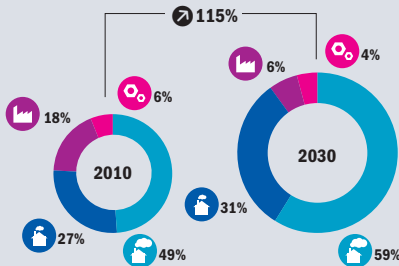
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **85** BILLION

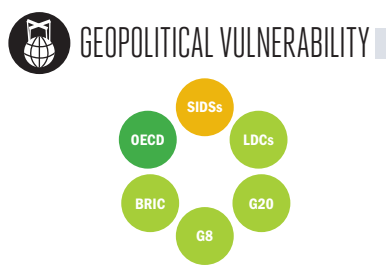
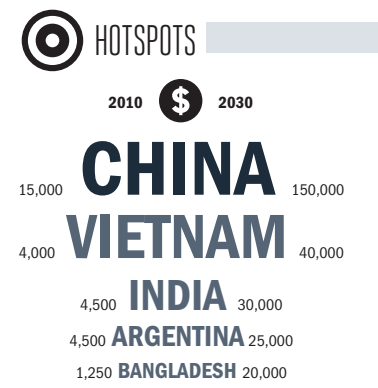
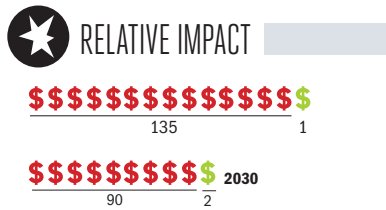
2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **550** BILLION

ECONOMIC IMPACT



- Melting of the polar ice sheets and mountain ice and glaciers is increasing the amount of water supplied to the oceans, causing sea-levels to rise relative to land
- The oceans heat up together with the atmosphere as the planet warms, and in so doing expand, leading to a greater and growing sea-level rise effect
- The rate of global sea-level rise is gradual—currently about 1cm every three years—but the effects are so comprehensive that its costs are already large-scale and growing
- Tackling sea-level rise is a monumental challenge and will significantly inhibit development in coastal areas attempting to stem growing damage



\$ Economic Cost (2010 PPP non-discounted) **★** \$ = Losses per 1,000 USD of GDP **🎯** \$ = Millions of USD (2010 PPP non-discounted)

🏠 Developing Country Low Emitters **🏭** Developed **🔄** Change in relation to overall global population and/or GDP

🏠 Developing Country High Emitters **🏭** Other Industrialized

Sea-level rise resulting from climate change has the potential to threaten the survival of whole nations, such as low-lying Maldives in the Indian Ocean, of which 80% are one metre or less above sea level; their highest elevation is a sand dune 4 metres above sea-level (Maldives MEEW, 2007). Low-elevation coastal zones, however, are common around the world (CReSIS, 2012). In general, where there is inhabited coastline, there will be vulnerability and economic and social impacts. Sea-level rise is therefore one of the most significant economic effects of climate change. For countries with a substantial proportion of the population and economy situated within reach of the shoreline at low elevation, the impacts of sea-level rise are a constant and crippling economic cost. Scientists have asserted that climate change will “shrink nations and change world maps” (Hansen, 2006).

CLIMATE MECHANISM

As the planet warms and the temperature rises, heat is melting glaciers and ice on land around the world, including the polar ice caps (Olsen et al., 2011). All of the world’s

glaciers have been in long-term retreat or have already disappeared (NSIDC, 2008). Arctic sea ice used to cover over 7 million square kilometres during the height of summer. As this report went to publication, sea ice was at a record low, close to 3 million km² in the Arctic Sea (NSIDC, 2012). Much of the heat in the atmosphere is also absorbed by the oceans, which release it back into the atmosphere (Hansen et al., 2005). In the meantime, as the oceans absorb more and more heat, they expand in accordance with the basic laws of physics. Viewed from land, this so-called “thermal expansion” is also a significant contributor to sea-level rise (RSNZ, 2010). Overall, sea-level rise is currently about 3mm per year, or 3cm a decade (NASA Climate, 2012). Current estimations point to increases in that rate, with several experts recently estimating a possible maximum of two or more metres of sea-level rise by the end of the century (Pfeffer et al., 2008; Grinstead et al., 2009; Füssel, 2012). Sea-level rise not only leads to coastal erosion and flooding, it also increases risks from storm surges and seasonal high tides. It can unfavourably increase the salinity of river ways and brackish aquaculture production ponds, contaminate coastal groundwater sources

with salt, and damage agricultural production through gradual salt intrusion into the surrounding soil (Nicholls and Cazenave, 2010; Füssel, 2012).

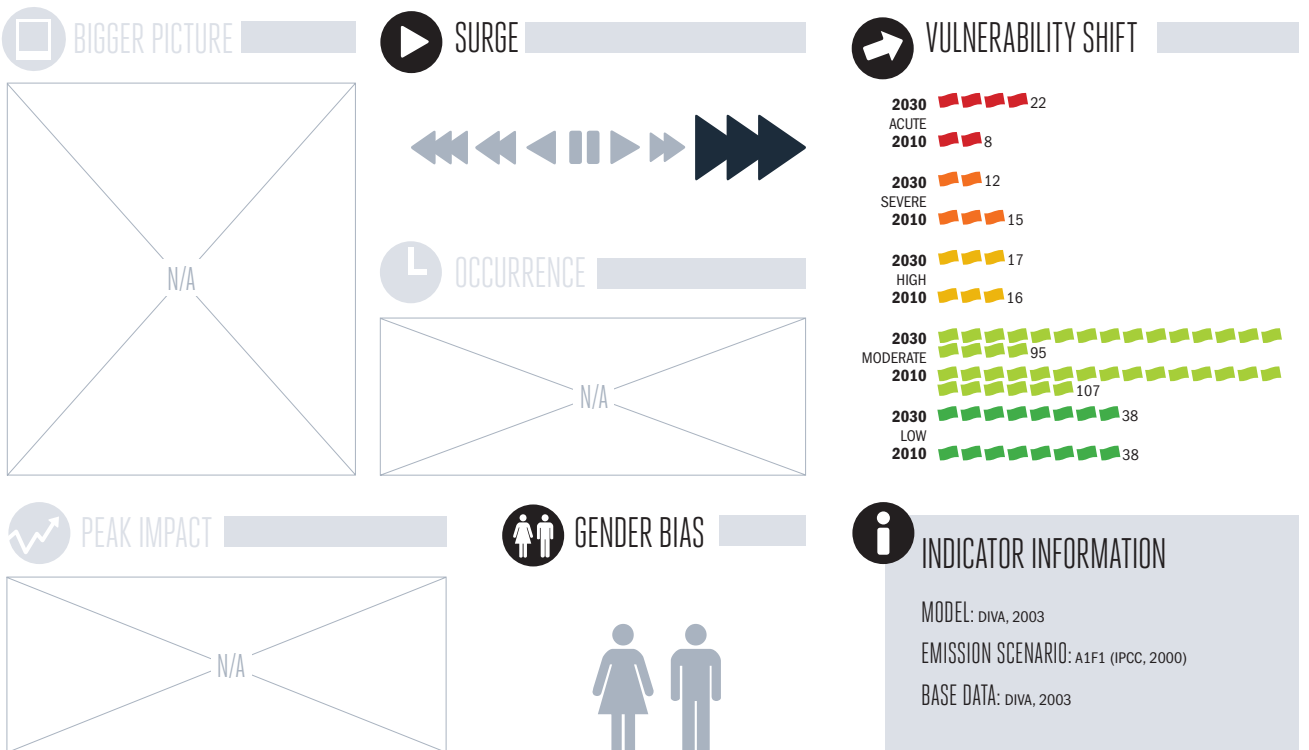
IMPACTS

The global impact of climate-driven sea-level rise on the world’s coastlines is estimated to cost 85 billion dollars a year today, increasing to over 500 billion dollars a year by 2030, with a doubling of costs as a share of GDP over this period. China suffers the largest impact today at 15 billion dollars a year, set to grow to almost 150 billion dollars a year in losses by 2030, reaching 0.3% of China’s projected GDP. By 2030, more than 15 countries will experience annual losses around or in excess of 10 billion dollars, including developing countries such as Bangladesh, Indonesia, or Vietnam, as well as developed countries such as the US and South Korea. Worst affected by share of GDP are small island states, especially in the Pacific, and several coastal African countries. For a handful of countries—the Marshall Islands, Guinea-Bissau, the Solomon Islands, and Kiribati—costs could represent as much as 20% or more of GDP in 2030.

In general, lower-income and least developed countries, especially small island developing states, dominate the ranks of those most vulnerable to the effects of climate-related sea-level rise, with serious implications for human development progress in these areas.

THE BROADER CONTEXT

Coastal erosion and geological subsidence, or the sinking of land due to earth plate tectonics and associated factors, are completely natural phenomena which are part of the basic geological processes sustaining the planet. When land surfaces are lowered near the sea, the result is indistinguishable from sea-level rise, when viewed from a local perspective (Törnqvist et al., 2008). Likewise, several issues related to the human presence in the environment have serious effects for coastal erosion. Groundwater pumping for irrigation or municipal/industrial purposes near shorelines can cause land to subside or become lower in relation to the sea (Larson et al., 2001). Coastal defences or port structures and other built infrastructure can alter or deflect sea currents and lead to serious erosion in adjacent



➡ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

coastal areas (Appearing Addo and Labri, 2009). Destruction of coastal ecosystems, such as mangrove forests, reduces coastal integrity and triggers erosion (Wilkinson and Salvat, 2012). In river estuaries, upstream dams for irrigation or in some cases hydro energy can be detrimental to the delta downstream, if river flow is reduced (due to diverted water), or if sediment that would otherwise have flowed to the sea is retained (Ly, 1980; Yang et al., 2005; Boateng, 2009; Baran, 2010; Fredén, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Length of coastline is not the main determinant of vulnerability to sea-level rise. Vulnerability is more closely related to the relative value of land in coastal areas, reflecting the concentration of populations and productive sectors of the economy under stress. It is also closely related to topography and geology: with current rates of sea-level rise, steep rocky coastlines are much less cause for concern than low-lying, sand-based atolls or river estuaries. Vulnerabilities can be higher, depending on whether or not adjacent communities build coastal defences, which can alter

wave dynamics and exacerbate erosion in nearby zones (Appearing Addo and Labri, 2009). This will pose an important challenge for international adaptation responses along contiguous coastlines under threat, as was illustrated in this report's Ghana country study. As mentioned earlier, unsustainable resource use, such as water withdrawals that lead to subsidence or the destruction of mangrove forests, only heightens vulnerabilities.

Where populations rely on ground water for irrigation or drinking water, particularly in small islands, salt intrusion is a further serious concern (Werner and Simmons, 2009). Lower-income communities generally cannot marshal the resources needed to protect against the effects of sea-level rise, and so must suffer the consequences of not adapting: loss of land, contamination of water sources, and growing dangers from extreme weather. As is highlighted in both the Ghana and Vietnam country studies in this report, international assistance is most often required to support adaptation. Furthermore, subsistence farmers who may not have their land submerged may see production decrease due to gradual salt intrusion into soils. These effects frustrate poverty reduction efforts in

affected areas and drive rural-urban migration (Dasgupta et al., 2009).

RESPONSES

Four different types of approaches can be combined in a variety of ways: 1) coastal defences, whether "hard" through infrastructure defences (dykes, polders, sea walls, dykes) or "soft", such as sand-banking, ecosystem, or a combination of these; 2) addressing human activities that aggravate sea-level rise, from intensive farming to ground water pumping for irrigation, or upstream dams in delta areas; 3) support programmes for affected communities, such as rainwater harvesting programmes; and 4), retreat or land sacrifices, including relocation and abandonment.

If the value of the land is deemed less than the costs of protecting it, then land is most likely to be let go (DIVA, 2003). However, if communities are involved, they would normally need support to obtain new property and/or migrate and resettle elsewhere (Warner et al., 2009). As mentioned earlier, reducing upstream irrigation loads, and retrofitting dam infrastructure to allow more water and sediment to flow downstream can help counteract localized sea-level rise.

THE INDICATOR

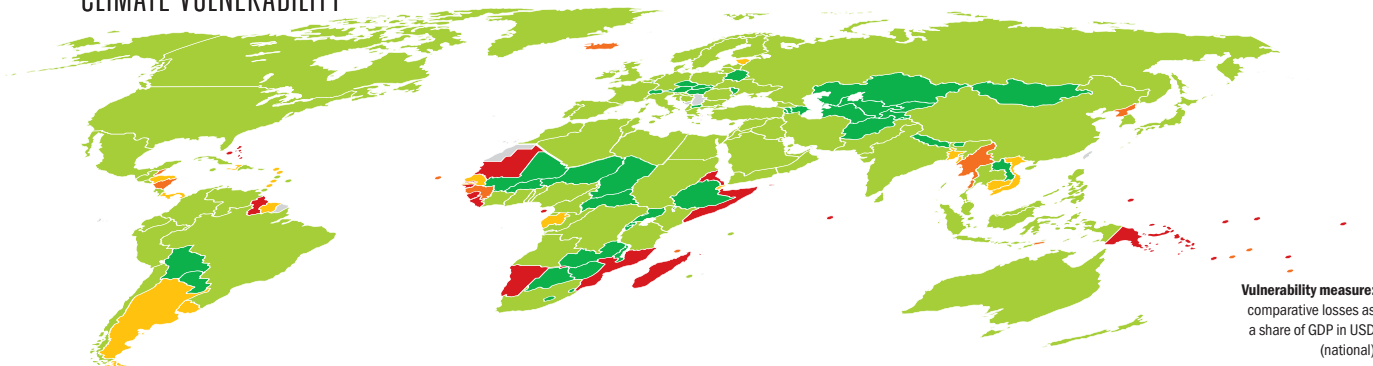
The indicator is deemed robust for several reasons: first, the science is firm on the increase in sea levels over time around the world, as recognized by the IPCC (IPCC, 2007). Second, there is relatively low uncertainty compared to other areas of climate change regarding the scale and rates of change between different models in the near term (Rahmstorf, 2009). Third, the indicator is built on a high-resolution global model (DIVA, 2003). Improvements in the estimation of the complex set of costs involved across countries and in the actual model resolution, now 75km segments, could nevertheless further improve the analysis going forward.

COUNTRY	\$		👤		+		COUNTRY	\$		👤		+		COUNTRY	\$		👤		+	
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030
ACUTE																				
Bahamas	300	4,000	90	100	90	200	North Korea	1,750	10,000	1,250	1,250	10	30	Brazil	3,250	20,000	6,750	8,250	850	2,500
Eritrea	150	650	10	15	20	55	Samoa	20	150	15	15			Brunei	50	100	100	150	5	10
Gambia	150	750	80	100	40	100	Timor-Leste	95	600	25	1			Bulgaria	30	150	10	10		
Guinea-Bissau	400	2,250	150	200	50	150	Tonga	20	100	70	75	1	1	Cameroon	100	850	1,250	1,750	45	100
Guyana	200	1,000	150	150	15	40	HIGH						Canada	1,500	3,500	900	1,000	700	3,000	
Kiribati	90	550	80	85	100	250	Antigua and Barbuda	10	70	55	70	1	1	Chile	550	2,750	400	500	2,000	4,500
Liberia	80	400			30	75	Argentina	4,500	25,000	650	800	150	300	China	15,000	150,000	40,000	45,000	250	350
Madagascar	850	4,000	100	200	45	100	Bangladesh	1,250	20,000	40,000	45,000	200	450	Colombia	350	2,250	400	450	350	600
Maldives	150	900	250	300			Cambodia	250	1,750	20	25	20	45	Congo	30	150	100	150	5	5
Marshall Islands	90	550	50	55	1	1	Djibouti	25	150	60	85	1	1	Costa Rica	90	650	10	15	55	100
Mauritania	250	1,500	15	20	350	900	Dominica	15	95	55	75	1	1	Cote d'Ivoire	150	750			10	25
Micronesia	30	200	15	15			Estonia	250	1,250	10	10	60	200	Croatia	150	700	20	20	25	35
Mozambique	1,000	5,250	3,250	4,750	100	300	Gabon	400	2,000	15	25	150	200	Cuba	550	3,000	350	450	1,500	3,500
Namibia	10	5,250	1	1	850	2,000	Grenada	15	80	20	25	1	1	Cyprus	20	45	20	20		1
Palau	10	60	5	5	1	1	Haiti	100	650	100	150	5	15	Denmark	550	1,000	1,000	1,250	100	250
Papua New Guinea	550	3,250	150	150	550	1,500	Honduras	250	1,500	50	65	200	500	Dominican Republic	100	700	30	35	150	300
Sao Tome and Principe	15	80					Panama	300	2,000	90	100	150	400	DR Congo	15	75	1	1	20	50
Sierra Leone	200	1,000	45	65	35	85	Saint Vincent	10	70	20	25			Ecuador	150	1,000	450	500	400	900
Solomon Islands	300	1,750	60	65	10	20	Senegal	200	1,250	350	550	35	75	Egypt	1,500	10,000	2,250	3,250	200	450
Somalia	750	3,750	75	100	45	150	Suriname	70	400	80	95	40	100	El Salvador	55	300	50	60	5	15
Tuvalu	1	10	5	5			Uruguay	500	3,250	150	200	5	10	Equatorial Guinea	50	250			25	60
Vanuatu	100	700	15	20	1	1	Vietnam	4,000	40,000	20,000	25,000	150	300	Finland	85	150	250	250	15	50
SEVERE																				
Belize	70	400	20	25	25	40	MODERATE						France	700	1,250	2,750	2,750	100	150	
Cape Verde	40	200	45	65	1	1	Albania	40	200	45	50	5	5	Georgia	60	300	65	70	50	100
Comoros	25	150	20	30			Algeria	95	550	450	600	40	70	Germany	1,000	1,750	2,750	3,000	85	150
Fiji	150	800	50	55	10	25	Angola	100	650	550	800	400	950	Ghana	200	850			15	35
Guinea	250	1,500	5	10	45	100	Australia	800	1,500	2,250	2,250	2,500	7,250	Greece	250	500	300	350	30	50
Iceland	350	700	30	35	40	150	Bahrain	35	95	150	250	1	1	Guatemala	60	400	35	45	10	20
Myanmar	1,750	9,500	2,250	2,500	350	1,250	Barbados	10	35	30	35	1	1	India	4,500	30,000	30,000	35,000	450	1,000
Nicaragua	400	2,250	15	20	40	100	Belgium	350	25	2,250	2,250	10	15	Indonesia	2,750	15,000	15,000	15,000	2,000	4,500
							Benin	25	150			60	85	Iran	350	2,000	100	150	200	400
							Bosnia and Herzegovina	1	5					Iraq	20	150	250	350	1	1



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	\$		👤		⊕		COUNTRY	\$		👤		⊕		COUNTRY	\$		👤		⊕		
	2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030		2010	2030	2010	2030	2010	2030	
Ireland	250	500	300	300	5	10	Seychelles	15	60	20	25	10	25	Burundi							
Israel	10	40	10	15	1	1	Singapore	10	55	600	700			Central African Republic							
Italy	250	550	1,250	1,500	30	50	Slovenia	1	5	1	1			Chad							
Jamaica	75	450	20	25	75	95	South Africa	600	3,000	100	200	65	200	Czech Republic							
Japan	950	2,000	6,000	6,250	50	80	South Korea	2,500	10,000	2,500	2,500	10	15	Ethiopia							
Jordan	1	5					Spain	200	450	1,000	1,250	35	65	Hungary							
Kenya	200	900	200	300	20	60	Sri Lanka	150	1,000	800	1,000	45	75	Kazakhstan							
Kuwait	55	500	100	150	5	15	Sudan/South Sudan	50	300	1	1	10	30	Kyrgyzstan							
Latvia	90	400	55	60	1	5	Sweden	150	300	550	600	5	10	Laos							
Lebanon	15	95	150	200			Syria	10	65	10	15			Lesotho							
Libya	200	1,000	80	100	90	250	Tanzania	200	1,250	1,500	2,000	25	70	Luxembourg							
Lithuania	40	200	30	35	1	10	Thailand	1,500	6,750	5,250	6,250	65	150	Macedonia							
Malaysia	900	5,750	2,250	2,500	250	450	Togo	10	55			10	25	Malawi							
Malta	1	5	25	30			Trinidad and Tobago	50	300	65	80	1	1	Mali							
Mauritius	20	100			1	1	Tunisia	500	2,750	500	700	20	45	Moldova							
Mexico	2,250	15,000	1,250	1,750	1,000	2,000	Turkey	300	750	850	1,250	55	85	Mongolia							
Morocco	250	1,750	1,250	1,750	15	30	Ukraine	1,000	5,250	2,000	2,250	45	95	Nepal							
Netherlands	1,250	1,250	15,000	15,000	20	25	United Arab Emirates	50	250	20	30	1	5	Niger							
New Zealand	200	400	600	650	450	1,250	United Kingdom	1,500	2,750	5,000	5,250	100	300	Nigeria							
Nigeria	500	2,500	150	200	750	2,000	United States	4,250	9,000	10,000	15,000	10,000	25,000	Paraguay							
Norway	500	1,250	250	250	25	75	Venezuela	850	5,000	1,000	1,250	200	400	Rwanda							
Oman	100	600	35	45	10	20	Yemen	150	1,250	70	100	45	150	Slovakia							
Pakistan	500	2,750	1,000	1,250	100	250	LOW						Swaziland								
Peru	150	1,000	350	450	60	80	Afghanistan							Switzerland							
Philippines	850	4,750	3,500	4,000	350	850	Armenia							Tajikistan							
Poland	200	850	200	200	15	35	Austria							Turkmenistan							
Portugal	100	200	400	400	25	40	Azerbaijan							Uganda							
Qatar	45	250	60	85		1	Belarus							Uzbekistan							
Romania	80	400	150	150	90	200	Bhutan							Zambia							
Russia	3,000	10,000	1,750	1,750	400	1,000	Bolivia							Zimbabwe							
Saint Lucia	10	60	15	15			Botswana														
Saudi Arabia	300	1,500	75	100	40	90	Burkina Faso														

⊕ Additional land lost due climate change (km³) - yearly average

WATER

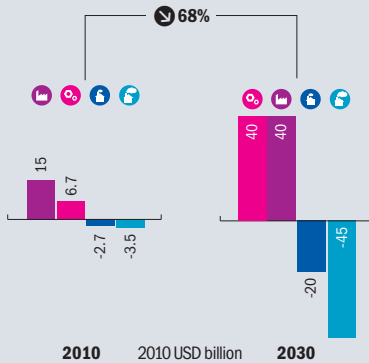


ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY
 USD LOSS PER YEAR **15** BILLION

2030 EFFECT TOMORROW
 USD LOSS PER YEAR **15** BILLION

ECONOMIC IMPACT



CONFIDENCE
SPECULATIVE

SEVERITY

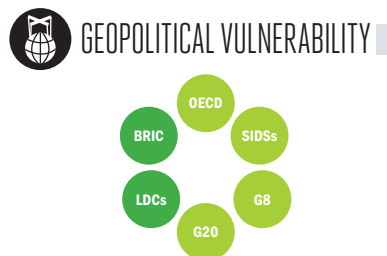
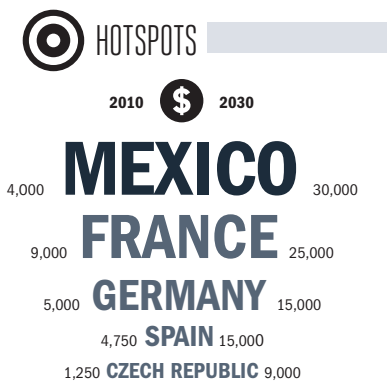
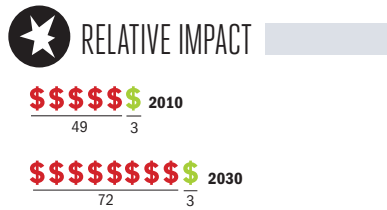
AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

- Climate change brings extra rain as warmer oceans evaporate more moisture
- Water resources will not increase everywhere: in places more rain may not keep pace with strong heat
- Longer, hotter summers deplete water resources but melting glaciers can cause short-term surges
- Where less or more water is made available to countries already facing chronic water scarcity, losses or gains match heightened marginal water supply costs
- Adapting to impacts of climate change on water is feasible in most cases, but in highly arid regions, solutions may prove too costly



\$ Economic Cost (2010 PPP non-discounted)

f Developing Country Low Emitters **h** Developed

h Developing Country High Emitters **o** Other Industrialized

★ \$ = Losses per 10,000 USD of GDP

↻ Change in relation to overall global population and/or GDP

◎ \$ = Millions of USD (2010 PPP non-discounted)

Water is an important input to the full range of economic activities and is therefore a crucial natural resource with market value (Morrison et al., 2009). Rainfall is highly uncertain (Blöschl and Montanari, 2010). Two global climate change projections could show mirror opposites for a region like Brazil: one dry and the other wet (Murray et al., 2012). A full ensemble of IPCC models was used to predict water supply change presented here (Nohara et al., 2006). But selecting only some models as opposed to others would likely have produced a different set of results. For some regions it is more certain whether they will be dry (such as Southern and Eastern Europe and North Africa) or wet (North America, East Asia). Others are completely unsure about what the future holds (Australasia, South America). In this assessment, roughly half of all countries are expected to either gain or have a no impact. The other half will suffer losses. Water is supplied according to specific local conditions at the market price (McKinsey & Company, 2009). However, the price of water varies widely around the world, from more than 8 dollars per m3 in Denmark to less than 8 cents/m3

in parts of India (GWI, 2008). Generally speaking, water costs a larger share of income in most developed than in developing countries. As a result, climate change is contributing to a worsening of water availability in the Mediterranean basin, and generating a large share of estimated global losses.

CLIMATE MECHANISM

Climate change increases rainfall globally, since the planet's water cycle accelerates as it warms (Huntington, 2006). As temperature increases, so does the overall moisture content of the air and rain falls back to ground levels (Allen and Ingram, 2002). More moisture in the air from the world's oceans is the main contributor to the water cycle's acceleration (Syed et al., 2010). However, much of the additional rain falls in the far north or south (Nohara et al., 2006). Recent evidence shows that rainfall has already declined in the tropics and increased significantly in the far north and south (Helm et al., 2010). Even where more rainfall occurs, if evaporation rates are high due to greatly increased temperature, a loss of water availability can result (Chu et al., 2009). Long-term decline in the world's

glaciers and longer drier summers also aggravate water scarcity in certain areas and lead to near-term surges in flows elsewhere before declining again (NSIDC, 2008; Immerzeel et al., 2012; Marengo et al., 2011; Olefs et al., 2009). Economic impacts will cause the greatest challenges where water scarcity and the cost of water are already high (Morrison et al., 2009).

IMPACTS

The effect of climate change on water scarcity is already estimated to cost affected countries 45 million dollars a year. However, 30 billion dollars in yearly gains in water resources in countries experiencing increasing water availability mean a net global loss of 15 billion dollars a year. This net global loss is stable at 15 billion dollars a year to 2030 and declines by three times as a share of global GDP. By 2030, affected countries will incur 200 billion dollars in yearly losses, which are almost entirely offset by similar levels of gains in other countries. The bulk of losses is estimated to affect wealthy European countries, such as France, Germany, Spain, and Italy. Mexico and Turkey are also expected to experience high losses in absolute

terms. Canada, China, Japan, India, and Russia are estimated here to recoup the largest gains.

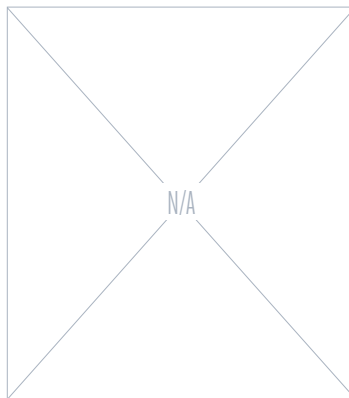
Southern and Eastern European countries are estimated to be worst affected relative to GDP, along with a number of Central American countries, such as Belize and Panama.

The impacts represent a possible outcome of highly unpredictable rainfall and should be treated with caution, especially for countries in sub-regions with considerable uncertainty about the direction of change (wet or dry). On a global level, the results could be considered more robust since different hydrological regimes will invariably favour some and disfavour others in terms of water availability.

THE BROADER CONTEXT

The world is experiencing a growing water crisis. Between 2010 and 2030, global water demand is expected to increase by around 40%, requiring an additional 3 trillion m³ of water, as compared with a total global demand of only 4.5 trillion m³ today, without accounting for the possible impacts of climate change (McKinsey & Company, 2009). This increase is driven largely by population growth and economic

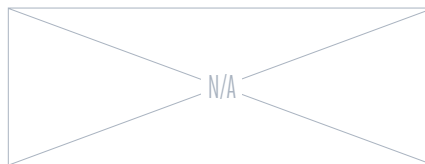
BIGGER PICTURE



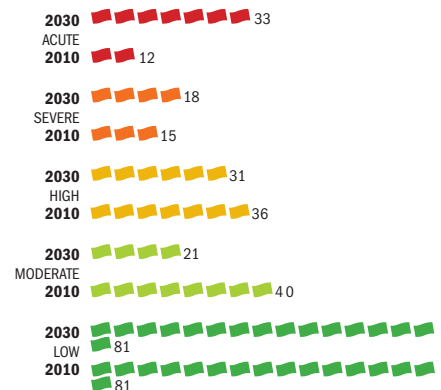
SURGE



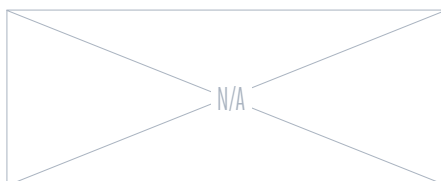
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Hoekstra et al., 2010; McKinsey and Company, 2009; Nohara, 2006; Portmann et al., 2010; Rosengrant et al., 2002

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Nohara, 2006

= 5 countries (rounded)

growth, which brings greater industry demand for water. Over half of the water gap is expected to be met through infrastructure and other changes which deviate from business-as-usual approaches to water. Unless countries develop more sophisticated responses to dealing with the water supply, the expense of closing this gap, while technically possible, will become increasingly cost-prohibitive, because of the steep cost of generating water to compensate for the water scarcity in an economy.

VULNERABILITIES AND WIDER OUTCOMES

Pollution, over-grazing, deforestation, and other environmentally unsustainable practices can all exacerbate water scarcity (Economy, 2010). Farmers who must rely on rainfall alone and who cannot afford or get access to irrigation are highly vulnerable to falling water availability. Water insecurity can lead to food insecurity in marginalized communities and to a lack of water for sanitation and drinking, leading to further negative health consequences, or even violence and conflict (Ludi, 2009; Raleigh, 2010).



Economies heavily reliant on agriculture, responsible for about 70% of global water demand, are also more vulnerable to water stress (FAO AQUASTAT, 2012).

RESPONSES

Managing water often requires large-scale investment that can have an important impact on longer-term development prospects (Aerts and Droogers in Kabat et al. (eds.), 2009). Planning for the wrong outcome is costly. Where uncertainty is high, it is therefore vital that responses are appropriate for a wide range of possible outcomes, i.e., a wet or a dry future (Dessai et al., 2009). However,

planning for different outcomes can add significantly to the costs of adaptation. Five broad response areas are central to effective water management: 1) Enhancing catchment capacity or access to supplies, through reservoirs or wells for instance; 2) There is wide scope for improving water efficiency in many contexts (Wallace, 2000), from micro-irrigation, to improved drainage and re-use of water, lining canals and limiting water leakage, as well as the cultivation of more water-efficient crops (Rodríguez Díaz et al., 2007; Wilby and Dessai, 2010; Elliot et al., 2011); 3) Supporting improved institutional environments to enable communities to make and implement effective decisions is critical (Rogers and Hall, 2003); 4) The vulnerability of communities to water stress can also be reduced, whether for socio-economic reasons (e.g., subsistence farmers), pollution, land degradation, or deforestation (Sullivan, 2011; Kiparsky et al., 2012; Epule et al., 2012; Postel and Thompson, 2005); 5) GHG emission reductions do not instantaneously slow or accelerate the hydrological cycle, but will limit the extent of changes in water availability due to climate change in the long term (Wu et al., 2010; Arnell et al., 2011).

THE INDICATOR

The indicator measures costs of changes in the re-supply of water resources due to temperature and precipitation changes caused by climate change (Nohara et al., 2006). It considers agricultural, domestic/municipal and industrial demand and country or region-specific marginal water costs (Rosengrant et al., 2002; McKinsey & Company, 2009). A key limitation not controlled for is that while climate change may increase water availability over a year, if it does not fall when water demand peaks in the absence of adequate catchment, reservoir and irrigation facilities, water scarcity may still increase. It has been estimated that around 20% of areas experiencing increased water could also experience an increase in water scarcity, including India, Northern China, and Europe (Yamamoto et al., 2012). Since the indicator is aggregating the country-level picture of change, it is possible that increases in water availability for some parts of a country are not compensating fully for decreases in water availability elsewhere.

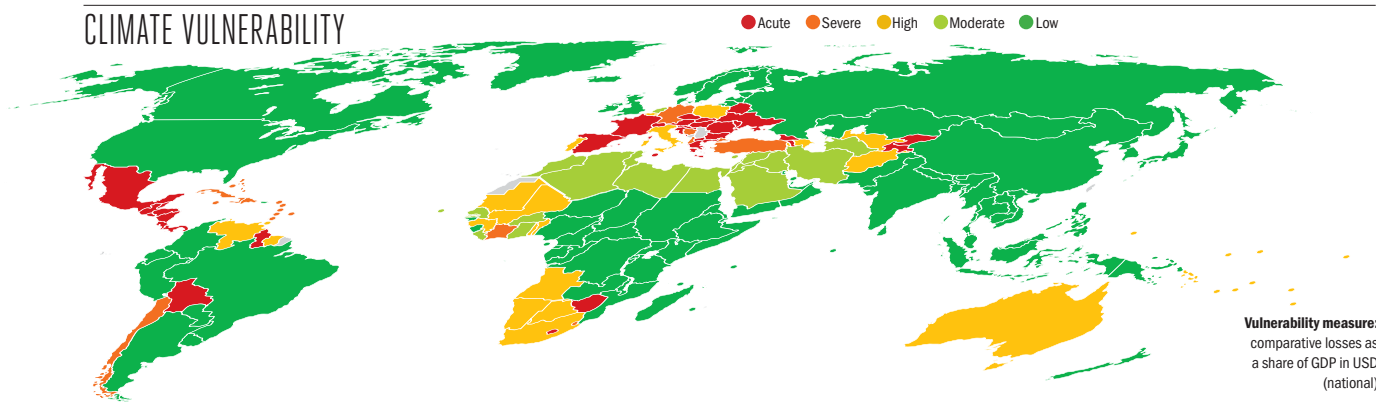
COUNTRY	\$		💧	
	2010	2030	2010	2030
ACUTE				
Armenia	70	500	0.25	0.50
Austria	2,000	6,000	1	1
Belarus	400	2,500	0.50	1
Belize	35	250		0.25
Bolivia	350	2,500	1	1
Bulgaria	600	4,000	1	1
Costa Rica	150	1,000	0.50	0.75
Croatia	700	4,750	0.50	1
Czech Republic	1,250	9,000	0.75	1
El Salvador	150	1,000	0.00	
France	9,000	25,000	5	10
Georgia	200	1,250	0.75	1
Greece	900	2,750	0.50	1
Guatemala	150	1,250	0.75	1
Guyana	15	100		
Honduras	80	650	0.75	1
Hungary	500	3,500	0.75	1
Kyrgyzstan	40	300	0.75	1
Lesotho	10	65	0.50	0.75
Macedonia	100	850	0.25	0.50
Malta	40	100		
Mexico	4,000	30,000	20	35
Moldova	30	200	0.25	0.50
Nicaragua	75	600	1	1
Panama	200	1,250	0.75	1
Romania	1,000	6,750	1	5
Slovakia	700	5,000	0.50	1
Slovenia	400	2,750	0.25	0.50
Spain	4,750	15,000	5	5
Switzerland	800	2,250	0.50	1
Tajikistan	45	300	0.75	1

COUNTRY	\$		💧	
	2010	2030	2010	2030
Ukraine	1,000	7,000	1	5
Zimbabwe	30	200	1	5
SEVERE				
Albania	35	250	0.25	0.50
Antigua and Barbuda	1	20		
Bahamas	15	100		
Barbados	10	70		
Bosnia and Herzegovina	40	300	0.25	
Chile	400	3,250	1	5
Cote d'Ivoire	45	300	1	5
Cuba	150	1,250		
Dominica	1	10		
Dominican Republic	100	950		
Germany	5,000	15,000	1	5
Grenada	1	15		
Haiti	15	100		
Jamaica	35	250		
Saint Lucia	1	20		
Saint Vincent	1	15		
Swaziland	10	70		0.25
Turkey	1,750	5,500	10	20
HIGH				
Afghanistan	35	250	1	5
Angola	70	450	1	1
Australia	750	2,000	0.50	1
Azerbaijan	100	800	0.25	0.50
Belgium	350	1,000	0.25	0.50
Benin	10	75	0.25	0.75
Botswana	20	100		0.25
Fiji	1	20		
Guinea	10	60	0.25	0.75
Italy	2,250	6,750	1	5

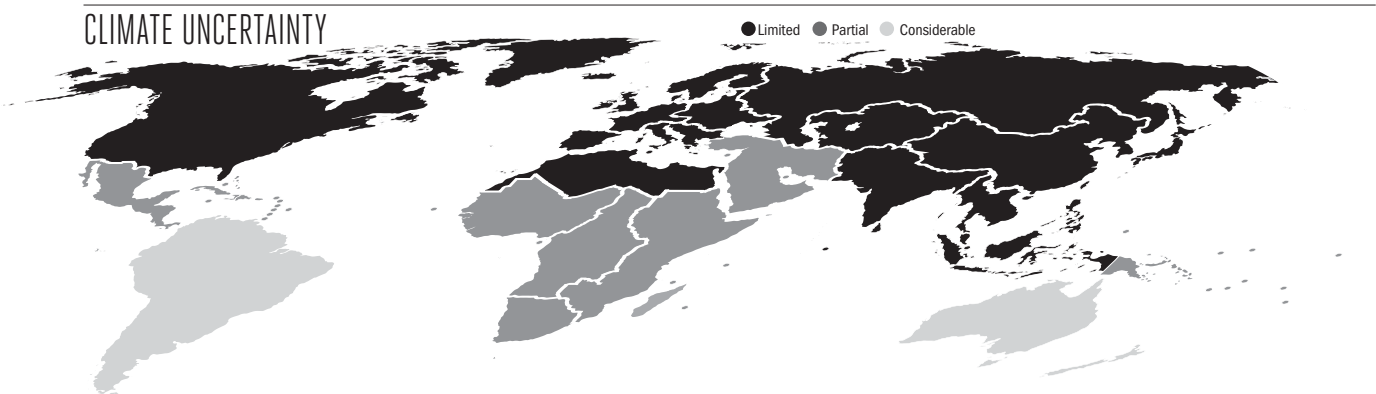
COUNTRY	\$		💧	
	2010	2030	2010	2030
Kiribati		1		
Luxembourg	50	150		
Mali	15	95	0.75	1
Marshall Islands		1		
Mauritania	5	40	0.25	0.25
Micronesia		1		
Namibia	10	55		0.25
Palau		1		
Poland	900	6,250	1	1
Portugal	250	700	0.25	0.25
Samoa	1	5		
Solomon Islands	1	5		
South Africa	550	3,500	5	5
Suriname	1	15		
Togo	5	30	0.25	0.50
Tonga	1	5		
Trinidad and Tobago	15	150		0.25
Tuvalu				
Uzbekistan	40	300	0.50	1
Vanuatu	1	5		
Venezuela	350	2,750	1	5
MODERATE				
Algeria	15	95		0.25
Burkina Faso	1	15		0.25
Cape Verde	1	5		
Cyprus	5	15		
Egypt	1	15		
Gambia	1	5		
Ghana	10	55	0.25	0.25
Iran	300	2,250	1	1
Iraq	5	55	0.25	0.25
Israel	10	65		



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		%		COUNTRY	\$		%		COUNTRY	\$		%	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Jordan	1	10			Equatorial Guinea	-5	-35			Oman	-25	-200		-0.25
Lebanon	1	10			Eritrea					Pakistan	-10	-60		-0.25
Liberia	1	1			Estonia	-100	-800	-0.25	-0.50	Papua New Guinea	-100	-850	-5	-5
Libya	1	5			Ethiopia	-100	-650	-5	-5	Paraguay	-25	-200	-0.25	-0.50
Morocco	10	70		0.25	Finland	-1,000	-3,000	-0.75	-1	Peru	-200	-1,500	-1	-1
Netherlands	150	500		0.25	Gabon	-1	-10			Philippines	-45	-350	-0.50	-1
Saudi Arabia	20	150		0.25	Guinea-Bissau		-1			Qatar	-10	-55		
Senegal	1	5			Iceland	-25	-70			Russia	-2,500	-15,000	-5	-10
Syria	10	65		0.25	India	-2,000	-15,000	-15	-35	Rwanda	-5	-40	-0.25	-0.50
Tunisia	1	15			Indonesia	-950	-7,500	-10	-20	Sao Tome and Principe		-1		
Turkmenistan	10	75		0.25	Ireland	-250	-700	-0.25	-0.25	Seychelles	-1	-5		
LOW					Japan	-4,250	-10,000	-1	-5	Sierra Leone		-1		
Argentina	-150	-1,250	-0.25	-0.50	Kazakhstan	-50	-350	-0.25	-0.25	Singapore	-250	-2,000		
Bahrain	-1	-5			Kenya	-65	-400	-1	-5	Somalia	-5	-40	-0.50	-1
Bangladesh	-25	-200	-0.50	-1	Kuwait		-1			South Korea	-85	-650	-0.25	-0.50
Bhutan	-85	-700	-0.50	-1	Laos	-70	-750	-1	-1	Sri Lanka	-1	-20		
Brazil	-1,250	-10,000	-5	-10	Latvia	-55	-350		-0.25	Sudan/South Sudan	-40	-300	-1	-1
Brunei	-55	-450		-0.25	Lithuania	-20	-150			Sweden	-1,500	-4,500	-1	-1
Burundi	-1	-10	-0.25	-0.25	Madagascar	-1	-5			Tanzania	-200	-1,250	-5	-10
Cambodia	-15	-150	-0.25	-0.50	Malawi	-1	-15		-0.25	Thailand	-300	-2,250	-1	-5
Cameroon	-35	-250	-0.75	-1	Malaysia	-800	-6,000	-1	-5	Timor-Leste	-5	-35		
Canada	-2,500	-7,250	-1	-1	Maldives	-10	-60			Uganda	-70	-450	-1	-5
Central African Republic	-5	-25	-0.25	-0.50	Mauritius	-10	-65			United Arab Emirates	-15	-150		
Chad	-25	-150	-0.50	-1	Mongolia	-1	-10			United Kingdom	-1,250	-4,000	-0.75	-1
China	-5,750	-60,000	-30	-55	Mozambique	-1	-5			United States	-1,250	-4,000	-1	-1
Colombia	-250	-2,000	-1	-5	Myanmar	-75	-600	-1	-5	Uruguay	-10	-70		
Comoros	-1	-1			Nepal	-25	-200	-1	-1	Vietnam	-100	-1,000	-1	-1
Congo	-5	-50		-0.25	New Zealand	-90	-250		-0.25	Yemen	-10	-60	-0.25	-0.25
Denmark	-65	-200			Niger	-10	-55	-0.50	-1	Zambia	-1	-5		
Djibouti	-1	-5			Nigeria	-65	-400	-1	-1					
DR Congo	-20	-100	-1	-5	North Korea	-20	-200	-0.50	-1					
Ecuador	-750	-5,500	-1	-5	Norway	-1,250	-4,000	-0.75	-1					

COSTS

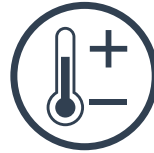
2010
23 BILLION

2030
106 BILLION

HEALTH IMPACT



DIARRHEAL INFECTIONS



HEAT & COLD ILLNESSES



HUNGER



MALARIA & VECTOR-BORNE



MENINGITIS

85,000
15,000

2010
2030



35,000
35,000

2010
2030



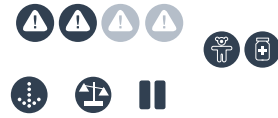
225,000
380,000

2010
2030



20,000
20,000

2010
2030



30,000
40,000

2010
2030



DIARRHEAL INFECTIONS



ESTIMATES GLOBAL CLIMATE IMPACT

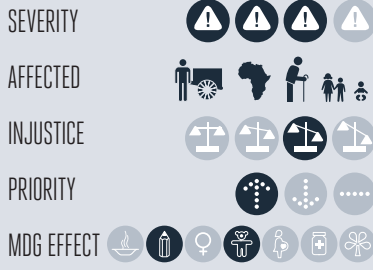
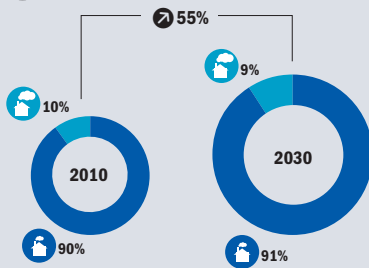
2010 EFFECT TODAY

DEATHS PER YEAR **85,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **150,000**

MORTALITY IMPACT

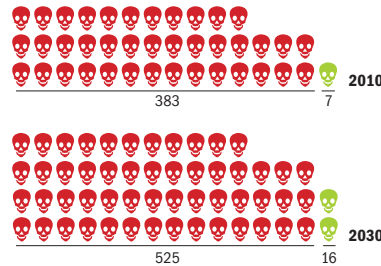


Diarrheal disease is one of the leading causes of preventable death in developing countries, especially among children and infants

Today, diarrheal diseases kill 2.5 million people per year globally

Germs causing these infections favour warmer environments; as the planet heats, the risks of diarrheal diseases will worsen unless counteracting measures are taken

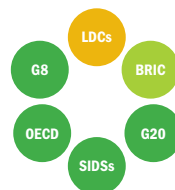
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



Deaths
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Deaths per 10 million
 Change in relation to overall global population and/or GDP

Diarrheal infections are one of the world's top communicable disease groups globally by overall death toll (WHO, 1999; WHO BDD, 2011). Food spoils more quickly and water contamination accelerates at higher temperatures, with the result that diarrheal infection rates may be 3-4 times higher in the summer than in the winter. Too much water, from flooding and contamination, or too little water, causing difficulties in treating/rehydrating the ill, are also problematic (WHO, 2009). Diarrheal disease influenced by climate change is a major concern for developing countries because risks are simply higher: inadequate refrigeration, difficult access to plumbed water in homes, or sanitation, such as basic toilet facilities (Bilenko et al, 1999; WHO, 2004; Ashbolt, 2004). In order to save lives and steadily reduce the prevalence of these diseases, simple interventions from vaccines to breastfeeding can prevent death. Systemic improvements in water, sanitation and hygiene are necessary for a more comprehensive reduction in risks (Jamison et al. (eds.), 2006).

CLIMATE MECHANISM

Several climate parameters affect diarrheal diseases from the level of infectious agents (bacteria, pathogen and viruses) through to population level practices. Direct observation of the effects of rising temperatures on infectious agents shows increases in disease replication rates and survival duration (WHO, 2004). Temperature changes also affect hospitalizations rates, with noticeable percentage increases in patient admissions as temperatures rise above normal levels (Checkley et al., 2000). Diarrheal diseases are transmitted via the fecal-oral route through food, water, human contact, or contact with objects such as cups (Dennehy, 2000). Key types of infectious diarrhea include cholera and rotavirus. Other factors such as humidity and rainfall also influence diarrhea. For instance, extremely low rainfall can force people in developing countries to make more use of polluted waters, while too much rain can contaminate unpolluted waters (Hunter, 2003; Ashbolt, 2004). Diarrheal diseases are also affected by malnutrition rates, which are influenced by climate change. This relationship is studied under "Hunger" (WHO, 2004).

IMPACTS

Owing to general temperature increase, the current impact of climate change on diarrheal diseases is estimated to lead to over 80,000 additional deaths per year in developing countries. Each year, over 100 million people are estimated to be affected by diarrheal diseases resulting from climate change. By 2030, these impacts will increase to over 150,000 deaths proportionate to the future global population, taking into account expected evolutions in the disease in relation to socio-economic development, unless measures are taken to counteract them. Over 200 million people could be affected by 2030. Africa is by far the region worst affected by diarrheal disease as result of the effects of climate change, with more than a dozen countries estimated to be experiencing similarly extreme levels of impact. Some parts of Asia, particularly, Afghanistan, Pakistan, and India are also particularly vulnerable. In general, low-income and least developed countries are significantly worse off than middle income countries. No significant impact is expected for developed countries, but primarily because of a higher level of public awareness, and not because people in

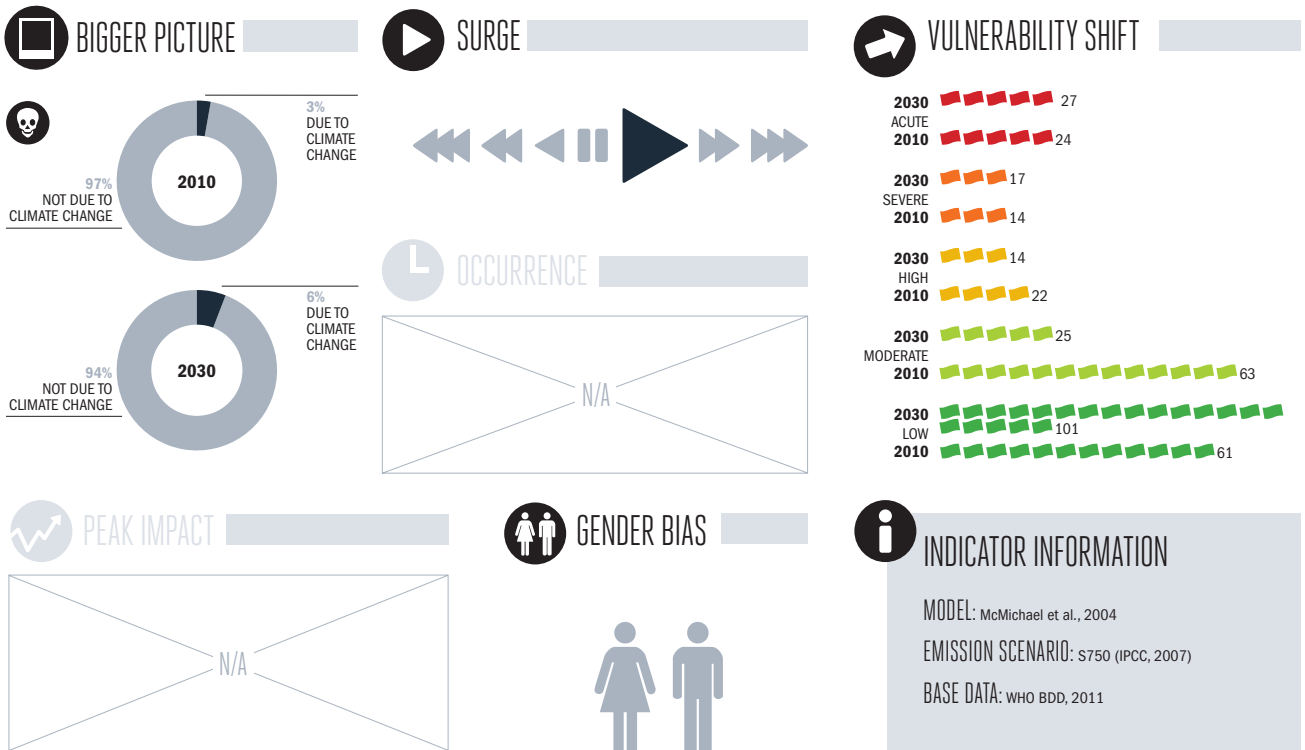
those countries are invulnerable (WHO, 2004; Bentham, 1997).

THE BROADER CONTEXT

While many preventable diseases in developing countries are seeing reductions in prevalence or declines in growth rates, diarrheal diseases have expanded rapidly since the year 2000, with nearly three quarters of a million additional deaths worldwide by 2010 (Mathers and Loncar, 2006; WHO BDD, 2011). However, different regions have evolved in different ways. In the last 10 years, Africa has worsened considerably, while East Asia has markedly diminished its burden of suffering from diarrheal disease.

VULNERABILITIES AND WIDER OUTCOMES

Less than 1% of diarrheal disease deaths occur in developed countries. Lower-income countries with already significant burdens of diarrheal infections will face serious challenges in combating the disease as temperatures continue to rise, since the same preconditions prevail. Prevalence of diarrhea is closely linked



to income levels for two reasons: 1) the main vulnerabilities relate to sanitation and by association, hygiene, whereby certain minimum standards in higher-income countries are enough to greatly reduce infection rates; and 2) deaths from diarrhea are easily preventable, especially among infants and toddlers, but only when either medical treatment or clean water are accessible and awareness about treatments is widespread; this is, unfortunately, not the case in many least developed contexts (Ashbolt, 2004; Jamison et al. (eds.), 2006).

While children make up more than half of the death toll, the millions who do survive what may often be repeated illnesses can, in many cases, be left with long-term cognitive impairments (Niehaus et al., 2002). Combined economic and social costs constitute a serious impediment to development progress for the world's poorest communities. With respect to the Millennium Development Goals, 2 (universal education) and 4 (child health) are particularly affected.

RESPONSES

Responses are needed at the treatment and prevention level. In terms of



treatment, simple water and salt, called "oral rehydration" solutions (ORS) cost next to nothing and can prevent death from extreme dehydration, the most common trigger of diarrheal mortality. In terms of prevention, access to clean water and basic sanitation are the central concerns (WHO, 2009). In this context, four sets of strategies are commonplace: 1) vaccination, especially against rotavirus and to a lesser extent cholera, has the potential to save up to half a million lives each year; 2) child

breastfeeding programmes which limit the transmission of infections through food and water to infants; 3) sanitation improvements, in the form of improved water sources for houses or small communities, construction of wells, and improved waste and latrine systems; and 4) education programmes, which target awareness about the other three areas and which promote personal hygiene through the use of soap and other simple measures (Jamison et al. (eds.), 2006).

THE INDICATOR

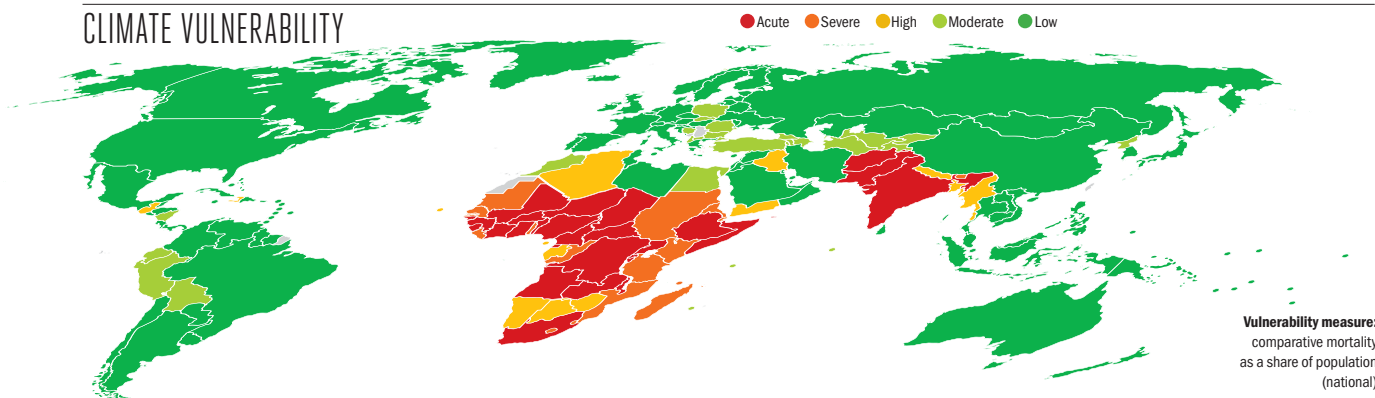
The indicator is deemed robust, particularly because of its reliance on temperature—among the most certain of climate effects—as the parameter for estimating a climate effect and because of the quality of the global health database compiled by the WHO on which the estimates are based (WHO BDD, 2011). Nevertheless, a number of improvements could be envisioned: for example, the WHO modelled the global effect on the basis of two detailed studies, which could benefit from further expansion into different areas, particularly detailed analysis of climate change effects on diarrhea in Africa (WHO, 2004). Moreover, the model does not take into account factors other than temperature, such as humidity and rainfall, nor does it take into account effects for developed countries which, while potentially low in terms of mortality, could be high in terms of the number of illnesses; one study identified a 9% increase in food poisoning causing diarrhea in the UK for every one degree increase in temperature (Bentham, 1997).

ESTIMATES COUNTRY-LEVEL IMPACT

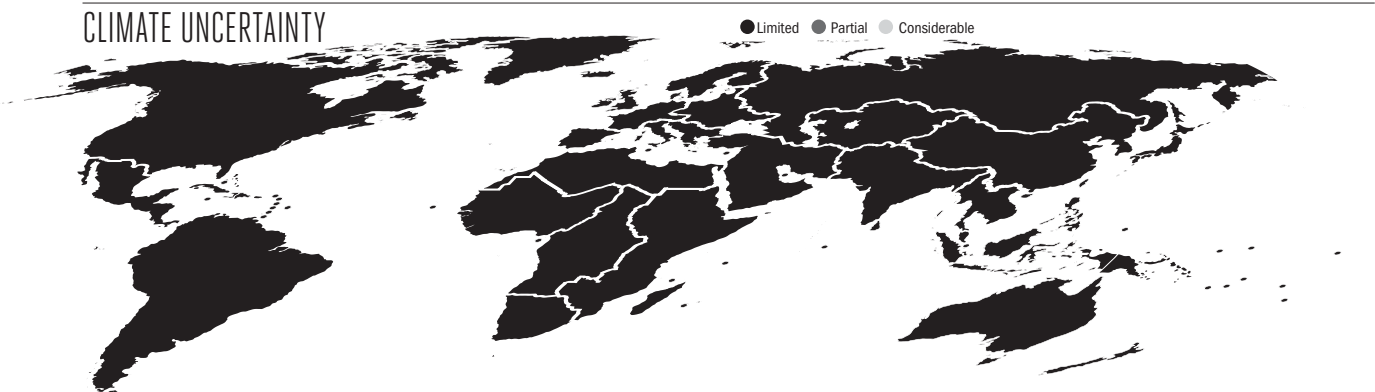
COUNTRY	☠		👤		COUNTRY	☠		👤		COUNTRY	☠		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
ACUTE					ACUTE					ACUTE				
Afghanistan	2,000	4,000	2,500	5,000	Djibouti	15	25	85	150	Azerbaijan	15	10	95	55
Angola	1,250	1,750	7,750	10,000	Eritrea	85	150	100	200	Bolivia	80	70	450	450
Benin	350	450	400	550	Gambia	45	65	60	80	Bosnia and Herzegovina			1	
Burkina Faso	900	1,250	1,000	1,500	Kenya	800	1,500	1,000	1,750	Bulgaria	1	1	1	1
Burundi	400	750	500	900	Lesotho	25	45	30	55	Ecuador	15	15	100	80
Cameroon	900	1,250	1,250	1,500	Liberia	150	200	200	250	Egypt	95	150	550	1,000
Central African Republic	150	250	200	350	Madagascar	500	700	600	850	Georgia	1	1	15	5
Chad	900	1,250	1,000	1,500	Mauritania	100	150	150	200	Kyrgyzstan	15	5	15	10
Cote d'Ivoire	550	950	650	1,250	Mozambique	550	950	650	1,250	Macedonia			1	1
DR Congo	3,500	6,500	4,500	8,000	Senegal	300	400	400	500	Maldives		1	1	5
Equatorial Guinea	25	35	200	300	Sudan/South Sudan	850	1,500	1,000	2,000	Mauritius	1	1	5	10
Ethiopia	3,500	6,500	4,500	8,250	Swaziland	15	30	100	200	Morocco	150	250	850	1,500
Ghana	900	1,250	1,250	1,500	Tanzania	1,000	2,000	1,250	2,250	Nicaragua	15	15	15	15
Guinea	400	550	500	700	Togo	150	250	200	300	North Korea	60	100	75	150
Guinea-Bissau	100	150	150	200	HIGH					Peru	45	35	250	200
India	40,000	85,000	50,000	100,000	Algeria	350	500	2,250	3,000	Poland	1	1	10	5
Malawi	450	800	550	1,000	Bangladesh	1,250	2,250	1,500	2,750	Romania	1	1	5	1
Mali	950	1,250	1,250	1,750	Botswana	15	25	100	200	Seychelles			1	1
Niger	1,000	1,500	1,250	1,750	Cape Verde	5	5	25	35	Slovakia			1	1
Nigeria	6,750	9,250	8,250	10,000	Gabon	20	30	200	250	Tajikistan	45	25	60	30
Pakistan	3,250	9,250	4,000	10,000	Guatemala	150	150	850	800	Turkey	25	15	250	150
Rwanda	350	650	450	850	Haiti	150	100	200	150	Turkmenistan	20	15	100	85
Sierra Leone	350	450	400	550	Iraq	300	850	1,750	5,000	Uzbekistan	55	35	70	45
Somalia	550	1,000	700	1,250	Myanmar	550	1,000	650	1,250	LOW				
South Africa	1,000	2,000	9,000	15,000	Namibia	15	25	85	150	Antigua and Barbuda				
Uganda	1,000	2,000	1,250	2,500	Nepal	300	550	350	650	Argentina				
Zambia	400	750	500	950	Sao Tome and Principe	1	5	1	5	Australia				
SEVERE					Yemen	400	850	500	1,000	Austria				
Bhutan	10	20	10	25	Zimbabwe	150	250	150	300	Bahamas				
Comoros	20	30	25	35	MODERATE					Bahrain			1	
Congo	80	150	100	200	Albania	1	1	5	1	Barbados				
					Armenia	1	1	5	5	Belarus				



CLIMATE VULNERABILITY

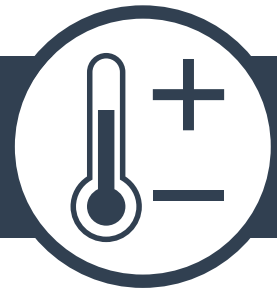


CLIMATE UNCERTAINTY



COUNTRY	☠		👤		COUNTRY	☠		👤		COUNTRY	☠		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Belgium					Israel					Russia	5		45	
Belize					Italy					Saint Lucia				
Brazil					Jamaica					Saint Vincent				
Brunei					Japan					Samoa			1	
Cambodia	100		150		Jordan	5		25		Saudi Arabia	15		250	
Canada					Kazakhstan	1		15		Singapore				
Chile					Kiribati	1		5		Slovenia				
China	550		3,000		Kuwait			1		Solomon Islands	1		1	
Colombia					Laos	35		45		South Korea	5		55	
Costa Rica					Latvia					Spain				
Croatia					Lebanon	1		10		Spain				
Cuba					Libya	5		30		Sri Lanka				
Cyprus			1		Lithuania					Suriname				
Czech Republic					Luxembourg					Sweden				
Denmark					Malaysia	5		55		Switzerland				
Dominica					Malta					Syria	15		85	
Dominican Republic					Marshall Islands			1		Thailand				
Dominican Republic					Mexico					Timor-Leste				
El Salvador					Micronesia			1		Tonga			1	
Estonia					Moldova					Trinidad and Tobago				
Fiji	1		10		Mongolia	5		5		Tunisia	10		55	
Finland					Netherlands					Tuvalu				
France					New Zealand					Ukraine	1		5	
Germany					Norway					United Arab Emirates			1	
Greece					Oman	1		10		United Kingdom				
Grenada					Palau					United States				
Guyana					Panama					Uruguay				
Honduras					Papua New Guinea	30		35		Vanuatu			1	
Hungary			1		Paraguay					Venezuela				
Iceland					Philippines	200		1,250		Vietnam	90		100	
Indonesia					Portugal									
Iran	100		600		Qatar			1						
Ireland														

HEAT & COLD ILLNESSES



ESTIMATES GLOBAL CLIMATE IMPACT

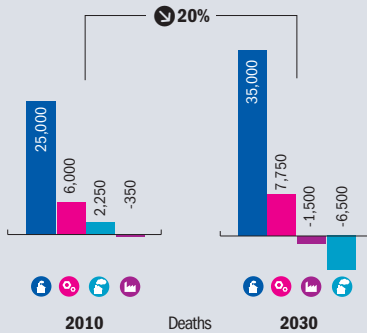
2010 EFFECT TODAY

DEATHS PER YEAR **35,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **35,000**

MORTALITY IMPACT

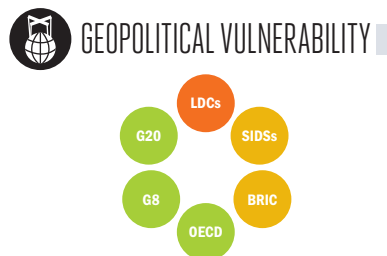
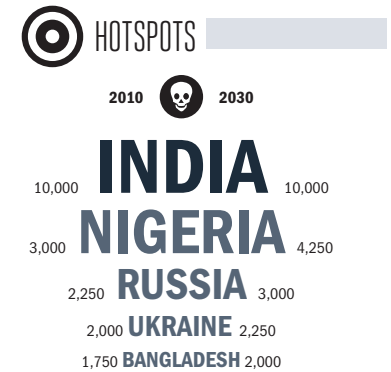
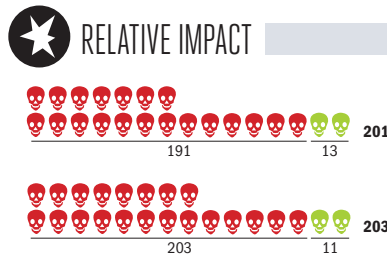


➤ Extreme heat is dangerous, entails high risks for the elderly, sufferers of chronic cardiovascular and respiratory diseases, and may increase skin cancer rates

➤ Shorter and less harsh winters alleviate dangers for the same risk groups and reduce the incidence of flu-like illnesses

➤ Some developed countries are estimated to experience modest health gains, as winters become less severe on average

➤ Effective responses to heat and cold illnesses benefit from a restricted high-risk group, concentrated on the elderly and chronic disease sufferers, while skin cancer risk is more diffuse in the population



☠ Deaths
 🇨🇪 Developing Country Low Emitters
 🇨🇪 Developed
 🇨🇪 Developing Country High Emitters
 🇨🇪 Other Industrialized

☠ = Deaths per 10 million
 ↻ = Change in relation to overall global population and/or GDP

🎯 \$ = Millions of USD (2010 PPP non-discounted)

Changes in the average levels and the extremities of heat and cold affect health. Increases in hospitalization and mortality rates are particularly evident for those suffering from chronic disease during heat waves (Michelozzi et al., 2009). Vulnerabilities to extreme hot and cold exist both in developed and developing countries and involve cardiovascular and respiratory diseases, skin cancer, and influenza-like illnesses, with both positive and negative effects. In tropical developing countries, exposure to heat is higher, especially since air conditioning, being linked to income, is less prevalent (Isaac and van Vuuren, 2009). Nor do tropical countries reap any of the potential benefits of shorter, warmer winters. While cooler, wealthy countries are likely to see improved health outcomes, experts have argued that even in developed countries, heat-related deaths may be greater than any gains from milder winters (McMichael et al., 2006). In Europe for example, 2003 was the hottest summer in some 500 years and left an estimated death toll of approximately 35,000–70,000 additional deaths (Patz et al., 2005; Robine et al., 2008). Scientists have argued the extent to which such extreme heat waves would be unlikely

without climate change (Hansen et al., 2012). Responses to the challenge benefit from clearly delineated groups among chronic disease sufferers. Skin cancer risk is much more generalized and presents a growing challenging for the promotion of safe behavioural adjustments for communities at risk (Bharath and Turner, 2009).

CLIMATE MECHANISM

Warm spells and heat waves have become more common and extreme, cold spells less so (IPCC, 2007). Because heat causes sweating, which removes water from the blood, high temperatures “thicken” blood, causing heart attacks or strokes (Solonin and Katsyuba, 2003). Sufferers of chronic respiratory illnesses, such as chronic obstructive pulmonary disease are also under additional stress during periods of high heat, but reduced stress in cold extremes. The elderly are another major risk group, due in part to impaired body temperature regulation (Lin et al., 2009; Gosling et al., 2009). Populations are thought to gradually acclimatize to increasing heat up to a point, a process for which the elderly are poorly equipped to handle; however, the speed of heat increase is outstripping the

capacity to acclimatize (Kennedy and Munce, 2003; Kjellstrom, 2009b). Skin cancer rates are expected to be affected by behavioural change—as people in colder climates spend more time outdoors as the planet warms, increasing the carcinogenicity of UV radiation—and by the delay or speed of recovery of the ozone layer, due to temperature effects in the upper atmosphere (Bharath and Turner, 2009; Gilchrest et al., 1999; Waugh et al., 2009). In some regions, ozone recovery is speeded up through climate change; in others, the recovery is slowed. Finally, influenza-like illnesses, in particular pneumonia, respond in complex ways to weather, but are generally more prevalent at lower temperatures, i.e., during winter, with climate change reducing the risks (van Noort et al., 2012).

IMPACTS

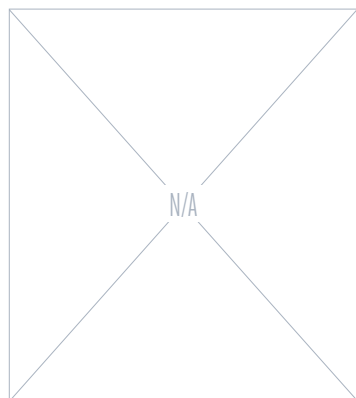
The global impact of climate change on heat and cold-related illnesses is estimated at 35,000 additional deaths a year in 2010, with one million more people affected than would have been the case without climate change. The net figure includes approximately 45,000 deaths, mainly in developing countries, and close to 10,000 deaths avoided in

developed countries, which are expected to see a net positive effect. The worst affected countries are mainly developing countries of Africa and Asia, but include Russia and several Commonwealth of Independent States countries where chronic disease burdens are very high. The largest total effects occur in India, with over 10,000 deaths per year. Very high total impacts are also seen in countries such as Nigeria, Russia, the Ukraine, Bangladesh, and DR Congo. The death toll is expected to remain relatively stable through to 2030, with mortality increasing to 55,000 people, but with avoided deaths also doubling from 10,000 to 20,000 over the same time period.

THE BROADER CONTEXT

The types of illnesses, particularly non-communicable illnesses, that are most affected by extreme heat and cold fluctuations are widely prevalent in both developed and developing countries. The incidence of cardiovascular and chronic respiratory diseases as well as skin cancer have increased in the last decade, while respiratory, including influenza-like diseases have declined (WHO BDD, 2000 and 2011).

BIGGER PICTURE



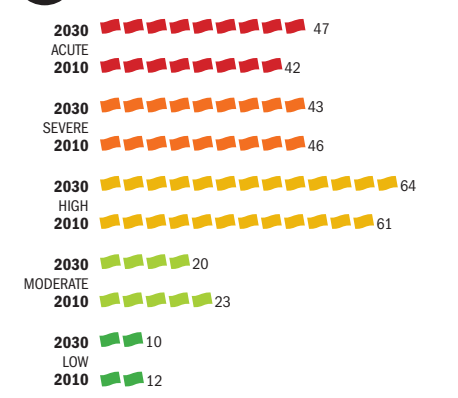
SURGE



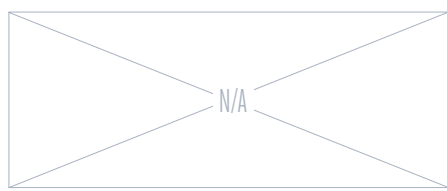
OCCURRENCE



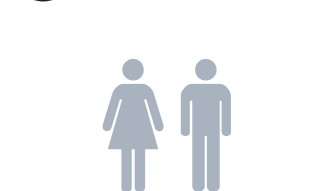
VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Curriero et al., 2002; Knutti et al., 2008; Toulemon and Barbieri, 2006; Van Noort et al., 2012
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: CIA World Factbook, 2012; WHO BDD, 2011

VULNERABILITIES AND WIDER OUTCOMES

Elderly populations are at the greatest risk by far, with two-thirds of all mortality in persons of 70 years of age, and over 80% of all mortality in persons over 60.

Countries with higher relative burdens of cardiovascular risk and chronic respiratory diseases have higher levels of vulnerability. Those same sufferers are less at risk of disease aggravation during milder winters; so geography is key: those in cold countries will benefit, while those in warmer countries will suffer more. Heat stress effects are deemed also to be stronger in tropical regions where temperatures are already elevated, air conditioning and insulation less prevalent, and outdoor work more common (Kovats and Hajat, 2008; Kjellstrom, 2009b). Since most developing countries fall in this category, there are negative implications for poverty reduction and development. Cities are more vulnerable, because they exaggerate extreme heat through the well-known heat island effect (Campbell-Lendrum and Corvalán, 2007). More frequent and severe hot periods



with sudden impacts will contribute to temporary capacity overloads on the health systems of affected areas, which may lead to further degradations in health services, with still additional negative health outcomes (Frumkin et al., 2007; Gosling et al., 2009). The well-being and health of outdoor workers especially in hot countries is also seriously jeopardized (Kjellstrom et al., 2009b).

RESPONSES

Responses include a variety of measures from preventative (pre-

summer) health assessments, early-warning procedures for heat spells, and behaviour adjustments, such as increasing fluid intake, adjusting medication, and avoiding midday heat, as well as increasing climate-controlled indoor cooling or heightened vigilance of high risk patients. Longer-term measures might include changes to building design and housing, improved institutional care for the elderly, and stricter controls on urban air pollution, which seriously exacerbates the heat effects of the summer hot spells (Kovats and Hajat, 2008; Ayres et al., 2009).

THE INDICATOR

The indicator measures the impact of new heat or cold patterns on cardiovascular and respiratory diseases, skin cancer, and influenza-like illnesses (Curriero et al., 2002; Bharath and Turner, 2009; Hill et al., 2010; van Noort et al., 2012). Baseline mortality is drawn from World Health Organization disease data (WHO BDD, 2011). The indicator has corrected for the so-called “harvesting effect” – i.e., climate change merely shifts the timing of mortality, as opposed to triggering it, given the high share of mortality in already high-risk groups. Baseline research from a wider set of countries studies would help improve the analysis, although the basic mechanisms of heat stress are understood to be broadly similar from country to country (Suchday et al., 2006). While the temperature effect is highly certain, other weather effects, such as humidity, which plays a key role, are more unpredictable. The complex interplay of disease and climate parameters for influenza-like illnesses is particularly difficult to map.

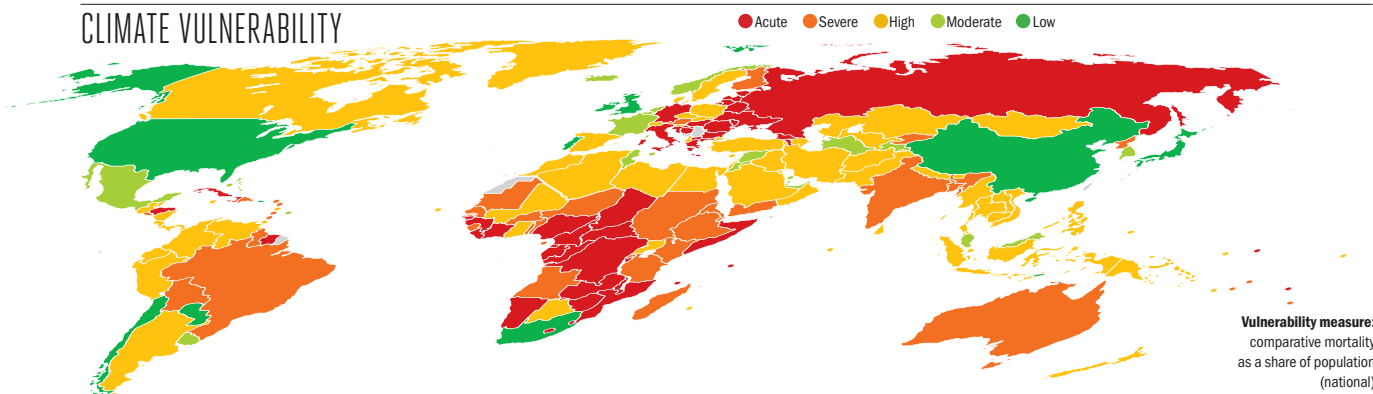
COUNTRY	👤		👤	
	2010	2030	2010	2030
ACUTE				
Armenia	75	85	400	-1,250
Belarus	250	300	6,000	6,750
Bosnia and Herzegovina	50	85	1,000	1,500
Bulgaria	200	200	2,000	-250
Burundi	150	200	6,250	9,250
Cameroon	350	450	15,000	20,000
Central African Republic	95	150	4,000	5,500
Chad	250	400	10,000	15,000
Comoros	10	15	450	700
Congo	70	100	3,000	5,000
Cote d'Ivoire	350	450	15,000	20,000
Croatia	55	75	650	-300
Cuba	150	150	5,000	4,750
DR Congo	1,250	2,000	50,000	85,000
Equatorial Guinea	15	20	550	850
Estonia	20	25	700	750
Gabon	25	40	1,250	1,750
Georgia	65	100	1,750	3,000
Germany	700	1,250	80,000	150,000
Greece	150	200	15,000	20,000
Guinea	150	250	6,750	10,000
Guinea-Bissau	25	40	1,250	1,750
Haiti	200	250	8,750	10,000
Honduras	150	150	3,750	4,750
Hungary	100	200	4,000	5,250
Italy	600	850	60,000	95,000
Latvia	45	60	1,500	1,750
Lesotho	40	35	1,750	1,500
Liberia	75	150	3,250	5,750
Lithuania	10	55	-600	300
Macedonia	45	60	950	1,250

COUNTRY	👤		👤	
	2010	2030	2010	2030
SEVERE				
Angola	200	300	5,250	9,000
Antigua and Barbuda	1	1	40	40
Australia	100	250	8,000	20,000
Austria	30	85	3,000	8,750
Bangladesh	1,750	2,000	70,000	85,000
Barbados	5	1	150	100
Benin	90	150	3,750	5,750
Bolivia	100	150	3,250	4,250
Brazil	1,750	2,000	50,000	55,000
Burkina Faso	150	250	6,000	10,000
Djibouti	10	10	300	350
Dominica	1	1	35	35
Dominican Republic	150	150	4,000	4,250
El Salvador	55	65	1,500	2,000
Eritrea	45	65	1,750	2,750

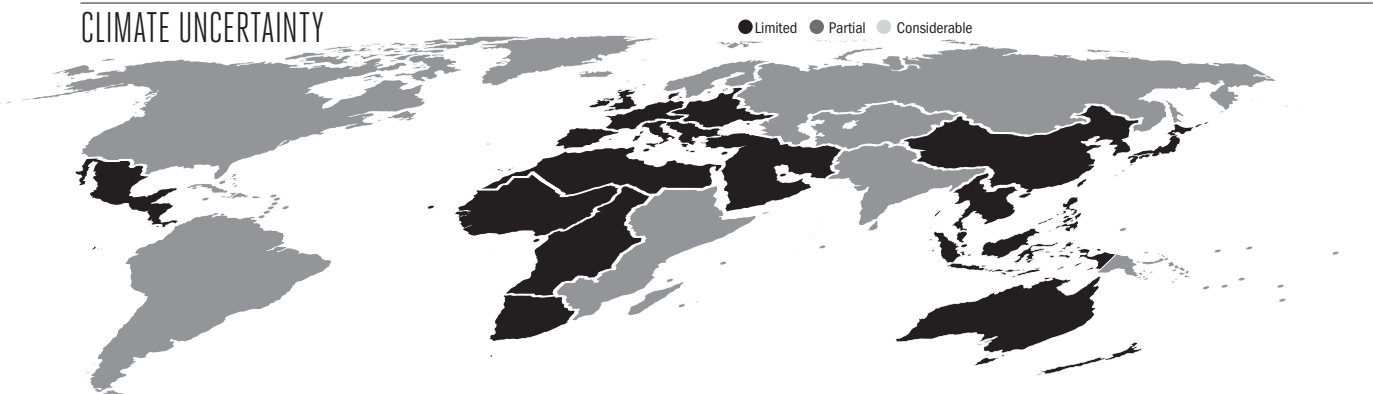
COUNTRY	👤		👤	
	2010	2030	2010	2030
HIGH				
Afghanistan	250	400	10,000	15,000
Albania	5	20	-1,500	-3,250
Algeria	150	200	4,750	5,750
Ethiopia	750	1,250	30,000	50,000
Fiji	10	10	250	250
Finland	30	70	3,000	6,750
Gambia	20	25	750	1,000
Grenada	1	1	50	50
Guyana	10	5	250	200
India	10,000	10,000	500,000	500,000
Kenya	350	450	15,000	20,000
Kyrgyzstan	60	75	1,000	-600
Madagascar	200	350	9,000	15,000
Mauritania	30	45	1,250	2,000
Myanmar	600	650	25,000	30,000
New Zealand	20	50	1,500	3,750
Niger	150	250	5,500	9,750
North Korea	150	300	7,250	10,000
Poland	250	350	-3,000	-15,000
Rwanda	100	150	5,250	7,250
Saint Vincent	1	1	55	55
Samoa	1	1	55	65
Sao Tome and Principe	1	5	85	150
Senegal	100	150	4,500	6,500
Sierra Leone	75	100	3,000	4,750
Sudan/South Sudan	600	850	25,000	35,000
Sweden	45	90	5,500	10,000
Tanzania	350	550	15,000	20,000
Togo	55	80	2,250	3,250
Tonga	1	1	30	35
Yemen	200	450	8,250	20,000



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	2010		2030		COUNTRY	2010		2030		COUNTRY	2010		2030	
	♀	♂	♀	♂		♀	♂	♀	♂		♀	♂	♀	♂
Argentina	300	250	-9,750	-45,000	Micronesia	1	1	30	35	Belgium	20	20	5,500	9,250
Azerbaijan	25	65	-2,250	-5,000	Mongolia	15	10	100	-700	France	20	150	10,000	30,000
Belize	1	1	85	100	Morocco	100	150	3,500	4,000	Iceland		1	50	150
Bhutan	5	10	250	400	Nepal	250	300	9,500	15,000	Jordan	10	10	200	300
Botswana	15	15	650	700	Nicaragua	40	55	1,750	2,250	Kuwait	5	5	350	450
Brunei	1	1	100	150	Oman	10	15	350	650	Malaysia	1	65	40	3,000
Cambodia	100	150	5,000	5,500	Pakistan	1,250	1,750	55,000	75,000	Malta			200	350
Canada	75	200	10,000	25,000	Palau			10	10	Mexico	150	95	5,500	4,250
Cape Verde	5	5	95	100	Panama	15	20	750	800	Netherlands	-10	1	3,000	8,500
Colombia	300	350	8,750	10,000	Papua New Guinea	60	80	2,500	3,500	Norway	5	10	1,250	2,750
Costa Rica	20	25	850	1,000	Peru	100	150	3,500	4,000	Qatar	1	1	70	70
Cyprus	5	10	600	900	Philippines	700	800	20,000	25,000	South Korea	-1	30	5,000	15,000
Czech Republic	30	70	-3,000	-5,250	Saint Lucia	1	1	70	65	Syria	10	10	300	300
Denmark	15	30	2,500	5,250	Saudi Arabia	75	150	7,250	10,000	Tajikistan	45	20	-1,000	-7,250
Ecuador	60	70	1,750	2,000	Singapore	25	25	2,250	2,500	Tunisia	1	30	75	900
Egypt	450	500	10,000	15,000	Slovakia	40	40	-1,000	-3,500	Turkmenistan	25	5	-4,500	-15,000
Ghana	200	250	8,250	10,000	Slovenia	5	10	900	1,500	United Arab Emirates	5	1	300	250
Guatemala	90	100	2,500	3,500	Solomon Islands	5	5	150	200	Uruguay	20	10	-1,750	-5,000
Indonesia	1,250	1,250	35,000	35,000	Spain	250	300	30,000	45,000	LOW				
Iran	250	300	7,250	8,750	Sri Lanka	90	150	2,750	3,750	Chile	-20	-70	-9,250	-25,000
Iraq	100	150	3,500	4,750	Switzerland	15	40	2,000	5,250	China	-5,500	-15,000	-500,000	-1,000,000
Israel	30	35	2,750	3,000	Thailand	200	350	5,250	9,750	Ireland	-15	-15	-250	900
Jamaica	15	15	400	400	Trinidad and Tobago	5	5	300	250	Japan	-850	-1,750	20,000	50,000
Kazakhstan	15	85	-8,000	-15,000	Turkey	250	500	10,000	20,000	Paraguay	-5	-25	-3,000	-9,000
Kiribati	1	1	20	25	Uganda	250	500	10,000	20,000	Portugal	-15	-60	5,250	7,750
Laos	45	50	2,000	2,000	Uzbekistan	200	300	2,500	-1,500	South Africa	-300	-1,250	-100,000	-200,000
Lebanon	35	40	1,500	1,750	Vanuatu	1	1	50	70	Timor-Leste				
Libya	20	30	1,000	1,250	Venezuela	150	150	6,250	7,250	United Kingdom	-55	-200	25,000	40,000
Luxembourg	1	1	100	400	Vietnam	450	350	20,000	15,000	United States	-1,500	-3,250	-100,000	-250,000
Maldives	1	1	25	40	MODERATE									
Mali	80	150	3,500	5,500	Bahamas	1	1	40	70					
Mauritius	5	5	200	300	Bahrain	1	1	150	150					

HUNGER



ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

DEATHS PER YEAR

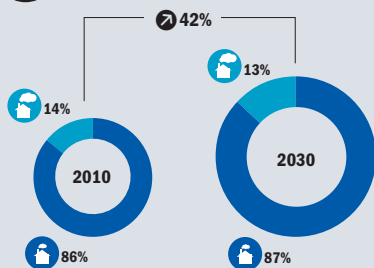
225,000

2030 EFFECT TOMORROW

DEATHS PER YEAR

380,000

MORTALITY IMPACT



SEVERITY



AFFECTED



INJUSTICE



PRIORITY



MDG EFFECT



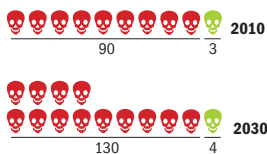
➤ 200 million people are estimated to suffer from food insecurity as a result of climate change in lower-income countries

➤ Half of all such deaths are among children and infants in the world's poorest communities, the group least responsible for climate change

➤ Although hunger is among the most preventable causes of human death, there are no quick fixes to the 850 million people facing hunger today

➤ There are major ongoing food emergencies and famine facing populations in the Horn of Africa and the Sahel

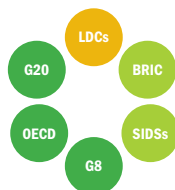
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



Deaths
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Deaths per million
 Change in relation to overall global population and/or GDP

Fifteen percent of all human beings are undernourished and 850 million people are prevented from leading active lives as a result of hunger (FAO, 2011). The Millennium Development Goal (MDG) target for reducing hunger has remained static since the early 1990s in all the world's developing regions. Despite enormous increases in wealth over the last two decades, the world has made almost no progress on hunger and its roots in the most extreme forms of poverty. A humanitarian food emergency continues in the Sahel and the Horn of Africa (HPN, 2012; Oxfam, 2012; CARE, 2012). It has long been understood that drought is a key trigger of famine and extreme drought has also been closely linked to climate change. (Glanz (ed.), 1987; Hansen et al., 2012). The combined effects of climate change on agricultural production on land, rivers, coastal zones, and oceans reduces disposable incomes and food availability for the world's poorest, especially in those communities with the least resources to adjust and diversify activities in the face of warmer and more extreme weather (Nelson et al., 2009; Allison et al., 2009). When people are hungry for prolonged periods, they not only suffer illness and potentially death as a result of acute nutritional imbalances, but may also

become seriously predisposed to illness and death from other diseases, such as pneumonia, diarrheal infections, malaria, and measles, dramatically expanding the death toll that is attributable to hunger (WHO, 2004).

CLIMATE MECHANISM

The effects of climate change on agriculture and fisheries are well covered in other sections of this report and extensively examined in the scientific, development, and humanitarian literature (IPCC, 2007; UNDP, 2007; World Bank, 2010). Rising heat, increasing variability, overabundance, or absence of rainfall, flooding, drought, disease and insect infestations are real threats to agricultural communities around the world (Parry et al., 2004; Gregory et al., 2009). Coastal areas are endangered by the rise in sea levels and the depletion of fish populations (Dasgupta et al., 2009; Allison et al., 2009). Increasing temperatures are making it difficult for subsistence farmers to accomplish the same amount of work in a given day and leave them few options other than to go hungry when food availability and/or incomes fall below critical levels (Kjellstrom et al., 2009b). Communities outside of the

subsistence spectrum are much better able to adjust to the effects of climate change and minimize losses.

IMPACTS

The global impact of climate change on rates of hunger causes more than 200,000 deaths each year, half of which are among children in low-income countries. This implies that over 200 million people each year are affected by hunger as a result of climate change. Anticipated increases in socio-economic development should continue to reduce the global burden of malnutrition deaths into the future (Mathers and Loncar, 2005). However, unless actions are taken by 2030, nearly 400,000 lives could be lost each year, and the number of people affected could exceed 400 million. Lower-income developing countries of Africa and Asia are worst affected, with Sub-Saharan Africa, least developed, and land-locked developing countries dominating the list of those hit hardest. However, even as the scale of the problem expands, researchers project a decrease in the number of countries suffering the most acute effects, resulting from expected socio-economic development over the next 20 years. India suffers more than half of all the

hunger effects of climate change, with an estimated climate change-aggravated death toll in excess of 100,000 people yearly. Bangladesh, Indonesia, Nigeria, and Pakistan are also heavily affected.

THE BROADER CONTEXT

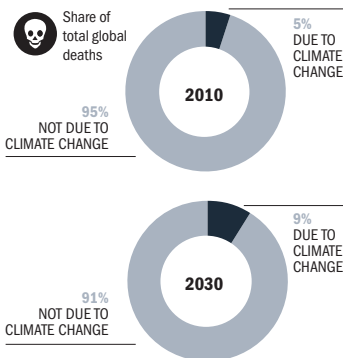
Poverty is declining. Although serious progress has been made on the MDGs, despite the array of challenges faced, the important goal for hunger is not among the success stories (UN, 2012). More than 2 million children die each year solely as a result of undernutrition (WHO, 2009). The number of people living with hunger has been stable for decades and remains undiminished by the opposing forces of rapidly expanding income and population growth. Food prices adjusted to inflation were at their highest in the 1960s and 1970s, declining until around 2000, at which point they have continued to rise, culminating in current new highs (FAO, 2011).

VULNERABILITIES AND WIDER OUTCOMES

The world's poorest groups spend virtually all their income on food,



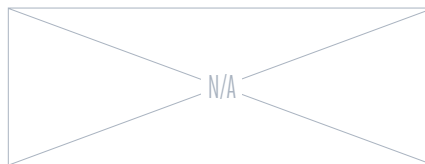
BIGGER PICTURE



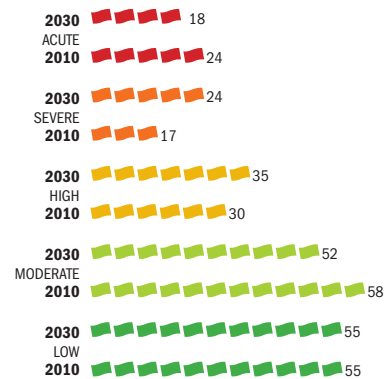
SURGE



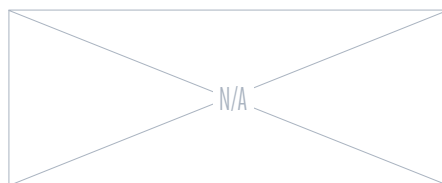
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

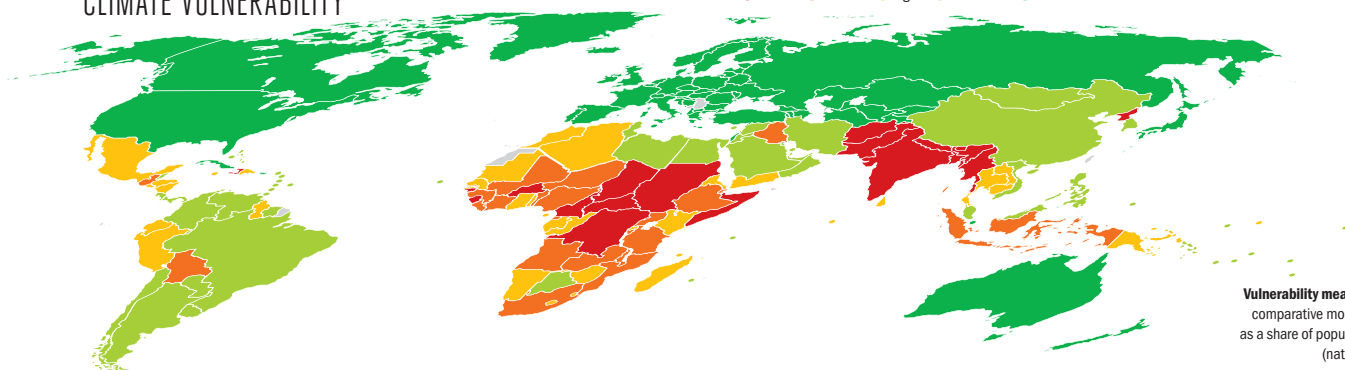
MODEL: McMichael et al., 2004
 EMISSION SCENARIO: S750 (IPCC, 2007)
 BASE DATA: WHO BDD, 2011

➡ = 5 countries (rounded)



CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative mortality
as a share of population
(national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



COUNTRY	☠		👤		COUNTRY	☠		👤		COUNTRY	☠		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Egypt	600	750	550	650	United Arab Emirates	5	10	20	35	Japan				
Fiji	5	5	15	25	Uruguay	25	40	55	90	Kazakhstan				
Grenada	1	1	1	1	Vanuatu	1	1	5	10	Kyrgyzstan				
Iran	200	400	900	1,750	Venezuela	90	150	200	400	Latvia				
Jordan	20	45	85	200	Vietnam	200	250	850	1,250	Lithuania				
Kiribati	1	1	5	5	LOW					Luxembourg				
Kuwait	1	5	10	15	Albania					Macedonia				
Lebanon	5	15	30	55	Armenia					Malta				
Libya	15	20	70	80	Australia					Moldova				
Malaysia	75	100	350	450	Austria					Netherlands				
Mauritius	5	5	1	1	Azerbaijan					New Zealand				
Micronesia	1	1	5	5	Belarus					Norway				
Mongolia	5	15	35	60	Belgium					Poland				
Oman	1	5	5	20	Bosnia and Herzegovina					Portugal				
Palau				1	Brunei					Romania				
Panama	20	35	50	85	Bulgaria					Russia				
Paraguay	40	90	95	200	Canada					Singapore				
Philippines	550	700	2,250	3,250	Croatia					Slovakia				
Qatar		1	1	1	Cuba					Slovenia				
Saint Lucia	1	1	1	1	Czech Republic					Spain				
Saint Vincent	1	1	1	5	Denmark					Sweden				
Samoa	1	1	5	10	Estonia					Switzerland				
Saudi Arabia	55	150	250	550	Finland					Tajikistan				
Seychelles	1	1	1	1	France					Turkey				
Solomon Islands	5	5	15	20	Georgia					Turkmenistan				
South Korea	55	90	250	400	Germany					Ukraine				
Suriname	1	5	5	10	Greece					United Kingdom				
Syria	50	100	200	450	Hungary					United States				
Tonga	1	1	1	5	Iceland					Uzbekistan				
Trinidad and Tobago	5	10	15	25	Ireland									
Tunisia	75	85	300	350	Israel									
Tuvalu				1	Italy									

MALARIA & VECTOR-BORNE



ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

DEATHS PER YEAR

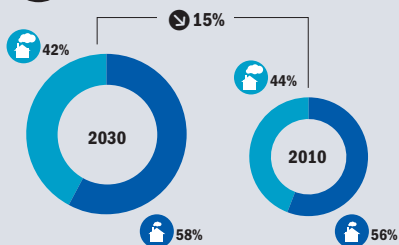
20,000

2030 EFFECT TOMORROW

DEATHS PER YEAR

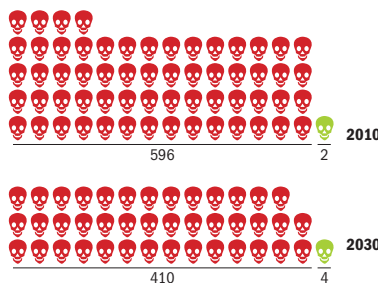
20,000

MORTALITY IMPACT

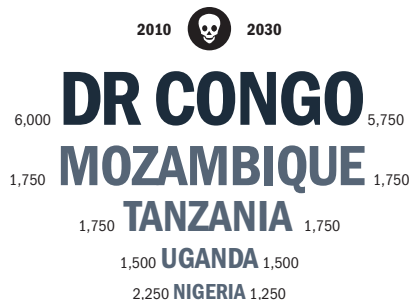


- Malaria is a large-scale cause of illness, with over 90% of deaths occurring among children in tropical regions, in particular in Africa and the Pacific
- Malaria and other vector-borne diseases have declined over the last decade, as a result of poverty reduction and anti-malaria programmes
- Vector-borne diseases are sensitive to climate; as climate becomes warmer and wetter, changes to their prevalence will slow and complicate efforts aimed at eradication
- Fighting vector-borne diseases is highly cost effective; minimizing vulnerability requires action to reduce or eradicate prevalence and increase the resilience of populations affected

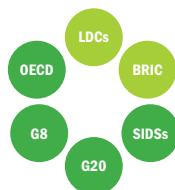
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



Deaths
 Developing Country Low Emitters
 Developed
 Developing Country High Emitters
 Other Industrialized

= Deaths per 10 million
 Change in relation to overall global population and/or GDP

A major cause of illness in developing countries, climate change will worsen the burden of vector-borne diseases, although it is difficult to predict with any precision the areas that will be worst affected (IPCC, 2007). Countries that already have serious malaria burdens should expect to see an aggravation of these diseases, due to increasing temperatures and other climate-related phenomena. Such aggravations will be offset to some degree through anticipated socio-economic development in the predominantly lower-income countries in which these diseases are most prevalent (Mathers and Loncar, 2005). But vector-borne outbreaks are also re-occurring in places where they have long been absent: a yellow fever epidemic in Uganda in 2010 was the first in 20 years (Rosenberg and Beard, 2011). As climate change brings warmer weather to colder places, the range of vector-borne disease is also shifting from the tropics, and to higher altitudes, as insects and other vectors roam further afield. In the US for instance, Leishmaniasis, a vector-borne disease originating in Mexico and Texas has begun to shift further north (González et al., 2010). Communities now linked by globalization are also

becoming exposed to higher risks, as illustrated for instance by a colony of yellow fever mosquitoes recently found in Holland (Enserink, 2010). Successful international programmes fighting these diseases should be reinforced in areas of particular risk, in order to safeguard against set-backs due to climate change in the fight to eradicate malaria and control other deadly vector-borne diseases (WHO and RBMP, 2010).

CLIMATE MECHANISM

Climate change is understood to enable the shift in vector-borne diseases like malaria, dengue, and yellow fever in several ways. As mountainous areas warm up for instance, vectors, such as mosquitos, would reach higher altitudes and increase exposure to disease in zones adjacent to affected areas; the same can be said of higher latitudes at the boundaries of current areas of infection. Transmission conditions and seasons are likely to expand in warm areas where rainfall used to be too low to support vectors, but now will increase. Temperature changes affect incubation rates and, together with range changes, increase the amount of time people are exposed to insect bites (Jetten and Focks,

1997). However, transmission could also decline, due to a drop in rainfall and temperature peaks—beyond which diseases like malaria cannot thrive—or due to very high rainfall that washes away insect larvae (WHO, 2004 and 2011). At a smaller scale, temperatures also influence the survival rates of mosquitoes (Martens et al., 1999). As was pointed out in the Ghana country study in this report, climate change also affects human behaviour, as, for instance, when people sleep outside on the hottest nights without mosquito net protection, significantly increasing their risk of contracting vector-borne diseases.

IMPACTS

The impact of climate change on the key vector-borne diseases of malaria, dengue fever and yellow fever is estimated to be over 20,000 deaths a year today, with 6 million people affected. Fourteen African and Pacific island countries are estimated to suffer Acute and Severe levels of vulnerability to the effects of climate change on vector-borne disease; most of these countries are land-locked developing countries, such as the Central African Republic or Zambia, or small island developing

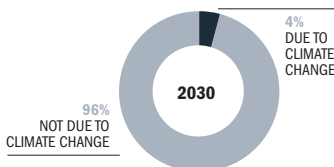
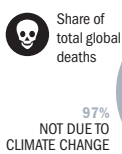
states, such as the Solomon Islands. The greatest total effects are estimated to occur in the DR Congo, with nearly 6,000 additional deaths due to vector-borne diseases in 2010. Five other countries also suffer large scale effects in the thousands: Nigeria, Mozambique, Tanzania, Uganda, and Côte d'Ivoire. By 2030, the effect of climate change on malaria is expected not to change since it is expected that there will be continued large-scale reductions in the prevalence of malaria, due mainly to economic growth over this 20-year period. In fact, as a proportion of population, malaria is estimated to decrease as a concern under these assumptions.

THE BROADER CONTEXT

According to the World Health Organization, malaria has undergone a major reduction in its overall prevalence in the last decade, falling from 1.2 million deaths in 2000 to 0.8 million deaths in 2008. However, most of the reduction occurred in the first years of the decade: over the four-year period between 2004 and 2008, there was a reduction of only 60,000 deaths (WHO BDD, 2000 and 2011). However, even at lowered rates of death, malaria



BIGGER PICTURE



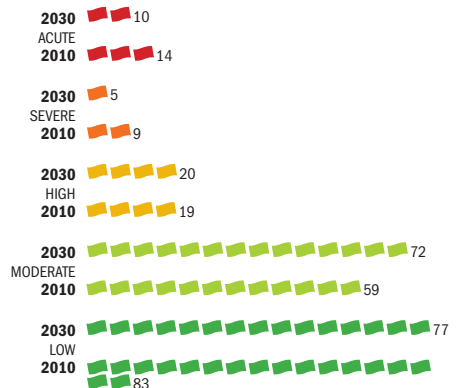
SURGE



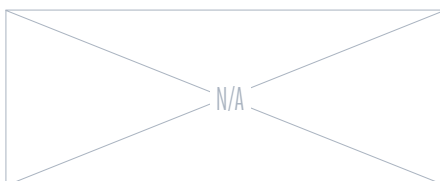
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: McMichael et al., 2004
EMISSION SCENARIO: S750 (IPCC, 2007)
BASE DATA: WHO BDD, 2011

➡ = 5 countries (rounded)

is considered one of the largest global contributors to sickness. Interpretations of the scale of the disease also vary dramatically, with some estimating more than 5 billion clinical episodes that resemble, and could be characterized as, malaria occurring in endemic areas annually (DCPP, 2006). Other factors, such as economic growth, will likely compensate for increased risks due to climate change, but they will also slow efforts to eradicate these diseases (Reiter, 2001).

Given that climate-aggravated malaria is highly prevalent in impoverished rural communities, delaying efforts to eradicate the disease will also delay development progress. As people in the affected communities also have a high propensity to migrate, malaria could also be carried to new areas, generating epidemics (Hales et al., 2000).

VULNERABILITIES AND WIDER OUTCOMES

Experts have identified various determinants of malaria and vector-borne diseases. Environmental conditions play an important role, such as high temperatures, high rainfall,

and humidity, together with pools of still, sun-drenched water (WHO, 2009). Social vulnerabilities include the level of education enabling people to take preventative measures, such as draining mosquito ponds, or address environmental predispositions to disease (Garg et al., 2009). Finally, poverty seriously inhibits access to medicine, vaccines, and preventative measures, such as insecticides and bed nets (Bremner, 2001).



Given that some 6 million people are affected, the economic productivity of those worst hit communities is jeopardized. For example, when members of rural, subsistence families lose working hours because of illness, their already minimal disposable income will be threatened further. The Ghana country study in this report illustrated how in malaria-infested areas, people were often ill several times in a given year. One study has showed how a 10% reduction in malaria is associated with a 0.3% increase in economic growth (Gallup and Sachs, 2001). With over 90% of the death toll assessed here affecting children under 15, a greater challenge faces those making efforts to improve child health, such as through attainment of Millennium Development Goal 4 for reducing child mortality.



RESPONSES



Responses are numerous and comprise preventative and treatment-type actions. Drugs and vaccines through national or region-specific immunization programmes (for dengue and yellow fever, not malaria), insecticide-treated bed nets, use of pesticides outdoors, insecticide for personal use and indoors, and civil engineering projects to drain malaria breeding sites are all key components of the anti-malaria and vector-borne response toolkit. Access to affordable health services, including through low-cost health insurance, is also critical for the speedy diagnosis and treatment of disease. Education and awareness can also help to raise the level of preventative responses and encourage health services to be sought soon after the onset of symptoms. Aside from civil infrastructure projects, vector-borne disease control is considered to be highly cost effective (DCPP, 2006).

THE INDICATOR

The indicator measures the effect of climate change on malaria, dengue fever, and yellow fever, based on World Health Organization research and data (WHO, 2004; WHO BDD, 2011). The climate change effect on malaria is used as a proxy for dengue and yellow fever, since research suggests similar mechanics apply (Epstein, 2001; Hales et al., 2002). Uncertainties in climate parameters, particularly rainfall, environmental, and socio-economic factors call into question the reliability of all estimations. The indicator is also conservative from the perspective that it does not take into account a variety of other vector-borne diseases, whose prevalence may also be significantly influenced by climate change, such as viral encephalitis, schistosomiasis, leishmaniasis, Lyme disease, and onchocerciasis (WHO, 2003).

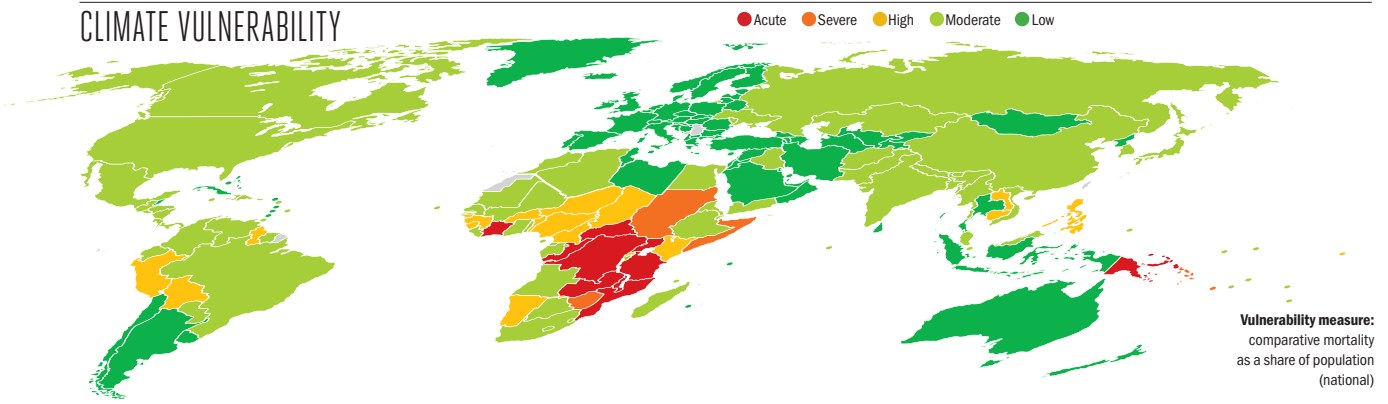
COUNTRY	 2010 2030		 2010 2030	
	2010	2030	2010	2030
ACUTE				
Central African Republic	400	400	100,000	100,000
Congo	200	200	55,000	55,000
Cote d'Ivoire	1,250	1,250	300,000	300,000
DR Congo	6,000	5,750	1,500,000	1,500,000
Malawi	600	600	150,000	150,000
Mozambique	1,750	1,750	500,000	450,000
Papua New Guinea	400	850	100,000	250,000
Tanzania	1,750	1,750	450,000	450,000
Uganda	1,500	1,500	400,000	400,000
Zambia	600	600	150,000	150,000
SEVERE				
Solomon Islands	20	15	5,250	4,500
Somalia	200	200	50,000	60,000
Sudan/South Sudan	750	950	200,000	300,000
Vanuatu	1	5	1,250	2,500
Zimbabwe	250	250	65,000	60,000
HIGH				
Benin	95	60	25,000	20,000
Bolivia	60	150	35,000	70,000
Burkina Faso	350	200	90,000	50,000
Burundi	150	150	40,000	40,000
Cambodia	90	90	25,000	30,000
Cameroon	250	150	65,000	40,000
Chad	250	150	65,000	35,000
Guinea	200	100	50,000	35,000
Guinea-Bissau	30	20	8,500	4,750
Guyana	1	5	800	1,250
Kenya	250	250	65,000	70,000
Kiribati	1	1	150	350
Laos	40	50	15,000	20,000
Namibia	30	30	10,000	10,000

COUNTRY	 2010 2030		 2010 2030	
	2010	2030	2010	2030
ACUTE				
Niger	250	150	70,000	40,000
Nigeria	2,250	1,250	600,000	400,000
Peru	100	200	60,000	100,000
Philippines	450	900	250,000	500,000
Rwanda	70	65	20,000	20,000
Sierra Leone	150	75	35,000	20,000
MODERATE				
Afghanistan	10	15	2,750	6,000
Algeria			5	5
Angola	150	90	65,000	35,000
Bangladesh			45	15,000
Barbados			5	15
Bhutan				100
Botswana	1	1	400	400
Brazil	100	250	55,000	100,000
Canada			100	150
Cape Verde			5	1
China	50	80	25,000	45,000
Colombia	45	100	25,000	55,000
Comoros	5	1	1,000	550
Costa Rica			20	55
Djibouti	1	1	350	400
Dominica			10	15
Dominican Republic	10	20	5,250	10,000
Ecuador	10	20	5,500	10,000
Egypt	10	10	4,250	5,000
El Salvador	1	5	900	2,000
Equatorial Guinea	5	5	2,750	1,500
Eritrea	1	1	450	450
Ethiopia	400	400	100,000	100,000
Fiji	1	1	350	550
Gabon	5	5	2,250	1,500

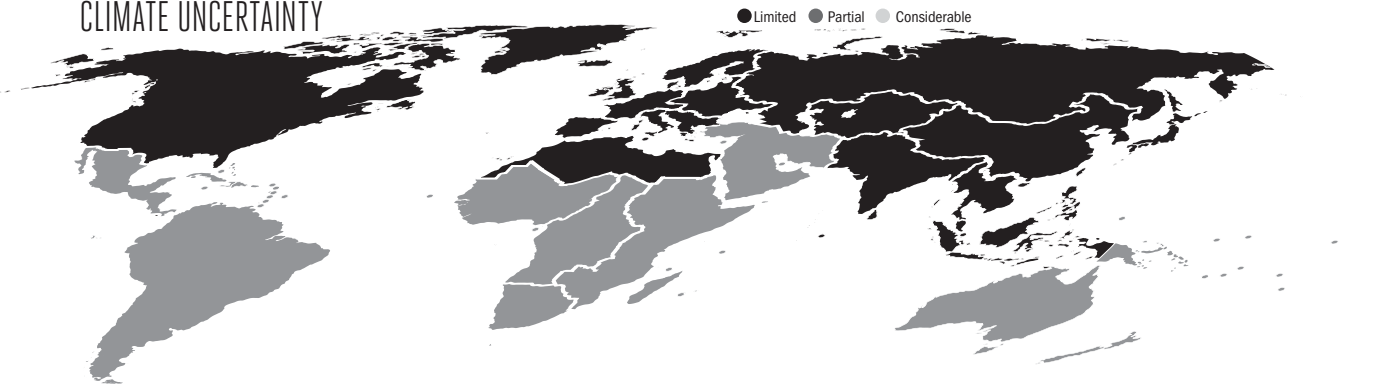
COUNTRY	 2010 2030		 2010 2030	
	2010	2030	2010	2030
ACUTE				
Gambia	15	10	4,000	2,250
Ghana	100	65	30,000	20,000
Guatemala	1	5	800	1,750
Haiti	35	45	10,000	20,000
Honduras	5	10	2,500	6,000
India			300	95,000
Iraq				5 15
Jamaica				5 5
Japan				100 150
Kazakhstan				80 150
Lesotho				25 35
Liberia	40	25	10,000	6,750
Madagascar	15	10	4,250	2,250
Malaysia	30	50	10,000	20,000
Maldives				75
Mali	150	90	45,000	25,000
Marshall Islands				65 150
Mauritania	10	5	3,000	1,750
Mexico	1	5	700	1,500
Micronesia				45 95
Moldova				35 65
Morocco				1 5
Myanmar			85	25,000
Nepal			1	450
Nicaragua	1	5	800	1,750
Pakistan	100	400	40,000	100,000
Palau				5 10
Panama				1 1
Paraguay				1 5
Russia	1	1	300	450
Samoa			1	150 300
Sao Tome and Principe				40 20



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	👤		👤		COUNTRY	💀		👤		COUNTRY	💀		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Senegal	100	65	30,000	20,000	Croatia					New Zealand				
Singapore	1	1	250	300	Cuba					North Korea				
South Africa	5	5	2,000	2,000	Cyprus					Norway				
South Korea	1	1	350	600	Czech Republic					Oman				
Suriname	1	1	500	1,000	Denmark					Poland				
Swaziland			75	75	Estonia					Portugal				
Togo	40	25	10,000	6,250	Finland					Qatar				
Tonga		1	85	200	France					Romania				
Trinidad and Tobago			20	40	Georgia					Saint Lucia				
Tuvalu			5	5	Germany					Saint Vincent				
Ukraine	1	1	200	300	Greece					Saudi Arabia				
United States	1	1	600	1,000	Grenada					Seychelles				
Venezuela	15	30	5,250	15,000	Hungary					Slovakia				
Vietnam	40	55	15,000	25,000	Iceland					Slovenia				
Yemen	80	95	20,000	25,000	Indonesia					Spain				
LOW					Iran					Sri Lanka				
Albania					Ireland					Sweden				
Antigua and Barbuda					Israel					Switzerland				
Argentina					Italy					Syria				
Armenia					Jordan					Tajikistan				
Australia					Kuwait					Thailand				
Austria					Kyrgyzstan					Timor-Leste				
Azerbaijan					Latvia					Tunisia				
Bahamas					Lebanon					Turkey				
Bahrain					Libya					Turkmenistan				
Belarus					Lithuania					United Arab Emirates				
Belgium					Luxembourg					United Kingdom				
Belize					Macedonia					Uruguay				
Bosnia and Herzegovina					Malta					Uzbekistan				
Brunei					Mauritius									
Bulgaria					Mongolia									
Chile					Netherlands									

MENINGITIS



ESTIMATES GLOBAL CLIMATE IMPACT

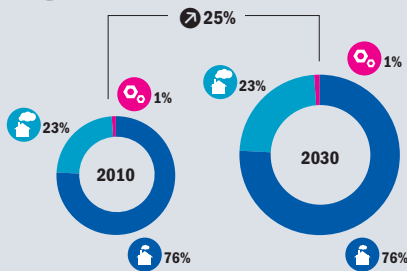
2010 EFFECT TODAY



2030 EFFECT TOMORROW



MORTALITY IMPACT



SEVERITY



AFFECTED



INJUSTICE



PRIORITY



MDG EFFECT



➤ Meningitis is growing worldwide and claims around 350,000 lives a year

➤ Humidity levels, wind, and dust are linked to outbreaks of the disease, factors actively influenced by climate change

➤ A “meningitis belt” stretches across northern Sub-Saharan Africa from Senegal to Ethiopia, sharing dusty and dry conditions, favouring meningitis

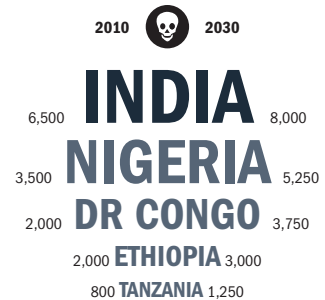
➤ Vaccines exist, but hundreds of millions of people living in risk areas around the world create a serious challenge for mass immunization

➤ Broader vulnerability measures, such as health education campaigns and improved sanitation will also be crucial

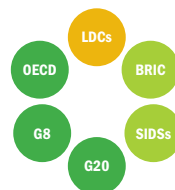
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



Deaths
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Deaths per 10 million
 Change in relation to overall global population and/or GDP

Meningitis is a lethal and greatly feared disease in affected areas, because of the rapid onset of symptoms and serious risk of mortality, as well as high rates of infection—as many as 1 per 1,000 in parts of the African Sahel (Adamo et al., 2011). With mortality having more than doubled since the year 2000 and risks escalating as a result of climate change, mass inoculation is an attractive and life-saving component of any response to this growing challenge. However, beyond tackling the disease itself, it is also critical to address underlying vulnerabilities, such as over-grazing, soil degradation, deforestation, and the lack of adequate sanitation.

CLIMATE MECHANISM

The fact that meningococcal meningitis is largely a seasonal disease indicates the extent to which its prevalence is determined by weather-related parameters directly affected by climate change. Models that attempt to recreate meningitis epidemics show a high degree of success when calibrated with climate and environmental parameters. Meningitis epidemics are more likely to

occur during the hottest, driest periods which are accompanied by high dust content in the air, and thus most likely to abate with the onset of the rainy season (Molesworth et al., 2006). The bacteria which causes meningitis is spread from person to person through coughing and sneezing, much like influenza or the common cold, and can be spread through poor sanitation (WHO, 2011; Schonning and Stenström, 2004). Bacteria can be present in a significant proportion of a population in areas affected by meningitis, but still remain benign. Dust is a key trigger, because it damages the tissues of the nose and throat, facilitating the passage of pathogenic meningitis bacteria into the bloodstream (Thomson et al., 2009). Climate change affects both weather (heat, humidity, wind) and the environment (extent of vegetation or desertification) and can increase heat, dust, and wind, resulting in exposure and creating peaks of meningitis (Patz et al., 1996; Sultan et al., 2005). Climate change intensifies those factors that most determine meningitis outbreaks, particularly humidity (drought) and dust levels for areas that will become more arid (Sheffield and Wood, 2008; Prospero and Lamb, 2003).

IMPACTS

The global impact of climate change on meningitis is estimated to cause around 20,000 deaths a year in 2010, with 50,000 people affected. Some 30 countries are acutely vulnerable to the impact of climate change on meningitis exclusively in Africa, both inside and beyond the meningitis belt. Least developed and landlocked countries of Africa are significantly more vulnerable than countries with even marginally higher levels of development. The largest impacts are estimated to occur in India, with nearly 7,000 deaths, and in Nigeria, the DR Congo, and Ethiopia, each of which is estimated to have an annual death toll in the thousands. As incidence of the disease is rapidly increasing, it is expected to moderately expand through to 2030 and increase proportionate to population growth, claiming over 40,000 a year by 2030 with 80,000 people affected each year.

THE BROADER CONTEXT

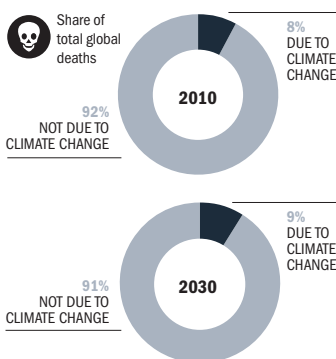
Meningitis underwent explosive growth in the first decade of the 21st century, doubling from just over 150,000 deaths in 2000, to well over 350,000 deaths a

year by 2008—this in spite of a dramatic increase in economic development during that period. Meningitis is one of the few communicable diseases to have rapidly expanded in the past decade (WHO BDD, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Pockets of environmental vulnerability to meningitis exist around the world, but outside of Africa, India makes up a large share of the remainder of the global burden of the disease. Environmental predispositions to meningitis are exacerbated through land degradation, such as deforestation, over-irrigation, and over-grazing—effects that also generate the dry and dusty conditions that are most favourable to meningitis (Nicholson et al., 1998). The incidence of meningitis is also closely related to cramped living conditions and poor sanitation, inadequate hygiene and access to water, since infection is carried through human contact, coughing, and sneezing (WHO, 2011). Levels of awareness and education can affect understanding of the disease and largely determine the measures taken by individuals to prevent contracting the

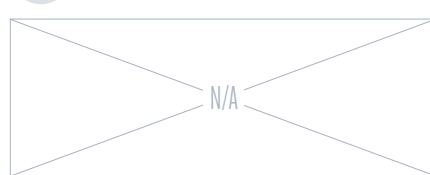
BIGGER PICTURE



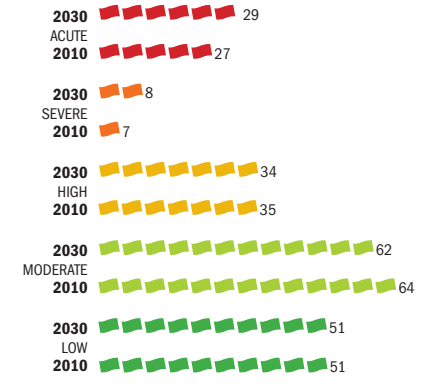
SURGE



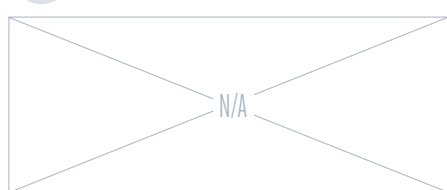
OCCURRENCE



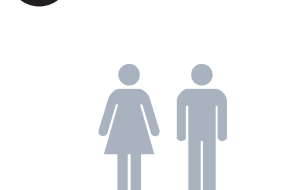
VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Adamo et al., 2011; Sheffield and Wood, 2008
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: WHO BDD, 2011

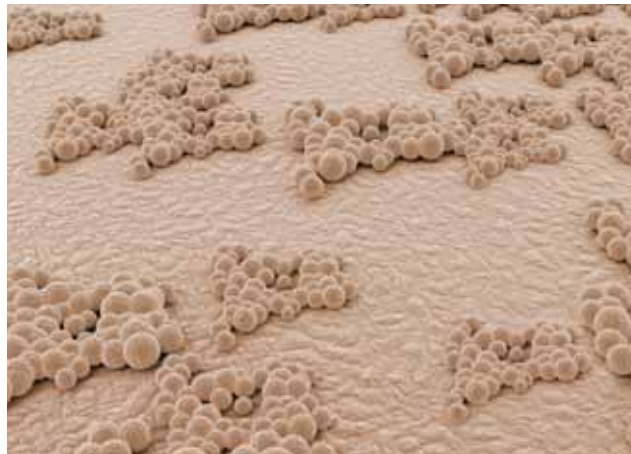
➡ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

disease (Nutbeam, 2000). Given the high prevalence of meningitis among some of the world's poorest communities, the impact of climate change on the disease is a serious concern for human development progress (Arora, 2001). More tangibly, the increasing prevalence of meningitis with its high death rate among children—around two-thirds of all mortality—limits progress in lag regions towards the achievement of Millennium Development Goal 4, which aims to tangibly reduce child mortality (WHO BDD, 2011).

RESPONSES

Meningitis is one of the few major deadly infectious diseases affecting developing countries for which several effective vaccines already exist. Immunization is a particularly cost effective response. There are now several success stories in the fight against meningitis, where programmes have managed to significantly reduce the burden of the disease (Kshirsagar et al., 2007; LaForce and Okwo-Bele, 2011). Given the large scale of the populations at risk—in Africa alone comparable to the entire population of the US—full breadth vaccination becomes



prohibitively expensive, even using the lowest-cost solutions available. For this reason, response strategies to meningitis outbreaks have favoured early warning monitoring and vaccine interventions at the community level, when outbreaks of meningitis exceed a certain threshold (LaForce et al., 2007). Although newer, more effective meningitis vaccines are currently being disseminated in affected zones of the Sahel which promise to dramatically reduce the incidence of meningitis, it

could take a full decade to provide them for the required numbers (Thomson et al., 2009).

Improving sanitation and living conditions, promoting education and awareness, and tackling environmental issues, including overgrazing, deforestation and land degradation will address the underlying causes of meningitis, in addition to ensuring the other well known benefits of such actions (DCPP, 2006; Nutbeam, 2000; Donohoe, 2003).

THE INDICATOR

The indicator is a simple model that relates the incidence of meningitis to the incidence of drought. Global changes in the frequency of drought were linked to a meningitis risk model and population density, the indicator being highly sensitive to the latter, since close human contact is a major vulnerability driver for meningitis outbreaks (Sheffield and Wood, 2007; Adamo et al., 2011). The indicator then draws on the main WHO database to estimate how the current burden of meningitis evolves as drought incidence changes (WHO, 2011; WHO BDD, 2011). Uncertainty in relation to the climate effect is present due to the unpredictability of future rainfall patterns, a determining factor of drought.

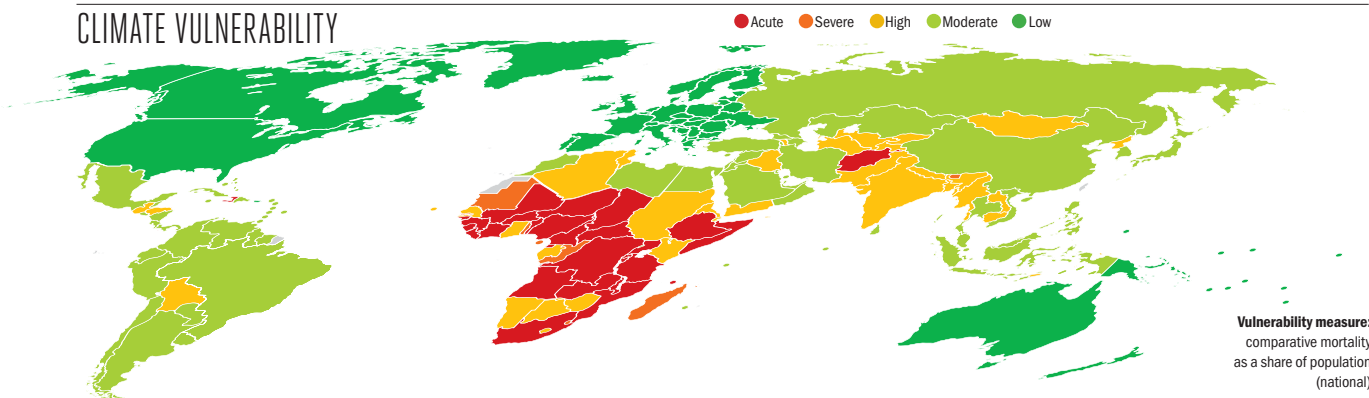
COUNTRY	☠		👤	
	2010	2030	2010	2030
ACUTE				
Afghanistan	500	850	850	1,250
Angola	500	900	1,250	2,500
Benin	250	350	350	600
Burkina Faso	300	600	500	950
Burundi	200	300	300	500
Cameroon	500	700	800	1,250
Central African Republic	90	150	150	200
Chad	300	550	500	850
Comoros	15	25	25	35
Cote d'Ivoire	450	600	700	1,000
DR Congo	2,000	3,750	3,250	6,000
Equatorial Guinea	15	25	50	85
Ethiopia	2,000	3,000	3,250	5,000
Guinea	250	400	400	600
Guinea-Bissau	65	100	100	150
Haiti	200	300	350	500
Liberia	90	150	150	300
Malawi	400	650	650	1,000
Mali	250	400	400	650
Mozambique	400	550	600	900
Niger	450	800	700	1,250
Nigeria	3,500	5,250	5,500	8,750
Rwanda	150	250	250	400
Sierra Leone	150	300	300	450
Somalia	150	250	250	450
South Africa	700	700	2,250	2,250
Tanzania	800	1,250	1,250	2,000
Uganda	500	900	800	1,500
Zambia	250	400	400	600
SEVERE				
Bhutan	5	10	10	15

COUNTRY	☠		👤	
	2010	2030	2010	2030
HIGH				
Congo	40	75	65	100
Gambia	15	25	30	40
Madagascar	200	300	300	500
Mauritania	45	75	70	100
Sao Tome and Principe	1	1	1	5
Swaziland	10	10	25	35
Togo	65	100	100	150
Algeria	150	200	350	550
Armenia	10	10	20	25
Bangladesh	600	800	950	1,250
Bolivia	45	75	150	200
Botswana	15	15	45	55
Cambodia	100	150	200	250
Cape Verde	1	5	5	10
Djibouti	5	5	10	15
Eritrea	25	35	40	60
Gabon	10	15	35	55
Ghana	95	150	150	200
Guatemala	50	90	150	250
Honduras	20	35	55	90
India	6,500	8,000	10,000	15,000
Iraq	150	250	400	700
Kenya	200	300	350	450
Kyrgyzstan	20	30	35	50
Laos	50	65	80	100
Lesotho	15	20	30	30
Mongolia	10	10	15	15
Myanmar	250	300	400	500
Namibia	10	15	25	40
Nepal	100	200	200	300
North Korea	90	100	150	150

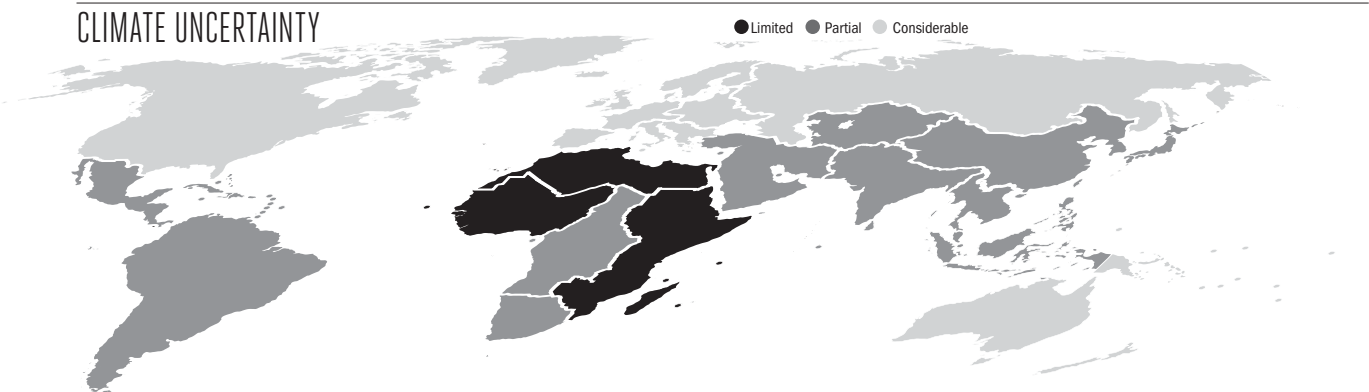
COUNTRY	☠		👤	
	2010	2030	2010	2030
MODERATE				
Pakistan	700	1,000	1,250	1,750
Senegal	100	150	150	250
Sudan/South Sudan	350	550	550	900
Tajikistan	55	80	85	150
Timor-Leste	5	5	10	10
Tunisia	45	60	100	150
Turkmenistan	25	35	60	95
Uzbekistan	90	150	150	200
Yemen	150	300	200	500
Zimbabwe	85	100	150	200
Antigua and Barbuda				
Argentina	40	55	150	200
Azerbaijan	20	25	55	70
Bahamas			1	1
Bahrain	1	1	5	10
Barbados			1	1
Belize			1	1
Brazil	200	300	550	750
Brunei			1	1
Chile	10	15	35	50
China	800	850	2,000	2,250
Colombia	55	75	150	200
Costa Rica	5	5	10	15
Cuba	5	5	15	20
Cyprus			1	1
Dominica				
Dominican Republic	15	20	40	60
Ecuador	20	30	55	80
Egypt	200	300	500	800
El Salvador	10	15	30	45
Georgia	5	5	15	15



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	👤		👤		COUNTRY	💀		👤		COUNTRY	💀		👤	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Grenada				1	Suriname	1	1	5	5	Latvia				
Guyana	1	1	1	1	Syria	30	50	80	150	Lithuania				
Indonesia	550	650	1,500	1,750	Thailand	40	50	100	150	Luxembourg				
Iran	65	90	150	250	Trinidad and Tobago	1	1	5	5	Macedonia				
Israel	1	5	25	35	Turkey	100	150	350	450	Malta				
Jamaica	5	10	15	20	United Arab Emirates	5	5	30	45	Marshall Islands				
Japan	25	25	250	250	Uruguay	1	5	10	10	Micronesia				
Jordan	10	15	25	40	Venezuela	25	40	85	100	Moldova				
Kazakhstan	40	45	100	100	Vietnam	70	85	100	150	Netherlands				
Kuwait	1	1	5	10	LOW					New Zealand				
Lebanon	5	5	15	25	Albania					Norway				
Libya	5	10	20	25	Australia					Palau				
Malaysia	10	15	30	40	Austria					Papua New Guinea				
Maldives	1	1	1	1	Belarus					Poland				
Mauritius	1	1	5	5	Belgium					Portugal				
Mexico	30	45	100	150	Bosnia and Herzegovina					Romania				
Morocco	40	55	100	150	Bulgaria					Samoa				
Nicaragua	15	20	20	35	Canada					Slovakia				
Oman	1	1	1	5	Croatia					Slovenia				
Panama	5	5	10	20	Czech Republic					Solomon Islands				
Paraguay	15	25	40	65	Denmark					Spain				
Peru	55	75	150	200	Estonia					Sweden				
Philippines	200	250	500	650	Fiji					Switzerland				
Qatar			1	1	Finland					Tonga				
Russia	200	200	650	650	France					Tuvalu				
Saint Lucia			1	1	Germany					Ukraine				
Saint Vincent					Greece					United Kingdom				
Saudi Arabia	15	25	150	300	Hungary					United States				
Seychelles			1	1	Iceland					Vanuatu				
Singapore	1	1	5	5	Ireland									
South Korea	5	5	45	50	Italy									
Sri Lanka	25	25	65	75	Kiribati									



INDUSTRY STRESS



AGRICULTURE



FISHERIES



FORESTRY



HYDRO ENERGY



TOURISM



TRANSPORT

↓ **\$** 50 BILLION LOSS 2010
350 BILLION LOSS 2030



↓ **\$** 15 BILLION LOSS 2010
150 BILLION LOSS 2030



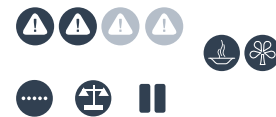
↓ **\$** 5 BILLION LOSS 2010
45 BILLION LOSS 2030



↓ **\$** 5 BILLION GAIN 2010
25 BILLION GAIN 2030



↓ **\$** NIL 2010
NIL 2030



↓ **\$** 1 BILLION LOSS 2010
5 BILLION LOSS 2030



AGRICULTURE



ESTIMATES GLOBAL CLIMATE IMPACT

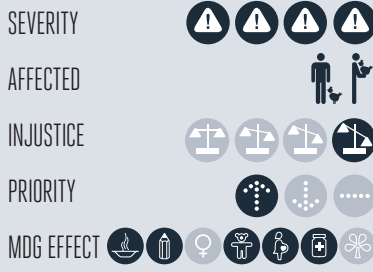
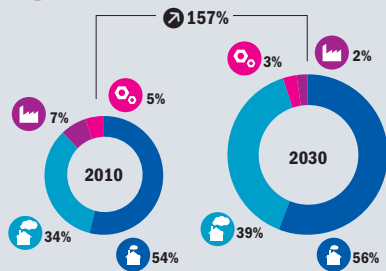
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **50** BILLION

2030 EFFECT TOMORROW

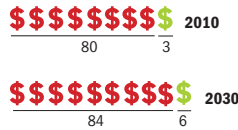
\$ USD LOSS PER YEAR **350** BILLION

ECONOMIC IMPACT



- Land-based agriculture is the sector worst affected by climate change, while global demand for food and agricultural products is booming
- Africa is most vulnerable, but several large Asian economies, small islands, and parts of Latin America also suffer
- The worst-affected economies have the highest shares of agricultural workers, so impacts will likely worsen national unemployment
- Adaptation responses abound, but technical solutions are not viable where farmers lack the means to take measures or finance them
- Extreme effects on rural subsistence farmers clearly delays human development, causing new food emergencies

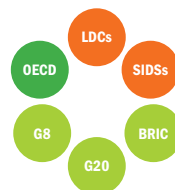
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
 Developing Country Low Emitters (blue icon) Developed (purple icon)
 Developing Country High Emitters (light blue icon) Other Industrialized (pink icon)

★ \$ = Losses per 10,000 USD of GDP
 Change in relation to overall global population and/or GDP (arrow icon)

◎ \$ = Millions of USD (2010 PPP non-discounted)

Agriculture was one of the first sectors widely recognized to be heavily affected by climate change (IPCC, 1990; Cline, 1992). Agriculture is one of the most significant and best studied impacts of climate change assessed in the Monitor, and for many, the best known (Nordhaus and Boyer, 1999). Within regions and countries, some will be affected, while others will benefit (Bindi and Olesen, 2011). Climate change will have a particularly serious impact on farmers with limited possibilities for adapting to shifts in climate, e.g., by planting different varieties of plants and implementing new irrigation techniques (Kurukulasuriya et al., 2006; Easterling in Hillel and Rosenzweig (eds.), 2011). Agricultural losses from climate change harm subsistence farmers whose insufficient income or capital reserves prevent them from taking steps to adapt to weather change (IPCC, 2007). In developing countries with economies still heavily reliant on agriculture, the negative effects for this sector are estimated to be severe and widespread (World Bank Data, 2012). The research undertaken as a part of the Monitor's development underscored the importance of empowering vulnerable farmers to generate more value for their

products in order to break the vicious spiral of poverty (see in particular the Ghana country study).

CLIMATE MECHANISM

Climate change increases heat stress and evaporation, and aggravates drought (Hansen et al., 2007). While many of these also change in relation to natural weather phenomena such as El Niño, recent evidence suggests a shift to more extreme warm weather conditions (Jung et al., 2010; Hansen et al., 2012). Climate change is altering the pattern of rainfall, which may become more or less abundant or more erratic (Kharin et al., 2007). Rainfall shifts can damage those crops and livestock, which are less suited to the changing weather or susceptible to disease or declining yield. Agricultural losses can be measured when climate deviates from optimal growing conditions, resulting in lower yield per acre (Cline, 2007). Gradual changes can be compounded by more extreme weather, especially large-scale floods (Mueller and Quisumbing, 2011).

IMPACTS

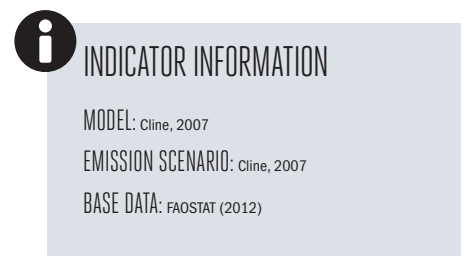
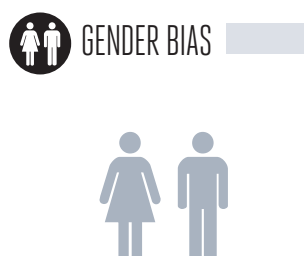
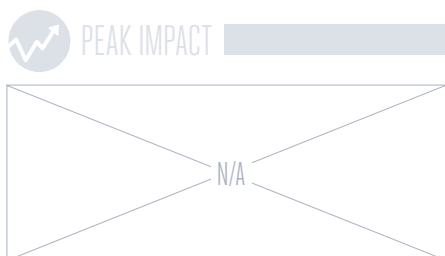
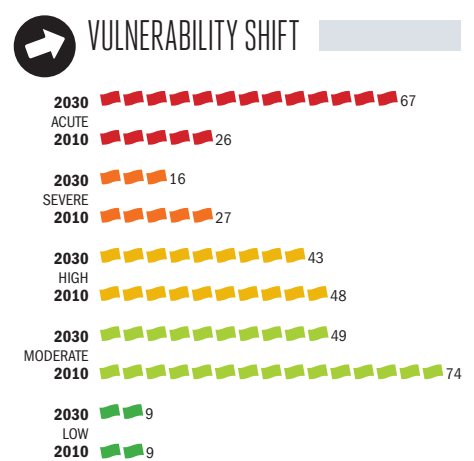
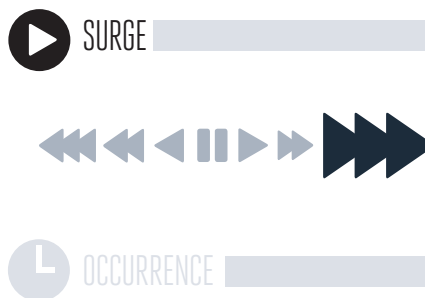
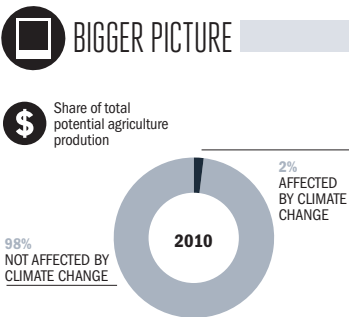
Globally, climate change is already estimated to cause 50 billion dollars a

year in agricultural losses, around 90% of which occur in developing countries, since the sector accounts for between just 1–5% of GDP in most developed countries. However, costs are still relatively small in most countries, except for a small handful of the most vulnerable, some of whom are already estimated to lose 1–2% of GDP. Low-income and least developed countries are more vulnerable and suffer the most extreme effects, creating serious concern for food security. Regionally, Sub-Saharan Africa is singled out, Central, East, and West Africa most seriously. Latin America, the Pacific, and parts of Asia also have elevated levels of vulnerability. India and China are currently estimated to suffer the greatest share of the total impact, each with 2010 losses estimated at over 5 billion dollars a year. A small fraction of countries are expected to experience any gains in the agricultural sector in the near future. The scale of effect jumps rapidly over the course of 20 years from less than 0.1% of global income in 2010, more than doubling as a share of global GDP to about 0.2% in 2030, or over 350 billion dollars in yearly losses. However, the rate of increase in damage is declining: as the share of global output

in service and industrial sectors grows, agriculture is expected to continue to lose importance—in line with the expansion of industrialization over the next 20 years (OECD, 2012).

THE BROADER CONTEXT

The agricultural sector is also struggling to meet the food demands of growing and wealthier populations (FAOSTAT, 2012; Friedman, 2009). But climate change is preventing the sector from meeting this demand, as indicated by both scientific research and statistical analysis (Cline, 2007). It will also lower the comparative advantage of agriculture-based, lower-income economies, with effects estimated to be especially severe for Africa (Nelson et al., 2009; Tol, 2011). Nevertheless, carbon fertilization—through which high concentrations of CO2 in the atmosphere might improve plant productivity and agricultural outputs—is understood by researchers to outweigh losses due to climate change at least early on (Mendelsohn in Griffin (ed.), 2003). This effect is accounted for in the Carbon section of the Monitor; where large-scale benefits are estimated by the IPCC to be possible, they never outweigh the costs of climate



= 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

change estimated here (IPCC, 2007). Recent research has been cautious about the practical realisation of these benefits (Ainsworth et al., 2008; Leaky et al., 2009). A World Bank study recently suggested that a high carbon fertilization effect would reduce adaptation costs by less than 10% (World Bank, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Underscoring the vulnerability of developing countries, especially the least developed, is the significance at the national level of the size and composition of the agricultural sector in terms of output and workforce. One of the few advantages that small-scale farmers have over large commercial operators is the ability to adjust crop varieties or experiment more readily with different crops. Agricultural companies that practice large-scale mono-cropping may suffer correspondingly large losses, if climate conditions shifted to the disadvantage of the chosen crops (Brondizio and Moran, 2008). Countries that rely heavily on just one or two cash crops face similar concerns, as highlighted in

the Ghana country study in this report. Poor environmental protection also increases vulnerability, such as when biodiversity losses inhibit resistance to invasive species (Castree et al. (eds.), 2009). In general, rainfed-only agriculture is much more vulnerable than irrigated land (Kurukulasuriya et al., 2006).

Communities reliant on subsistence farming are dangerously vulnerable, as global warming accelerates; the World Health Organization has estimated climate change to be a major driver of contemporary malnutrition (WHO, 2004). These health effects are measured in the Health Impact section of the Monitor.

Climate change is a major risk for food insecurity, since a number of the world's food-insecure regions are expected to experience the most severe climate shocks (Lobell et al., 2008). Indeed, climate effects on agriculture harm development, since they diminish the disposable incomes of communities already struggling to achieve gains (UNDP, 2007). They also drive the seasonal rural-urban migration of young adults, as shown by the Ghana country study.

RESPONSES

The vast literature on the impact of climate change on agriculture cannot be summarized here. All societies are understood to be "adaptive," but communities differ considerably in this capacity (Adger et al., 2003; Dixon et al., 2003). Response options vary widely, including from large-scale or micro irrigation infrastructure, to index-based weather insurance, new/hybrid seeds, and education/rural extension programmes. The involvement of local communities in the design of adaptation measures is advised, so that initiatives are feasible and practical (Smit and Wandel, 2006). The Monitor's country studies emphasize that where farmers cannot afford to take measures, efforts should focus on increasing capacity for investment and enabling local products to access more lucrative global supply chains and markets. Farmers with growing incomes could make better use of parallel extension schemes that offer appropriate adaptation options. Development plans that promote biodiversity and crop and livestock diversification will also lower vulnerability to plant and animal disease. Macroeconomic risks can only be offset by ensuring steady growth of less sensitive industrial and service sectors.

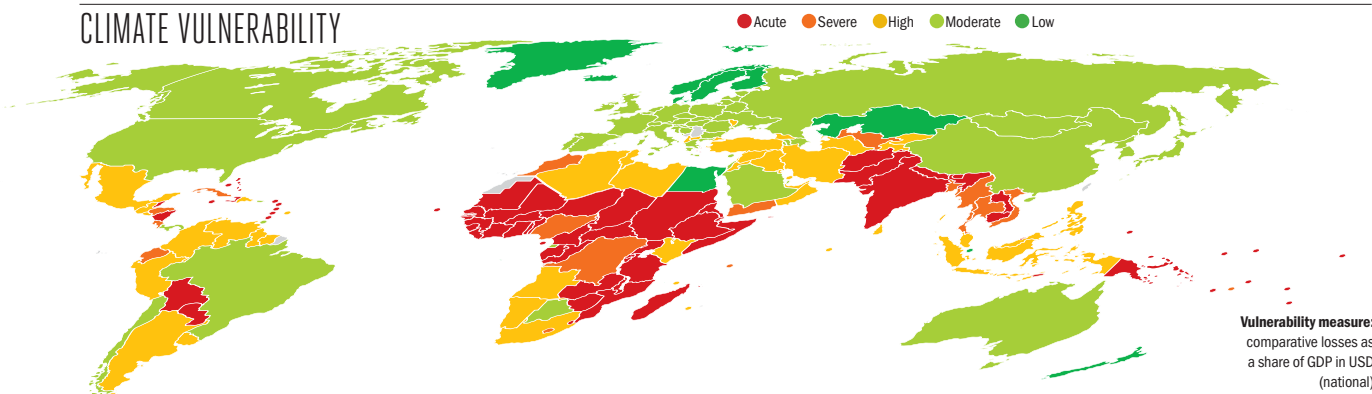
THE INDICATOR

This Indicator relies on a recent and comprehensive global review of agricultural impacts of climate change that combines a wealth of experience from a range of methods and models (Cline, 2007). The difficulties in predicting rainfall accurately make some regions more uncertain about agriculture outcomes. Carbon fertilization or other effects related to atmospheric pollutants are not considered here. The Monitor accounts for the effect under Agriculture in the Carbon section of this report.

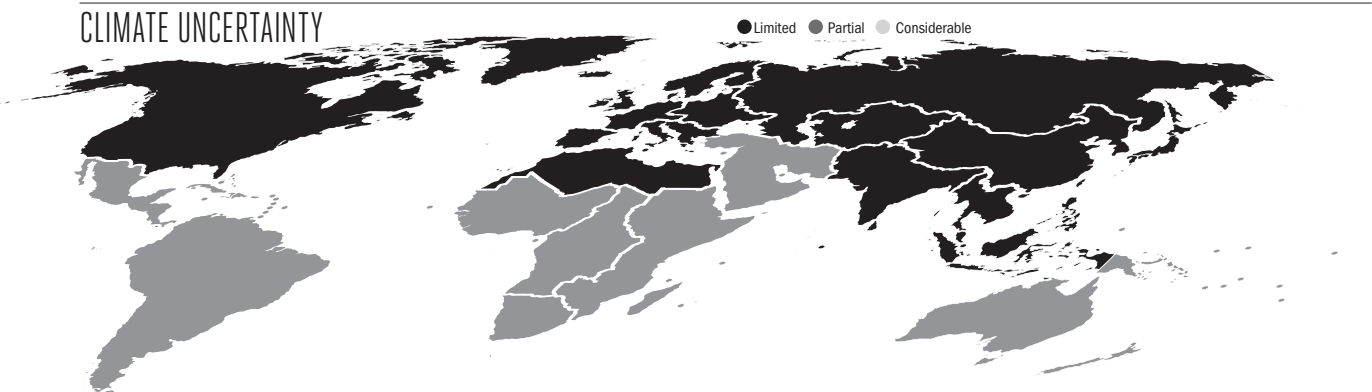
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE								
Afghanistan	85	700	Laos	90	1,000	Uganda	150	1,000
Antigua and Barbuda	5	45	Liberia	15	100	Vanuatu	5	40
Bahamas	45	350	Madagascar	100	800	Zambia	85	600
Belize	10	75	Malawi	150	1,000	Zimbabwe	75	500
Benin	90	600	Mali	150	1,000	SEVERE		
Bhutan	10	100	Marshall Islands	1	15	Bangladesh	650	5,500
Bolivia	150	1,250	Mauritania	40	250	Costa Rica	100	850
Brunei	75	650	Micronesia	5	30	Cuba	250	2,000
Burkina Faso	70	450	Mozambique	100	800	DR Congo	60	400
Burundi	60	400	Nepal	150	1,250	Ecuador	200	1,500
Cambodia	100	1,500	Nicaragua	55	450	Fiji	10	75
Cameroon	200	1,250	Niger	65	450	Honduras	75	600
Cape Verde	5	45	Pakistan	1,500	15,000	Lesotho	10	55
Central African Republic	50	350	Palau	1	10	Morocco	400	3,000
Chad	60	400	Papua New Guinea	45	350	Myanmar	200	1,500
Congo	50	350	Paraguay	150	1,250	Nigeria	900	6,250
Cote d'Ivoire	150	900	Rwanda	100	750	Seychelles	5	30
Djibouti	10	70	Saint Lucia	5	50	Thailand	1,250	10,000
Dominica	5	25	Saint Vincent	5	30	Uzbekistan	200	1,500
Eritrea	15	85	Samoa	5	30	Vietnam	550	6,000
Ethiopia	450	3,000	Sao Tome and Principe	1	15	Yemen	100	800
Gabon	300	2,000	Senegal	250	1,750	HIGH		
Gambia	15	100	Sierra Leone	30	200	Albania	15	100
Ghana	200	1,500	Solomon Islands	5	60	Algeria	300	2,250
Grenada	5	35	Somalia	35	250	Angola	150	1,000
Guinea	150	900	Sudan/South Sudan	650	5,000	Argentina	550	4,500
Guinea-Bissau	15	100	Swaziland	15	100	Bahrain	25	200
Haiti	35	300	Tanzania	350	2,500	Barbados	5	45
India	15,000	100,000	Timor-Leste	10	80	Colombia	300	2,500
Jamaica	250	2,000	Togo	55	400	Comoros	1	5
Kiribati	1	20	Tonga	5	25	Dominican Republic	150	1,000
			Tuvalu	1	1	El Salvador	60	500



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Georgia	15	100	Venezuela	350	2,750	Mongolia	1	15
Guatemala	100	850	MODERATE			Netherlands	50	100
Guyana	5	55	Armenia	5	45	North Korea	10	100
Indonesia	1,250	9,500	Australia	450	1,000	Panama	20	150
Iran	1,250	8,750	Austria	15	35	Poland	90	500
Iraq	150	1,000	Azerbaijan	25	200	Portugal	65	150
Jordan	20	150	Belarus	55	400	Qatar	1	10
Kenya	60	400	Belgium	35	85	Romania	100	800
Kuwait	95	750	Bosnia and Herzegovina	10	90	Russia	400	2,750
Kyrgyzstan	15	100	Botswana	1	10	Saudi Arabia	100	950
Lebanon	70	550	Brazil	900	6,750	Slovakia	10	50
Libya	150	1,000	Bulgaria	40	250	Slovenia	5	30
Macedonia	15	100	Canada	35	80	South Korea	550	3,250
Malaysia	500	4,000	Chile	150	800	Spain	350	850
Maldives	1	25	China	5,500	55,000	Switzerland	10	25
Mauritius	25	200	Croatia	25	150	Trinidad and Tobago	10	75
Mexico	1,250	7,750	Cyprus	1	1	Ukraine	150	1,250
Moldova	15	90	Czech Republic	25	100	United Kingdom	60	150
Namibia	10	80	Equatorial Guinea	5	50	United States	1,000	2,500
Oman	60	500	Estonia	5	20	LOW		
Peru	250	2,000	France	300	700	Denmark	-25	-60
Philippines	550	4,500	Germany	90	200	Egypt	-350	-2,750
South Africa	550	3,750	Greece	200	450	Finland	-15	-35
Sri Lanka	100	900	Hungary	30	150	Iceland		-1
Suriname	5	35	Ireland	1	5	Kazakhstan	-55	-400
Syria	90	700	Israel	80	450	New Zealand	-5	-10
Tajikistan	15	100	Italy	300	650	Norway	-5	-15
Tunisia	150	1,000	Japan	450	1,000	Singapore		
Turkey	1,250	3,000	Latvia	5	30	Sweden	-20	-40
Turkmenistan	40	300	Lithuania	15	100			
United Arab Emirates	200	1,500	Luxembourg		1			
Uruguay	30	250	Malta		1			

FISHERIES



ESTIMATES GLOBAL CLIMATE IMPACT

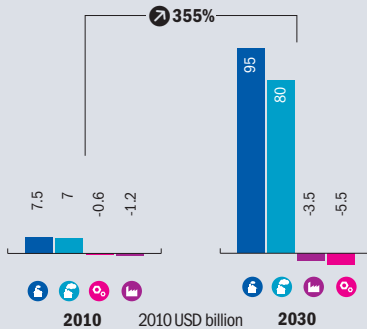
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **15** BILLION

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **150** BILLION

\$ ECONOMIC IMPACT



- Climate change is not just occurring over land, but also underwater
- Water temperature also rises as the planet heats up
- Over 1,000 commercially exploited fish species live in specific aquatic zones already affected: the location of their preferred waters shift as the tropics reach temperatures with no analogue to existing fish habitats and as cooler seas disappear
- Falling fish stocks will affect food security and human development in low-income fishing communities
- Increasing the sustainability of fishing operations and enhancing marine conservation zones may alleviate these strains

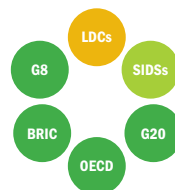
★ RELATIVE IMPACT



🎯 HOTSPOTS



🌐 GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
 Developing Country Low Emitters (blue icon) Developed (purple icon)
 Developing Country High Emitters (light blue icon) Other Industrialized (pink icon)

★ **\$** = Losses per 10,000 USD of GDP
 🎯 **\$** = Millions of USD (2010 PPP non-discounted)
 ↗ = Change in relation to overall global population and/or GDP

As climate change warms the world's oceans, seas, lakes and rivers, it is fundamentally changing the marine habitat, forcing fish to migrate or perish (Perry et al., 2005; Ficke et al., 2007; Rijnsdorp et al., 2009; Last et al., 2010; Cheung et al., 2011; Engelhard, 2011). Some far northern or southern zones may experience improved stocks as sea ice recedes and fish from the hottest waters seek relative cool (Hiddink and Hofstede, 2008). Declines brought about by climate change will only increase over time as temperature rise accelerates (Cheung et al., 2009). The world's fish stocks are in large-scale, long-term decline, with the ocean fish catch now half what it was 50 years ago due to an increase in commercial catch boats and unsustainable fishing (FAO, 2007; Watson et al., 2012). Climate change is the most significant driver of global marine ecosystem decline (Halpern et al., 2008). Responding effectively is challenging, since the international cooperation and regulations required are notoriously difficult to conclude, monitor, and enforce (Barkin in Dinar (ed.), 2011). In developing countries hard hit by declining fish stocks, food security and livelihoods are at risk (Srinivasan et al., 2010).

CLIMATE MECHANISM

Water temperature is a defining element of fish habitat (Hoegh-Guldberg and Bruno, 2010). Fish have low tolerance for thermal extremes (Pörtner and Rainer Knust, 2007). Part of the sea-level rise from climate change is caused by the thermal expansion of the seas as they warm (Domingues et al., 2008). As equatorial waters undergo unprecedented temperature increases beyond familiar heat thresholds for fish, the total available range of habitats is disappearing (Cheung et al., 2009). Nutrients are also declining in the warmest waters and reefs suffer as well (Brander, 2007; Munday et al., 2008). Considering the range of interconnected factors involved, from biological processes to changes in ocean current, the types of shocks that could occur in oceans which cover more than 70% of the planet's surface may be underestimated (Harley et al., 2006). The increase in temperature in polar waters shrinks the range of cold-water fish habitats towards the finite limit of the poles. Only the Arctic and southern oceans are compensating species loss by providing new ranges for an invasion of fish from other regions. Nearer the equator, decline will be permanent

(Cheung et al., 2009). Inland, similar processes are underway, although with little or no scope for fish migration, depletion could be faster and more permanent (Ficke et al., 2007).

IMPACTS

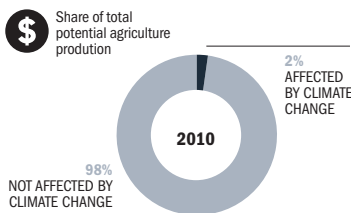
The current cost of climate change on the fisheries sector is estimated to be about 10 billion dollars a year. By 2030, the impact is expected to be more than triple its share as a cost of global GDP, when estimated losses will be over 160 billion dollars per year. The Pacific, South and Southeast Asia, and Africa, especially West Africa, are the regions worst hit by fishery sector losses due to climate change. Vietnam and China are estimated to suffer the greatest losses, with current impacts estimated to be in excess of 1 billion dollars per year. Vietnam could experience losses in excess of 20 billion dollars per year by 2030. Bangladesh, Indonesia, Myanmar, Morocco, Peru, and Thailand are also experiencing large-scale losses. The countries with the most severe impacts relative to GDP include small island countries in the Pacific, such as Vanuatu, Tuvalu, or Micronesia; in the Indian Ocean, the Seychelles; and

parts of West Africa, such as Sierra Leone and Gambia. By 2030, losses for these countries all exceed 4% of GDP. As traditional livelihoods are eroded, developing countries are worst affected, including a number of least developed countries and small island developing states, raising serious concerns for food security and poverty reduction efforts. Only a handful of countries are expected to gain from the large-scale ecosystem shift, with the largest share attributed to Norway, Russia, and Iceland, and with total gains not exceeding 15 billion dollars in 2030.

THE BROADER CONTEXT

Global fish catch is on a trend toward predictable long-term expansion owing to increases in aquaculture production (Brander, 2007). Global fish stocks, on the other hand, are experiencing a predictable long-term decline, as the number of commercial fishing craft has increased ten-fold since the 1950s, and 25-fold in Asia (Watson et al., 2012). Experts have estimated that marine fisheries declined by 40% between 1970 and 2007 (Hutchings et al., 2010). With or without climate change, global fisheries are endangered (Halpern et al., 2008). Unsustainable fishing

BIGGER PICTURE



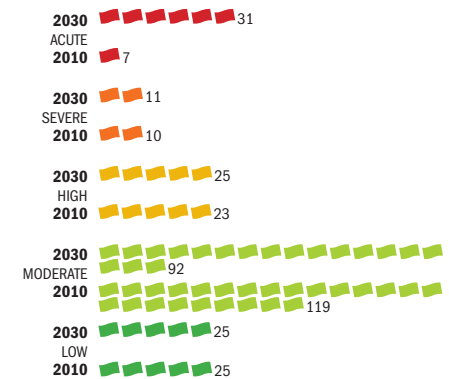
SURGE



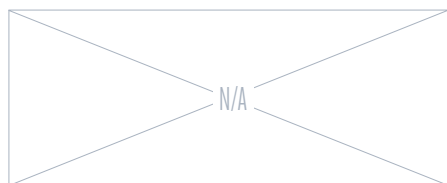
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Cheung et al., 2010; O'Reilly et al., 2003
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: FAOSTAT (2012)

➡ = 5 countries (rounded)

and environmentally unsound fishing practices, such as poison dumping, use of narrow-gauge nets that capture immature fish, bottom-dragging, and illegal fishing are important factors in the decline (Gray, 1997; Agnew et al., 2009; FAO, 2012). Bringing these practices under control will be key to responding to climate change-related fishery impacts.

VULNERABILITIES AND WIDER OUTCOMES

Countries with the highest levels of vulnerability are heavily dominated by lower-income nations which depend to a larger extent on fisheries as a share of GDP and are located in highly exposed latitudes or in particular geographical configurations, such as those near to closed water bodies (Allison et al., 2009). Effects will be most severe for subsistence or near-subsistence fisherfolk and fish-reliant communities, both coastal and inland (Srinivasan et al., 2010). The impacts of climate change on the fishing sector will therefore have significant effects on food security and human development progress and will likely feed migration trends (IOM, 2008; Le Manach et al., 2012).

RESPONSES

Responses concern three main types of fish zones where managed (aquaculture) and unmanaged (commercial) fishing are practised, including oceanic marine fish stocks, inland lake or river fish, and brackish or semi-salt waters.

In marine and inland environments, sustainable fisheries management will be key. This can include the strict setting and implementing of fishing quotas, net size restrictions, poison bans, and control of waters from exploitation, including by foreign fishing interests (Grieve and Short, 2007; FAO, 2007). When catch size reductions are unavoidable, compensatory measures can be implemented to ensure that there is no loss in community welfare; efforts can also be made to diversify livelihoods (Sumaila and Cheung, 2010). The establishment, expansion, and conservation of fish sanctuaries can also play an important role in sustaining or even increasing the resilience of stressed aquatic ecosystems (Gray, 1997).

In brackish environments and in all managed fishing regimes, the quality of otherwise high-risk hatchery production is vital. Post-larvae fish or shrimp carrying disease as they

leave hatcheries have the potential to contaminate whole aquaculture farms or systems in an area. Therefore, system-wide quality controls, from hatcheries through nurseries to pre-marketing grow-out ponds, will improve end-to-end resilience and resistance to disease. Here, water temperature is a principal environmental factor (Gilad et al., 2003).

As with agriculture, affected fisherfolk, if given access to higher levels of disposable income and diversified livelihoods, will have more scope for autonomous action (Teh et al., 2008). With surging global demand for food products, more benefits could be gained through strategies that increase the portion of the global value chain enjoyed by small-scale fisherfolk, as highlighted in the Ghana country study in this report. One example is the promotion of local light industrial processing, such as freezing and packaging works for marketing local fish products through global supply chains.

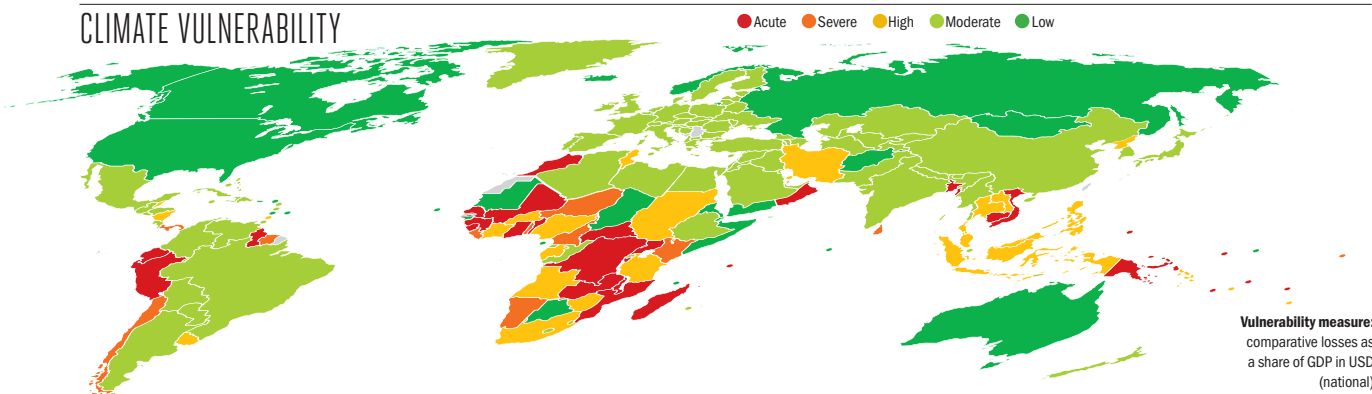
THE INDICATOR

The indicator relies on a global high resolution bio-climate study that maps the change in preferred water climates due to global warming for over a thousand key commercial species, as compared to their current habitats (Cheung et al., 2010). The main limitation is that the inland aspect of the indicator relies on a study carried out in one area (O'Reilly et al., 2003). Ocean temperature changes are fairly well studied and understood and the economic data from the UN Food and Agriculture Organization is comprehensive and accurate, all of which contributes to the robustness of the indicator (Domingues et al., 2008; FAOSTAT, 2012). Economic data on various segments of global fishery production could have been of a higher standard for the purpose of this analysis.

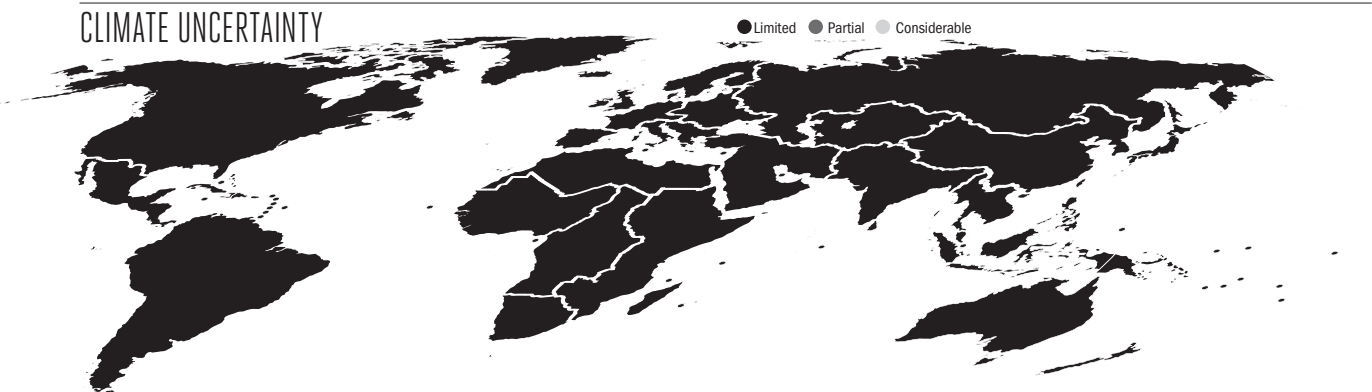
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			SEVERE					
Bangladesh	500	7,750	Cameroon	70	850	Tanzania	20	300
Benin	25	350	Chile	850	6,500	Thailand	700	8,500
Burundi	15	200	Kenya	90	1,250	Tonga	1	10
Cambodia	150	3,000	Kiribati	1	10	Tunisia	90	1,000
Central African Republic	10	150	Liberia	1	25	Uruguay	30	350
DR Congo	150	1,750	Namibia	30	300	Zimbabwe	5	70
Ecuador	300	3,250	Niger	15	200	MODERATE		
Gambia	45	450	Panama	85	1,000	Albania	1	20
Ghana	200	2,250	Sri Lanka	150	2,000	Algeria	30	350
Guinea	55	550	Suriname	10	100	Argentina	80	950
Guyana	25	300	Togo	10	150	Armenia		1
Madagascar	65	700	HIGH			Austria		
Malawi	60	900	Angola	80	800	Azerbaijan		5
Mali	60	850	Bahrain	20	200	Bahamas	1	35
Micronesia	15	150	Belize	1	20	Belarus	1	5
Morocco	850	7,250	Burkina Faso	10	150	Belgium	1	5
Mozambique	65	700	Cote d'Ivoire	20	200	Bhutan		1
Myanmar	600	7,500	Fiji	5	65	Bolivia	5	65
Oman	200	2,000	Gabon	20	200	Bosnia and Herzegovina	1	10
Palau	1	5	Grenada	1	10	Brazil	55	500
Papua New Guinea	95	1,250	Indonesia	650	7,750	Brunei	1	30
Peru	1,250	15,000	Iran	450	5,000	Bulgaria	1	25
Samoa	5	40	Laos	5	150	China	1,500	15,000
Senegal	90	950	Malaysia	500	5,750	Colombia	40	500
Seychelles	70	700	Nicaragua	15	200	Congo	1	20
Sierra Leone	65	650	Nigeria	300	3,750	Costa Rica	5	55
Tuvalu	1	15	North Korea	20	300	Croatia	5	65
Uganda	200	3,000	Philippines	450	5,000	Cuba	5	35
Vanuatu	80	950	Solomon Islands	1	20	Cyprus	1	5
Vietnam	1,500	25,000	South Africa	300	3,000	Czech Republic	1	10
Zambia	35	500	Sudan/South Sudan	40	650	Denmark	35	100
						Dominica		1



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$		
	2010	2030		2010	2030		2010	2030	
Dominican Republic	5	65	Malta		1	United Kingdom	1	1	
Egypt	150	2,250	Mauritius		5	55	Uzbekistan	1	10
El Salvador	5	85	Mexico		100	950	Venezuela	65	800
Equatorial Guinea	1	25	Moldova			5	LOW		
Estonia	15	90	Nepal		5	75	Afghanistan		
Ethiopia	15	200	Netherlands		15	45	Antigua and Barbuda		
Finland	15	55	New Zealand		30	90	Australia	-10	-25
France	30	90	Pakistan		100	1,250	Barbados		
Georgia	10	95	Paraguay			5	Botswana		
Germany	15	55	Poland		25	200	Canada	-45	-100
Greece	10	25	Portugal		20	60	Cape Verde		
Guatemala	5	85	Qatar		10	150	Chad		
Haiti	1	15	Romania		1	10	Comoros		
Honduras	5	65	Rwanda		5	55	Djibouti		
Hungary	1	15	Saint Lucia		1	10	Eritrea		
India	650	6,000	Saudi Arabia		85	950	Guinea-Bissau		
Iraq	20	250	Singapore		1	10	Iceland	-350	-1,000
Ireland			Slovakia		1	5	Luxembourg		
Israel	1	15	Slovenia			1	Maldives		
Italy	20	60	South Korea		200	1,750	Marshall Islands		
Jamaica	5	65	Spain		35	100	Mauritania		
Japan	200	600	Swaziland				Mongolia		
Jordan		5	Sweden		10	25	Norway	-900	-2,750
Kazakhstan	5	85	Switzerland			1	Russia	-1,250	-8,250
Kuwait	5	40	Syria		5	80	Saint Vincent		
Kyrgyzstan			Tajikistan			1	Sao Tome and Principe		
Latvia	15	150	Timor-Leste			5	Somalia		
Lebanon	5	35	Trinidad and Tobago		1	25	United States	-300	-1,000
Lesotho			Turkey		400	1,250	Yemen		
Libya	25	300	Turkmenistan		5	65			
Lithuania	15	150	Ukraine		55	600			
Macedonia		1	United Arab Emirates		40	450			

FORESTRY



ESTIMATES GLOBAL CLIMATE IMPACT

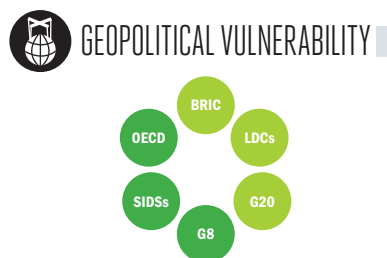
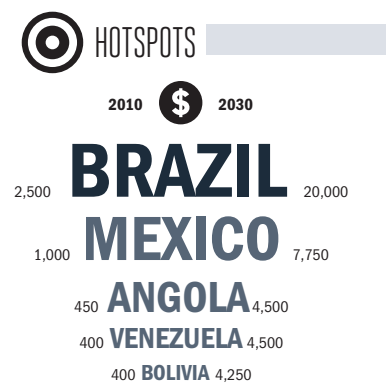
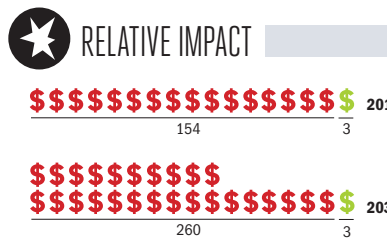
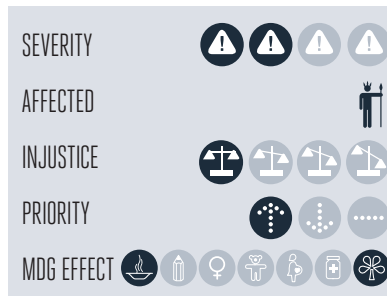
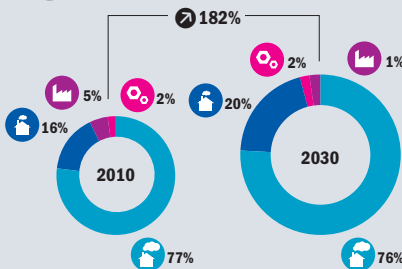
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **45 BILLION**

ECONOMIC IMPACT



- Climate change is shifting the world's climate zones as the planet warms
- As this occurs, commercial and native tree stands are becoming stranded in climate zones with less than optimal growing conditions
- Many forests are suffering from invasive species, more extreme weather, and flooding, further compounding stresses
- As a result, forests in all regions of the world are in decline or a state of flux, although gains in forest area and growth are evident in some regions
- Reversing the large-scale, rampant deforestation of recent decades would help to attenuate new losses due to climate change

\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **🏭** Developed
🏭 Developing Country High Emitters **🌐** Other Industrialized

★ **\$** = Losses per 100,000 USD of GDP
🔄 Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Forests cover nearly one-third of the world's land surface, and both commercial and native forests nearly everywhere are affected by the changing climate (Shvidenko et al. in Hassan et al. (eds.), 2005; Bolte et al., 2009). The potential for large-scale tree diebacks and loss of vegetation and forest biodiversity is considered significant. As the planet warms, climate zones are shifting, with stationary forests now in inhospitable conditions, triggering rapid decline and widespread tree mortality, although in some cases forests may be expanding into new areas (Gonzalez et al., 2010). The permanence of forests presents a unique challenge in terms of long-term planning and management, such as substituting tree varieties, although this is not a concern for seasonal crop-based agriculture. Communities that rely on forestry in threatened zones, including indigenous groups, are particularly at risk. If empowered through knowledge, resources, and legal support, these same communities can play a key role in helping forests to adapt. Forests are also a vital carbon sink, helping to contain GHG emissions, which widespread tree mortality counteracts (Kurz et al., 2008).

CLIMATE MECHANISM

Heat stress, increased propensity to drought and flooding, all consistent with climate change, can damage tree growth and forest stands (Allen et al., 2009; Lewis et al., 2011; Kramer et al., 2008). Growing risks from fires, pests, and disease are also of concern (Kurz et al., 2008). Above all, it is the shift taking place in forest habitats that outpaces the ability of stationary forests to naturally adapt (Shvidenko et al. in Hassan et al. (eds.), 2005; Bonan, 2008). Particularly affected are those tropical zones already at the maximum heat threshold, which will see further reductions in their viability as rainfall decreases. Boreal forests established at high altitudes or forest stands on permanently frozen land also risk the inevitable disappearance of their natural habitat as warming increases. Elsewhere forests have been observed, and are expected, to grow faster (McMahon et al., 2010).

IMPACTS

The impact of climate change on the world's commercial and native forests is currently estimated to incur annual losses of around 5 billion dollars, increasing by 2030 to around 45 billion

dollars or triple the cost as a share of global GDP. Brazil and Mexico incur the largest overall losses at around 10–20 billion dollars a year in 2030. A number of lower-income countries such as Angola, Central African Republic, Timor Leste and Zambia suffer the most severe effects as a share of GDP. Other South America countries, such as Bolivia, Chile, Colombia, Paraguay, and Venezuela are all also estimated to experience large-scale impacts. In general, developing countries on all continents are significantly affected. Among developed countries, Australia and Canada stand out, as well as those in Southern Europe, while Russia incurs the largest scale losses among industrialized nations. The negative effects are quite widespread, with around 50 countries showing vulnerability levels of high or above. Around 20 countries experience gains that are mainly small in scale, with the exception of Argentina, whose gains are already significant, reaching almost 10 billion dollars a year in 2030.

production over the last decade (FAOSTAT, 2012). Demand for forest products of all kinds including timber is expected to increase significantly over the coming decade. Illegal logging and deforestation, especially of native forests, remains a serious and widespread concern, with rates estimated at about 10 million hectares per year—an area larger than Greece—although in parts of Europe and North America in particular reforestation is significant (Shvidenko et al. in Hassan et al. (eds.), 2005).

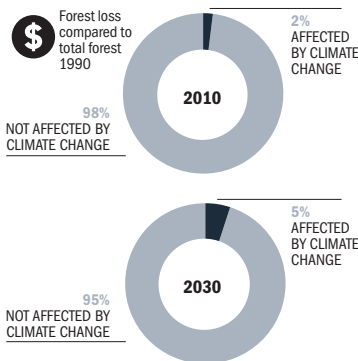
VULNERABILITIES AND WIDER OUTCOMES

The size of forests as an economic sector and their land area constitute the main components of structural vulnerability for countries in the affected zones. In 2005, 25 countries were estimated to have no remaining forest cover; other countries have less than 10% of forest cover remaining. High rates of deforestation clearly also accentuate vulnerability by diminishing local bio-capacity to withstand changes and increasing risks of invasive pests, flooding, drought, and irrigation-driven water stress (Shvidenko et al. in

THE BROADER CONTEXT

The Forestry sector is relatively stable, with increasing value but fluctuating

BIGGER PICTURE



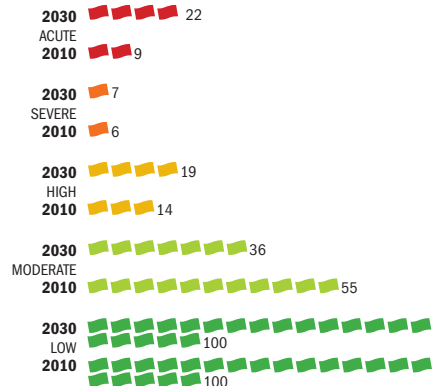
SURGE



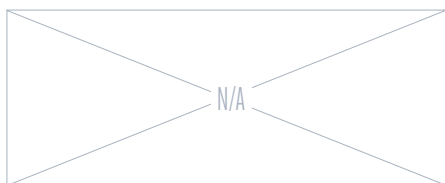
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: US Forest Service (2010)
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: FAOSTAT (2012)

➡ = 5 countries (rounded)

Hassan et al. (eds.), 2005; Bolte et al., 2009). Vegetation vulnerability is widespread globally, with forest stands at risk on every continent and in almost all regions, and with Boreal conifer and tropical broadleaf forests equally threatened (Gonzalez et al., 2010). Reliance on forests for market and non-market benefits, from water to biodiversity to wildlife or plant products, is highest among lower-income groups. Forest-based or forest-reliant indigenous groups are also heavily dependent on the health of local forest stands (Munasinghe, 1993; Salick and Byg, 2007). Accordingly, lower-income countries and countries with significant indigenous groups have accentuated vulnerability to the impact of climate change on forests. The loss of vital ecological services as forests die back or decline is a major concern for human development (SCBD, 2009).



RESPONSES

Despite the challenges presented, numerous responses can be foreseen to stem forest decline as a result of climate change or other man-made factors. Stand substitution with more suitable tree varieties can occur progressively; however, the substitution

options for the hottest and driest tropical zones are much more limited than elsewhere. Planting, harvesting and thinning regimes and schedules can be adjusted in accordance with altered local conditions (Bolte et al., 2009). Expanding primary forest conservation, particularly in high-risk developing countries, is a priority,

but requires increasing capacity to implement that will depend in many cases on foreign assistance (Lee and Jetz, 2008). Additional adaptation strategies may include the establishment and management of biodiversity corridors that reinforce self-supporting connections between forest and non-forest ecosystems (Tabarelli et al., 2010). Pest management could be considered in some managed forest situations. Community forest programmes that support local groups in taking a more proactive involvement in forest conservation and management or sustainable agroforestry projects have the potential to yield double dividends for the environment and development (Hella and Zavaleta, 2009). This could be extended to specific support to indigenous communities (Salick and Byg, 2007). Finally, strong environmental governance, especially if it is community-based, is also key to protecting forest ecosystems, including threats from illegal or condoned deforestation (Baltodano et al., (eds.), 2008). Payment for ecosystem services has met with success in some countries for preserving and enhancing forest ecosystems, Costa Rica being a prime example (Pagiola, 2006).

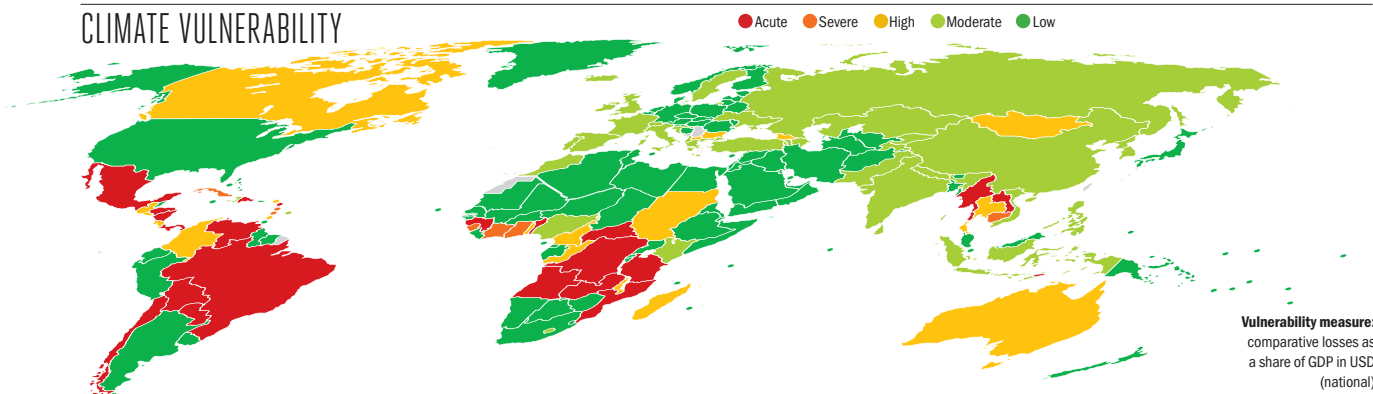
THE INDICATOR

The indicator considers the scale of estimated shifts in the location and area of different forest biomes due to climate change (Gonzalez et al, 2010). Forestry and biodiversity losses are well recognized in climate science, and are closely linked to significant temperature changes (IPCC, 2007). A key limitation is the valuation method for forests of commercial and non-commercial types, including all varieties of trees in every continent. To simplify the problem, generic values are used for tropical and non-tropical forest stands, including bundled biodiversity values (Costanza et al., 2007).

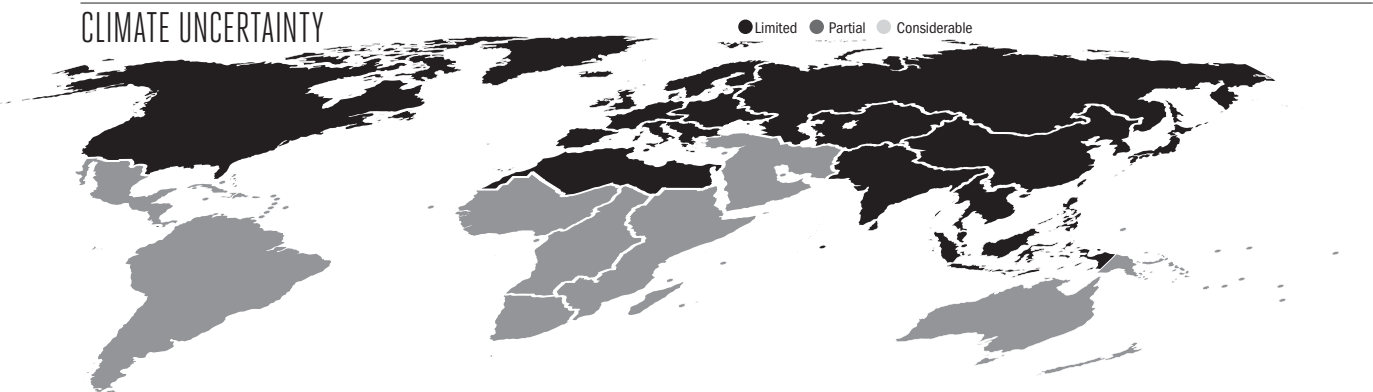
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE								
Angola	450	4,500	Antigua and Barbuda		1	Ireland	1	1
Benin	20	200	Australia	100	300	Italy	15	50
Bolivia	400	4,250	Bulgaria	10	100	Kazakhstan	5	75
Brazil	2,500	20,000	Cameroon	10	90	Kenya	5	30
Central African Republic	5	75	Canada	150	500	Kyrgyzstan	1	5
Chile	300	2,000	Colombia	80	900	Lesotho		
Dominica	1	10	Congo	1	20	Morocco	5	75
Dominican Republic	55	600	Costa Rica	10	150	Nepal		1
DR Congo	15	150	El Salvador	5	75	Nigeria	25	200
Guinea	10	100	Georgia	1	20	North Korea	1	5
Honduras	25	300	Grenada		5	Pakistan	1	15
Laos	5	100	Guatemala	10	150	Philippines	1	30
Mexico	1,000	7,750	Macedonia	5	35	Portugal	5	20
Mozambique	75	700	Madagascar	1	25	Russia	150	850
Myanmar	50	600	Malawi	1	10	South Korea	1	15
Nicaragua	10	150	Mongolia	1	30	Spain	35	100
Panama	35	400	Sudan/South Sudan	10	100	Sri Lanka	1	15
Paraguay	100	1,250	Thailand	100	1,500	Sweden	10	25
Tanzania	35	350	Togo	1	10	Switzerland	1	1
Timor-Leste	20	250				Tajikistan		1
Venezuela	400	4,500	MODERATE			Turkey	5	20
Zambia	150	1,500	Albania		1	Ukraine	1	10
SEVERE			Armenia	1	5	United Kingdom	5	10
Cambodia	10	150	Azerbaijan	1	25	Vietnam	1	20
Cote d'Ivoire	10	100	Barbados		1			
Cuba	40	450	China	60	650	LOW		
Ghana	15	150	Croatia			Afghanistan		
Saint Lucia	1	5	France	30	90	Algeria		
Saint Vincent		5	Greece	10	25	Argentina	-950	-10,000
Sierra Leone	1	10	Haiti	1	5	Austria	-1	-10
HIGH			Iceland			Bahamas		
			India	10	80	Bahrain		
			Indonesia	30	350	Bangladesh		-1



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY		\$		COUNTRY		\$		COUNTRY		\$	
		2010	2030			2010	2030			2010	2030
Belarus		-1	-15	Israel				Romania			-1
Belgium				Jamaica				Rwanda			
Belize				Japan		-10	-30	Samoa			
Bhutan				Jordan				Sao Tome and Principe			
Bosnia and Herzegovina				Kiribati				Saudi Arabia			
Botswana				Kuwait				Senegal			
Brunei				Latvia				Seychelles			
Burkina Faso				Lebanon				Singapore			
Burundi				Liberia				Slovakia			
Cape Verde				Libya				Slovenia			
Chad				Lithuania		-1	-5	Solomon Islands			
Comoros				Luxembourg				Somaia			
Cyprus				Malaysia				South Africa		-5	-60
Czech Republic				Maldives				Suriname			
Denmark				Mali				Swaziland			
Djibouti				Malta				Syria			
Ecuador		-40	-500	Marshall Islands				Tonga			
Egypt				Mauritania				Trinidad and Tobago			
Equatorial Guinea				Mauritius				Tunisia			
Eritrea				Micronesia				Turkmenistan			
Estonia			-1	Moldova				Tuvalu			
Ethiopia				Namibia				Uganda		-1	-10
Fiji				Netherlands				United Arab Emirates			
Finland		-5	-15	New Zealand				United States		-90	-300
Gabon				Niger				Uruguay		-5	-80
Gambia				Norway		-1	-5	Uzbekistan			
Germany		-1	-10	Oman				Vanuatu			
Guinea-Bissau				Palau				Yemen			
Guyana				Papua New Guinea				Zimbabwe			
Hungary		-1	-10	Peru		-70	-800				
Iran				Poland		-5	-40				
Iraq				Qatar							

HYDRO ENERGY



ESTIMATES GLOBAL CLIMATE IMPACT

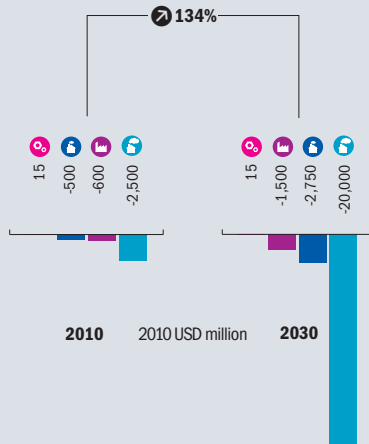
2010 EFFECT TODAY

\$ USD GAIN PER YEAR **5 BILLION**

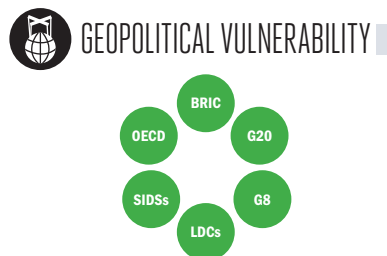
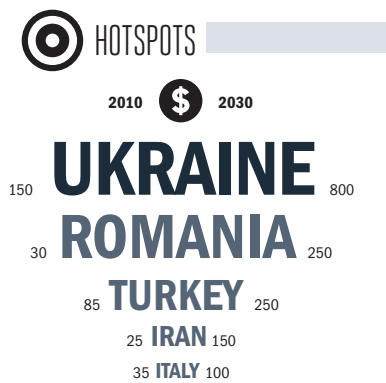
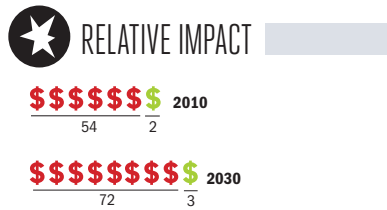
2030 EFFECT TOMORROW

\$ USD GAIN PER YEAR **25 BILLION**

\$ ECONOMIC IMPACT



- The world will benefit from increasing hydro energy wealth as climate change brings more rain to many places
- Some regions will be heavily affected by localized reductions in rainfall and a corresponding loss of energy potential for existing hydropower installations
- Additional hydro energy capacity can already be foreseen in zones where there is high certainty of more useable rainfall, especially in high latitudes
- The negative effects of hydro energy can be offset by measures such as expanding reservoirs to increase water holding capacity in affected zones, and through a forward-looking diversification of energy supply



\$ Economic Cost (2010 PPP non-discounted)
 Developing Country Low Emitters
 Developing Country High Emitters
 Developed
 Other Industrialized

\$ = Losses per 100,000 USD of GDP
 Change in relation to overall global population and/or GDP

\$ = Millions of USD (2010 PPP non-discounted)

Vulnerability of hydropower to climate effects can be high: in Brazil in 2001, intense drought was a key contributor to a “virtual breakdown” of power generation from hydro sources, a dominant energy supply for the country (IPCC, 2012b). Such extreme hydrological events are becoming more common (IPCC, 2007; Hansen et al., 2012). According to the assessment made here, however, fewer than 20 countries would be negatively affected to any significant degree, and many more could benefit. This is because water availability is increasing in many areas of the world as a result of climate change (Bates et al., 2008). New opportunities will arise over the next 30 years as precipitation increases global hydro energy capacity, and when access to this established clean energy technology will be most needed. Where reductions do occur, they may be severe: a study of nearly 6,000 European hydro stations concluded that 25% reductions in power generation could become a reality for the southern and Mediterranean areas (Lehner et al., 2005). Where the effects are likely to be negative, economies should plan for a diversification to other energy sources,

and mitigate the effects of rainfall loss through measures such as reservoir expansion. The intrinsic uncertainty of rainfall will make planning for these large-scale and capital-intensive energy systems difficult (IPCC, 2012b).

CLIMATE MECHANISM

The hydro energy sector has recognized sensitivities to climate change. This is because climate change alters the water cycle of the planet, notably accelerating it and increasing the amount of available rainfall, water, and river flow (Huntington, 2006; Stromberg et al., 2010). However, many countries will not experience an improvement in water availability, but will see declines, as water replenishments fail to keep pace with rising heat (Chu et al., 2009). In the long term, melting glaciers may further increase water scarcity, but in the coming years it is likely to increase water flows (Olefs et al., 2009). All these factors can have an impact on the power generation capacity of hydro energy installations (Lehner et al., 2001; Pereira de Lucena et al., 2009; Hamududu and Killingtveit, 2012). Globally, major rivers are expected to increase in flow or decline depending on local and regional climate conditions—

although these are uncertain for many areas (Nohara et al., 2006). Evidence tends to favour an increase in rainfall (or runoff) in the far north and south, and a decrease in tropical regions (Helm et al., 2010).

IMPACTS

Given the still relatively small scale of hydro power installations in the global energy mix—although it is still by far the largest source of renewable energy—the positive effect worldwide is small at around 4 billion dollars in 2010 (US EIA, 2011). Losses by comparison are estimated at around 0.5 billion dollars. The worst affected zones are Southern Europe and Central America, while the largest total gains include China, Canada, and the US, subject of course to different degrees of uncertainty linked to rainfall projections to 2030. Between 2010 and 2030 the estimated effect more than doubles as a proportion of GDP, with around 25 billion dollars in yearly gains by 2030. The number of worst affected countries has more than doubled, and there is a significant increase in gains among the many countries that are projected to benefit.

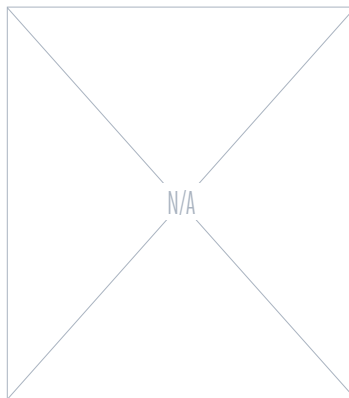
THE BROADER CONTEXT

The hydro energy sector has undergone continued expansion in recent decades—although not as rapidly as renewable energy technologies—and is expected to continue to grow as a source of power generation (US EIA, 2011; BP, 2012). Given the large-scale up-front capital investment involved and the long-term shelf life of installations, although it is still by far the largest source of renewable energy—the positive effect worldwide is small at around 4 billion dollars in 2010 (US EIA, 2011). Losses by comparison are estimated at around 0.5 billion dollars. The worst affected zones are Southern Europe and Central America, while the largest total gains include China, Canada, and the US, subject of course to different degrees of uncertainty linked to rainfall projections to 2030. Between 2010 and 2030 the estimated effect more than doubles as a proportion of GDP, with around 25 billion dollars in yearly gains by 2030. The number of worst affected countries has more than doubled, and there is a significant increase in gains among the many countries that are projected to benefit.

VULNERABILITIES AND WIDER OUTCOMES

Watershed or water catchment capacity in reservoirs is a key contributor to resilience of hydro power installations, since these can stock water during

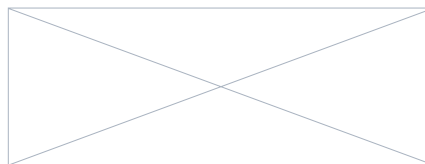
BIGGER PICTURE



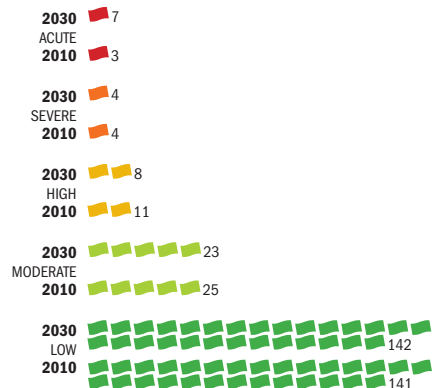
SURGE



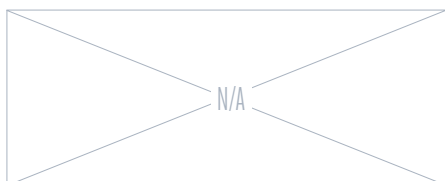
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Lehner, 2003; Nohara, 2006
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: IEA, 2011; Lehner, 2001

= 5 countries (rounded)

extended periods of drought, and retain water deposited at inconvenient times of the year and saved for later use (IPCC, 2012b). Hydro installations that are powered only by river flow and not through a reservoir are particularly exposed to diminished rainfall and water runoff, as was pointed out in the Vietnam country study in this report. Whether environmental management is poor or sound may also play a role: for example, Costa Rica, one of the countries worst hit, has begun to reverse its deforestation process, which is expected to result in improved watershed capacity, although only high altitude or mature forests are understood to add to surrounding water supplies (Morse et al., 2009; Postel and Thompson, 2005; Hamilton, 2008). Lower-income countries are relatively well shielded since investment in capital-intensive hydro power installations in these countries has so far been marginal (UNEP Risoe, 2012). Both the Ghana and Vietnam country studies in this report highlight the potential negative effects of hydro installations for coastal erosion, which can compound climate change-induced sea-level rise.

RESPONSES

Where energy potential is set to decline, there are two main response areas: first, undertaking or intensifying measures aimed at improving the supply of water through enhanced watershed catchment and upstream water resource conservation. Increasing forest area and certain types of nature reserves can help build up the water capacity under certain conditions (Postel and Thompson, 2005). Depending on the type of installation, expanding the size of drawing reservoirs to stock more water may also provide a buffer against declining rainfall. In more arid regions, managing upstream water consumption, such as irrigation, may also yield positive results by lessening water withdrawals (Kang et al., 2004). Second, ensure diversification of future energy investments away from hydro power. At the same time, there is a danger that affected economies compensate for lost production in the hydro energy sector through an increase in carbon intensive modes of energy supply. In some major economies, experts have recently been recommending further investment in oil and gas energy generation as a least-cost adaptation option for

hydro energy and other renewable energy sources that may be affected by climate change (Pereira de Lucena et al., 2010). Conversely, certain experts have argued that the promotion of hydropower has caused serious environmental damage and should be reconsidered (Haya, 2007).

THE INDICATOR

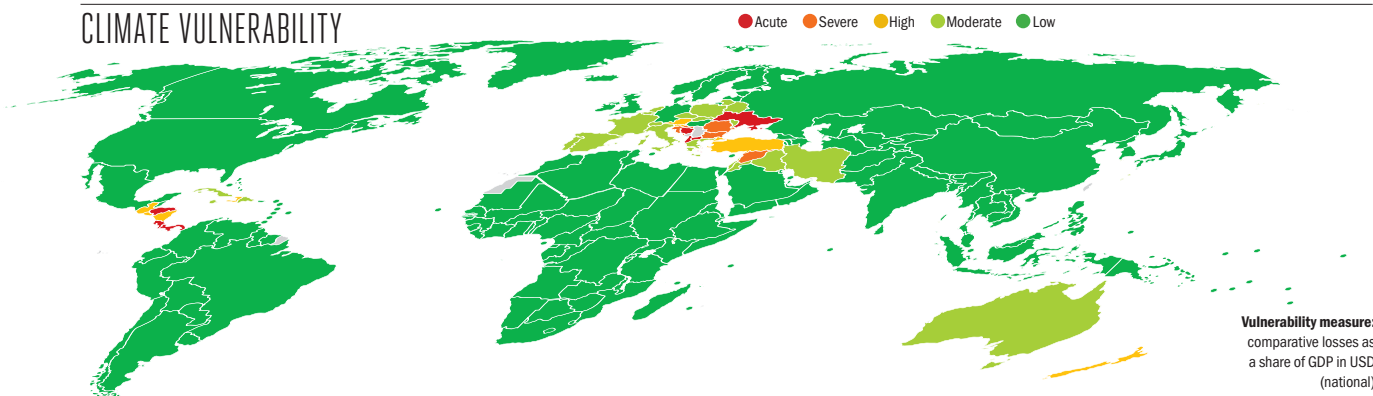
The indicator maps changes in river discharge in relation to estimated effects of climate change and the corresponding effect on the global hydro-energy potential of existing installations, and draws on International Energy Agency data (Lehner et al., 2001; IEA, 2012b). Key limitations relate to the scale of the information and uncertainty in the direction and magnitude of rainfall changes. The main model is geographically limited to Europe, and effects are extrapolated using river flow information (Nohara et al., 2006). Differences in anticipated changes in rainfall patterns could mean very different outcomes in river discharge and energy potential for those areas where there is less agreement and certainty around the direction of the change (Bates et al., 2008; Hamududu and Killington, 2012).

ESTIMATES COUNTRY-LEVEL IMPACT

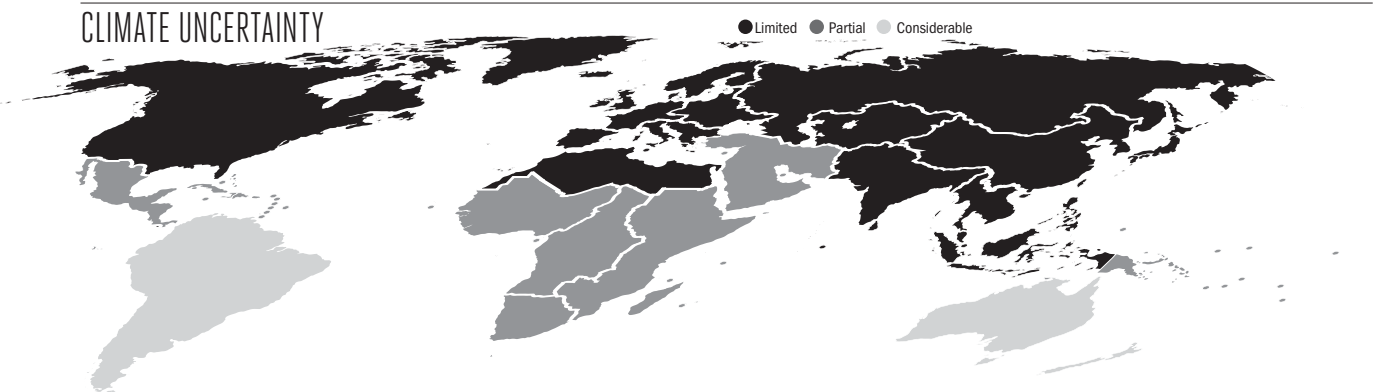
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			Iraq	1	15	Brunei		
Albania	10	100	Israel		1	Burkina Faso		
Bosnia and Herzegovina	15	100	Italy	35	100	Burundi		
Costa Rica	15	100	Jamaica	1	1	Cambodia		
Honduras	10	70	Jordan		1	Cameron	-5	-20
Macedonia	5	30	Lebanon	1	15	Canada	-350	-800
Panama	10	80	Lithuania			Cape Verde		
Ukraine	150	800	Moldova		1	Central African Republic		
SEVERE			Netherlands			Chad		
Bulgaria	5	95	Poland	5	20	Chile	-10	-60
Croatia	10	75	Portugal	-1	20	China	-2,250	-20,000
Romania	30	250	Slovakia	5	35	Colombia	-20	-100
Syria	20	100	Spain	10	95	Comoros		
HIGH			Switzerland	1	30	Congo		-1
Austria	10	50	LOW			Cote d'Ivoire	-1	-5
El Salvador	5	35	Afghanistan			Cyprus		
Guatemala	10	55	Algeria			Denmark		
Haiti	1	5	Angola	-1	-5	Djibouti		
New Zealand	10	25	Antigua and Barbuda			Dominica		
Nicaragua	1	10	Argentina	-20	-150	DR Congo	-5	-30
Slovenia	5	40	Armenia	-1	-15	Ecuador	-5	-40
Turkey	85	250	Azerbaijan	-5	-20	Egypt	-15	-95
MODERATE			Bahamas			Equatorial Guinea		
Australia	5	15	Bahrain			Eritrea		
Belarus			Bangladesh	-1	-20	Estonia		
Belgium			Barbados			Ethiopia	-1	-10
Cuba		1	Belize			Fiji		
Czech Republic		5	Benin			Finland	-10	-30
Dominican Republic	1	20	Bhutan			Gabon	-1	-5
France	25	100	Bolivia	-1	-10	Gambia		
Greece	1	20	Botswana			Georgia	-15	-75
Iran	25	150	Brazil	-150	-750	Germany	-10	-10



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Ghana	-5	-35	Micronesia			South Africa	-1	-5
Grenada			Mongolia			South Korea	-5	-40
Guinea			Morocco	-1	-5	Sri Lanka	-10	-55
Guinea-Bissau			Mozambique	-10	-55	Sudan/South Sudan	-1	-5
Guyana			Myanmar	-1	-15	Suriname		
Hungary		-1	Namibia	-1	-5	Swaziland		
Iceland	5	-1	Nepal	-5	-30	Sweden	40	-60
India	-250	-1,500	Niger			Tajikistan	-45	-250
Indonesia	-10	-75	Nigeria	-5	-30	Tanzania	-1	-15
Ireland	-1	-1	North Korea	-25	-200	Thailand	-10	-60
Japan	-80	-150	Norway	35	-150	Timor-Leste		
Kazakhstan	-10	-70	Oman			Togo		-1
Kenya	-1	-5	Pakistan	-55	-350	Tonga		
Kiribati			Palau			Trinidad and Tobago		
Kuwait			Papua New Guinea			Tunisia		-1
Kyrgyzstan	-40	-250	Paraguay	-40	-250	Turkmenistan		
Laos			Peru	-10	-75	Tuvalu		
Latvia	-1	-15	Philippines	-10	-75	Uganda		
Lesotho			Qatar			United Arab Emirates		
Liberia			Russia	-300	-1,500	United Kingdom	-5	-5
Libya			Rwanda			United States	-300	-700
Luxembourg			Saint Lucia			Uruguay	-5	-20
Madagascar			Saint Vincent			Uzbekistan	-15	-90
Malawi			Samoa			Vanuatu		
Malaysia	-10	-65	Sao Tome and Principe			Venezuela	-30	-200
Maldives			Saudi Arabia			Vietnam	-30	-300
Mali			Senegal			Yemen		
Malta			Seychelles			Zambia	-5	-25
Marshall Islands			Sierra Leone			Zimbabwe	-1	-15
Mauritania			Singapore					
Mauritius			Solomon Islands					
Mexico	-60	-350	Somalia					

TOURISM



ESTIMATES GLOBAL CLIMATE IMPACT

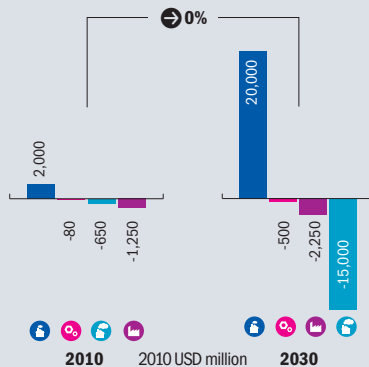
2010 EFFECT TODAY

\$
USD LOSS PER YEAR **NIL**

2030 EFFECT TOMORROW

\$
USD LOSS PER YEAR **NIL**

\$ ECONOMIC IMPACT



CONFIDENCE INDICATIVE

- Person icon
- Home icon
- Cloud icon
- Document icon

SEVERITY

AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

- Impacts will affect tropical beaches and island destinations reliant on seaside and tropical reef tourism and low-elevation winter resorts as reefs die and snowfall becomes unreliable
- Extreme and hot weather will affect tourism, but is not yet well understood
- Net global impact of climate change on tourism may not be negative; effects may redistribute tourism revenues among cooler countries with perceived climate advantages
- Adapting to impacts of climate change on tourism is challenging

★ RELATIVE IMPACT

2010: 55 (6 red \$, 1 green \$)

2030: 67 (6 red \$, 1 green \$)

🎯 HOTSPOTS

2010 \$ 2030

1,250 **INDONESIA** 10,000

1,250 **MALAYSIA** 10,000

800 **INDIA** 8,000

600 **EGYPT** 5,000

200 **SRI LANKA** 1,750

🌐 GEOPOLITICAL VULNERABILITY

\$ Economic Cost (2010 PPP non-discounted) **★ \$** = Losses per 10,000 USD of GDP **🎯 \$** = Millions of USD (2010 PPP non-discounted)

🇧🇩 Developing Country Low Emitters **🇩🇪** Developed

🇨🇳 Developing Country High Emitters **🇯🇵** Other Industrialized

🔄 Change in relation to overall global population and/or GDP

Tourism is clearly a climate-dependent sector. Weather conditions affect business in this sector, and general theory on the impact of climate change on tourism has been understood to favour cooler countries over tropical ones (Wall, 1998; Hamilton et al., 2005; Amelung et al., 2007). Yet there are exceptions: experts have suggested that Switzerland may see half of its ski stations become snow unreliable, with the snow reliability altitude rising from 1,200 metres today to over 1,800 metres, effectively stranding large, profitable, and irreplaceable ski zones (Elsasser and Bürki, 2002). Some economists have put forward evidence that the impact of climate change on tourism might result in an overall loss to global welfare (Berritella et al., 2004). Tourism is currently a fast growing industry, however, and in the near term it is more likely that any impacts would instead trigger redistribution of tourism revenues away from low- and middle-income tropical coastal resorts to other global destinations, in particular high-income countries, which benefit from more pleasant weather as the planet warms (UNWTO, 2012; Harrison et al., 1999). Experts have been unsure about national outcomes for some

countries—such as the tourist magnet France—which are exposed to a range of positive and negative tourism-related concerns (Ceron and Dubois, 2004). The full range of possible effects for tourism is large in scale, given the heavy reliance on outdoor recreation and environmental leisure activities (Jones and Phillips eds., 2011). This assessment is anchored in two relatively well-studied concerns: decline of reef-based and low-elevation winter sports tourism (Steiger, 2011; ECLAC, 2011). In this way, the Monitor's tourism indicator serves to ensure that adequate attention is given by policymakers to the issue of tourism and climate change, despite the lack of comprehensiveness in analysis here, since even through this narrow lens, some countries may experience 1% losses of GDP by 2030.

CLIMATE MECHANISM

The climate effect assessed here examines only the effects for reef-based and mountain tourism. The degradation and bleaching of coral reefs and a decline of tropical fish stocks is a clear consequence of the steady warming of the atmosphere and oceans (Hoegh-Guldberg et al., 2007). Likewise, climate propelled sea-level rise is leading to

coastal erosion, affecting beaches and coral reefs (Nicholls and Cazenave, 2010). Cultural heritage sites around the world's coastlines are also affected or threatened by this erosion (UNESCO, 2010). These effects penalize tourism that has flourished in places where there is an abundance of coral for diving and other related pursuits (Uyarra et al., 2005; ECLAC, 2011). Other clear effects on tourism are a general onset of shorter, milder winters, long-term glacier decline and a snow-line gradually gaining in elevation in mid- to high-latitude regions (Euskirchen et al., 2006; Kelly and Goulden, 2008). These combined effects entail a slight and gradual degradation of mountain resort offerings, especially in low-elevation areas, which in turn can limit revenues in a high-risk industry (Koenig and Abegg, 1997; Scott, 2003; Steiger, 2011).

IMPACTS

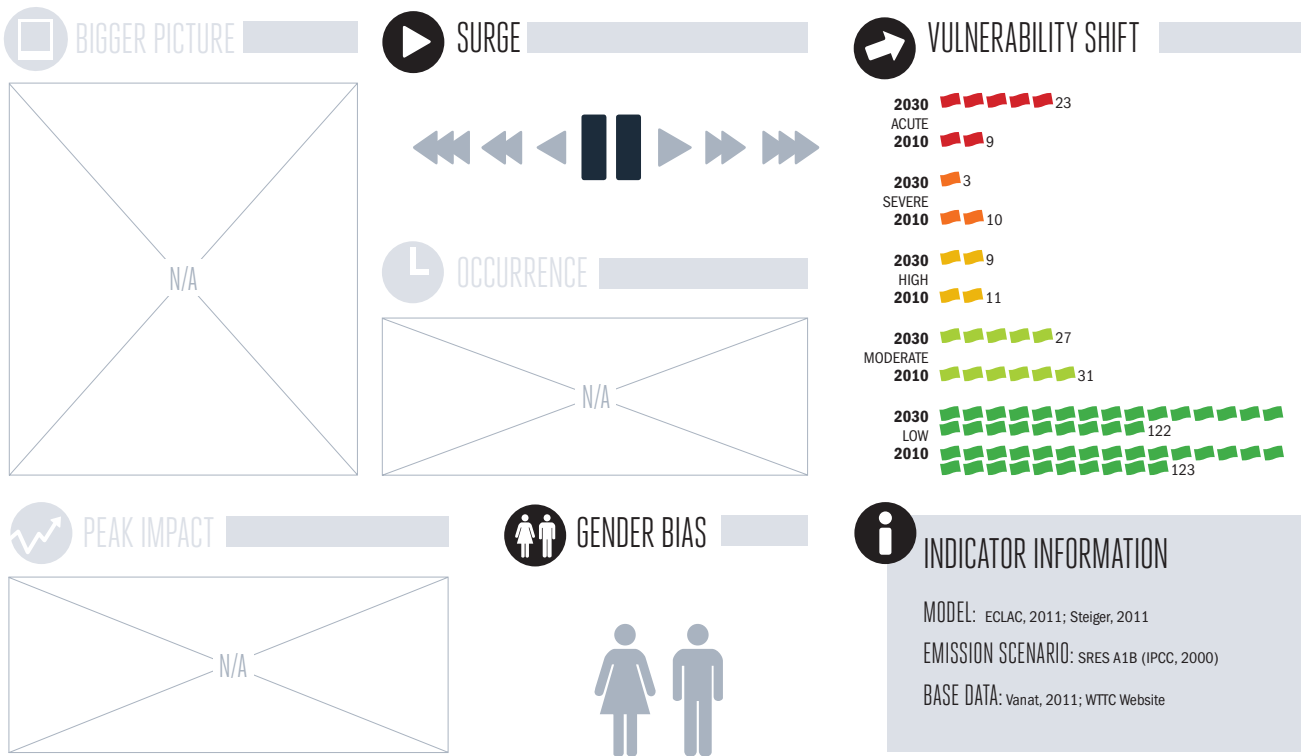
While the global effect is expected to be cost neutral, losses to affected countries are currently estimated at around 5 billion dollars a year, building to over 40 billion dollars, with an almost double share of global GDP in losses by 2030. Small island paradises such as the Bahamas, the Maldives, and Fiji

dominate the list of countries most vulnerable to the negative effects of climate change on tourism. More marginal effects will also be felt in traditional skiing destinations, such as Australia, Austria, France, and Switzerland.

By 2030, lost revenue in tourism could cost upwards of 1% of GDP for several of the worst affected small island nations, although the greatest overall losses will be incurred in larger economies such as Egypt, Indonesia, or Malaysia. The effects for winter tourism host countries are expected to be marginal on a national scale, but could be highly unfavourable to mountain communities, which rely on short, peak seasons for the bulk of annual profits. Around 20-30 countries are estimated to experience serious effects; losses are estimated to be redistributed among high-latitude countries where domestic and foreign tourism is expected to improve along with favourable climate change. High-altitude ski resorts may also see surges in demand.

THE BROADER CONTEXT

Tourism is a major growth industry globally, due especially to income and population trends that bolster



the leisure sector (UNWTO, 2012). Given this growth, it is unlikely that any areas will experience significant absolute declines in revenues in the next few years (Hamilton et al., 2005). However, some niches in the industry grow more slowly than others: ski trips to mountain resorts have been stable over the last decade (Vanat, 2011). The broader industry context suggests that countries are more likely to have the growth of their tourism revenue slowed, rather than incur absolute losses, at least in the near term. This assessment represents an estimate of the potential opportunity cost for affected communities.

VULNERABILITIES AND WIDER OUTCOMES

KPMG identified the tourism sector as one of the industries most vulnerable to climate change, especially in light of physical risks, but also as one of the industries least prepared and therefore most likely to incur losses (KPMG, 2008). Geography clearly plays a role in physical risk, given the emphasis some experts have given to winners and losers in the global tourism industry depending on latitude

(Amelung et al., 2007). The risks of coastal and mountain dependent tourist zones are also covered above. The size of the tourism sector and the level of its exposure to climate-related risks are the key determinants of vulnerability. Particularly in small island states, tourism is a large-scale revenue generator, whose remote locations allow unique access to a lucrative global market (Uyerra et al., 2005). Long-term sector decline could damage national income prospects and state expenditure on public goods such as schools, since tourism is an important form of public revenue in popular areas (Archabald and Naughton-Treves, 2001; Gooroochurn and Sinclair, 2005).

RESPONSES

In many cases, adaptation will require a diversification of the value offering of affected market segments, diversification away from long-term tourism-based risks where possible, and support or rehabilitation programmes to assist worst affected communities. Overcoming the unpreparedness of the sector to address climate stresses through awareness and education at different levels is of vital importance

(Scott, 2011). However, the lack of preparedness of the sector underscores fundamental gaps in current response strategies (Scott et al., 2009). A variety of quite costly coastal conservation measures exist to stem beach and coastland erosion, but are unlikely to render such places more attractive to tourists (Klein et al., 2001). Strong environmental protection and sustainable fishing regulations, along with the promotion and expansion of natural marine reserves or mangrove forests can also help to boost local ecosystem resilience against coral and fish stock decline (Hughes et al., 2003; Corcoran et al., 2007). For low-elevation winter ski spots, relying on energy-intensive snow-making can assist to some degree, but will constitute a paradoxical response to the locally felt effect of global climate change on these vulnerable mountain tourist areas (Dawson et al., 2009). More generally, experts have raised concern about the potential for the tourism sector to become a major contributor to GHG emissions in the coming decades (Scott et al., 2010).

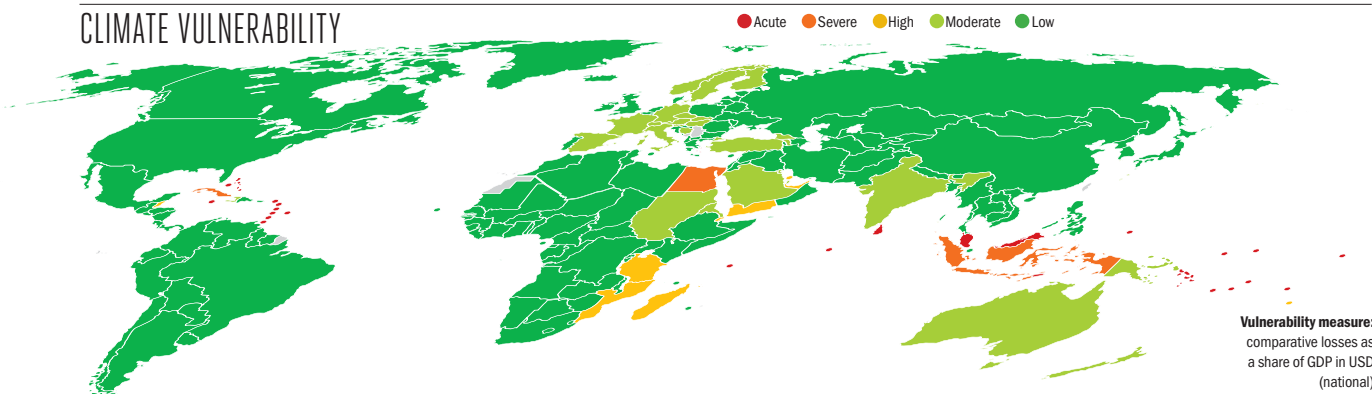
THE INDICATOR

The indicator measures the effects of the loss in tourism revenue potential in tropical seaside resorts and winter ski resorts, based only on two separate studies on the question (Steiger, 2011; ECLAC, 2011). Given the climate factors involved, such as ocean temperatures and the length and temperature of winter ski seasons, the IPCC has been firm on the anticipated effects for the tourism industry (IPCC, 2007). The indicator should still be considered only to address the types of effects countries with a heavy reliance on reef and winter tourism might face. The main limitation is the lack of scope of the indicator, which captures only a fraction of the broader problem.

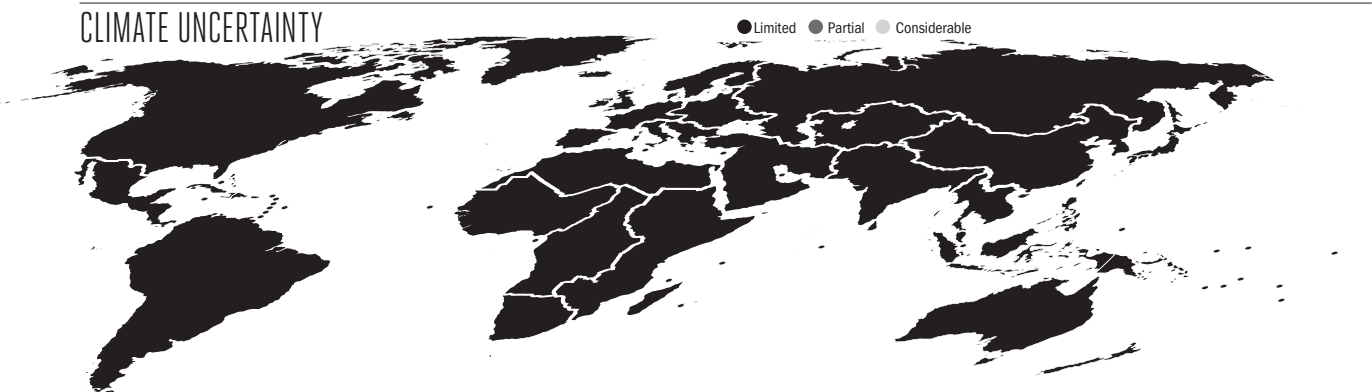
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE								
Antigua and Barbuda	10	100	Madagascar	15	100	Switzerland	20	90
Bahamas	65	550	Mozambique	10	65	Turkey		1
Barbados	40	400	Tanzania	25	200	LOW		
Dominica	5	30	Tonga	1	5	Afghanistan		
Fiji	20	200	United Arab Emirates	150	1,500	Albania		
Grenada	1	25	Yemen	30	250	Algeria		
Jamaica	100	950	MODERATE			Angola		
Kiribati	1	10	Armenia			Argentina	-10	-65
Malaysia	1,250	10,000	Australia	150	400	Azerbaijan		
Maldives	15	150	Austria	55	300	Bangladesh		
Marshall Islands	1	5	Bosnia and Herzegovina		5	Belarus	-1	-20
Micronesia	1	15	Czech Republic	5	70	Belgium	-1	-1
Palau	1	5	Eritrea	1	10	Benin		
Saint Lucia	10	100	Finland	1	5	Bhutan		
Saint Vincent	5	25	France	30	200	Bolivia		
Samoa	5	35	Georgia			Botswana		
Seychelles	15	100	Germany	10	70	Brazil		
Solomon Islands	5	45	Haiti	1	25	Brunei		
Sri Lanka	200	1,750	Hungary	-1	5	Bulgaria	-1	-5
Timor-Leste	5	65	India	800	8,000	Burkina Faso		
Trinidad and Tobago	100	900	Italy	15	85	Burundi		
Tuvalu		1	Myanmar	10	95	Cambodia		
Vanuatu	10	100	New Zealand	1	5	Cameroon		
SEVERE			Norway	1	15	Canada	-100	-200
Cuba	150	1,250	Papua New Guinea	1	25	Cape Verde		
Egypt	600	5,000	Qatar	10	80	Central African Republic		
Indonesia	1,250	10,000	Saudi Arabia	100	1,000	Chad		
HIGH			Slovakia	5	50	Chile	-1	-15
Bahrain	15	150	Slovenia	1	25	China	-3,500	-40,000
Belize	1	20	Spain	5	30	Colombia		
Djibouti	1	15	Sudan/South Sudan	10	60	Comoros		
			Sweden	1	15	Congo		



CLIMATE VULNERABILITY



CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Costa Rica			Laos			Portugal		
Cote d'Ivoire			Latvia	-1	-1	Romania	-1	-10
Croatia			Lebanon			Russia	-65	-500
Cyprus			Lesotho			Rwanda		
Denmark	-1	-1	Liberia			Sao Tome and Principe		
Dominican Republic			Libya			Senegal		
DR Congo			Lithuania	-1	-5	Sierra Leone		
Ecuador			Luxembourg			Singapore		
El Salvador			Macedonia			Somalia		
Equatorial Guinea			Malawi			South Africa	-60	-400
Estonia		-1	Mali			South Korea	-35	-150
Ethiopia			Malta			Suriname		
Gabon			Mauritania			Swaziland		
Gambia			Mauritius			Syria		
Ghana			Mexico			Tajikistan		
Greece			Moldova		-1	Thailand		
Guatemala			Mongolia	-1	-5	Togo		
Guinea			Morocco			Tunisia		
Guinea-Bissau			Namibia			Turkmenistan		
Guyana			Nepal			Uganda		
Honduras			Netherlands	-1	-5	Ukraine	-5	-35
Iceland			Nicaragua			United Kingdom	-5	-15
Iran			Niger			United States	-1,500	-3,250
Iraq			Nigeria			Uruguay	-1	-5
Ireland	-1	-1	North Korea	-15	-150	Uzbekistan		
Israel			Oman			Venezuela		
Japan	-55	-5	Pakistan			Vietnam		
Jordan			Panama			Zambia		
Kazakhstan			Paraguay			Zimbabwe		
Kenya			Peru					
Kuwait			Philippines					
Kyrgyzstan			Poland	-10	-65			

TRANSPORT



ESTIMATES GLOBAL CLIMATE IMPACT

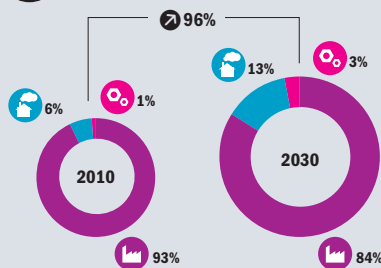
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **1** BILLION

2030 EFFECT TOMORROW

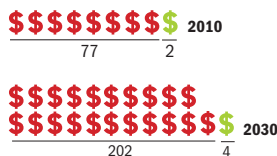
\$ USD LOSS PER YEAR **5** BILLION

ECONOMIC IMPACT



- The impact of climate change on the transport sector is relatively unstudied compared to other areas
- Changes will lead to geographic shifts in volume rather than overall losses
- Apparent net negative effects relate to losses incurred through increasing costs of logistics for inland transport, as some important river levels decline
- These losses are not expected to be offset by gains in transport effectiveness in parts of the world experiencing more flooding of river-ways due to climate change
- Water resource management and conservation are required to limit these effects

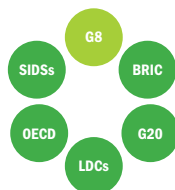
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
i Developing Country Low Emitters **f** Developed
i Developing Country High Emitters **o** Other Industrialized

★ **\$** = Losses per million USD of GDP
➤ Change in relation to overall global population and/or GDP

◎ **\$** = Millions of USD (2010 PPP non-discounted)

Only the impact of climate change on river transport is considered here. Many other negative and positive effects of climate change on the transportation sector are conceivable, but difficult to simulate (Koetse and Rietveld, 2009; Eisenack et al., 2012). Climate change, however, can clearly affect the flow of rivers, increasing or decreasing the rate and volume of water over which goods are transported (Stromberg et al., 2010). A number of the world's waterways are already independently stressed due to infrastructure, pollution, or water withdrawals, which can reduce river flows and make them more vulnerable to climate change impacts (Palmer et al., 2008; Sabater and Tockner, 2010). Climate change has been simulated to have potentially serious negative effects on the river levels of some of the world's most important waterways, including the Danube, the Rhine, and the Rio Grande rivers (Nohara et al., 2006). Lower water levels will continue to increase shipping costs for major global transport conduits affected by river level decline, with potentially significant effects for affected communities—for example, the Rhine carries around 70% of all inland waterway transport of the pre-2004 EU-15 (Jonkeren et al., 2007).

CLIMATE MECHANISM

There are also discernable linkages between river flows and climate factors, such as extreme heat, rainfall, and drought (Kaczmarek et al. (eds.), 1996). Increasing temperatures, the earlier onset of spring, longer, hotter summers, long-term glacial decline, and changes in rainfall patterns, among other effects characteristic of climate change, will have an increasing role in determining water levels in the world's rivers. Increased rainfall and heavy flooding will also affect rivers in some places. However, there is little evidence of any beneficial effect from higher river levels, which are more likely to increase flooding and other risks, since most additional water will fall during the rainy season, when flows and supply are in abundance (Arnell, 2004). When river levels decline, an economic loss arises by affecting the maximum cargo payload that can be transported, or the size of ships transporting goods. The inefficiencies thus created increase shipping costs in a predictable way (Jonkeren et al., 2007).

IMPACTS

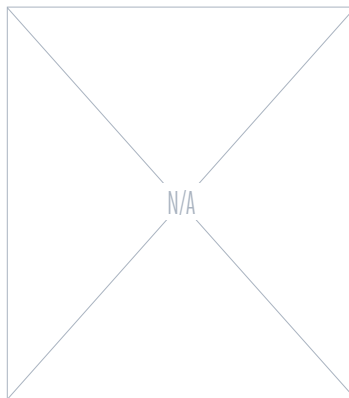
Only a handful of countries are affected in any significant way by the impact of

climate change on river transportation. This is because large-volume, inland, water-borne transportation is a major economic activity in only a few river basins of the world (UNECE, 2012a). Moreover, only a small number of river basins are currently projected to see continued decline, mainly because in many areas rainfall will increase with climate change (Nohara et al., 2006). The costs of climate change on the transport sector as a result of effects for inland water-borne logistics are currently estimated at 1 billion dollars per year, increasing to over 7 billion dollars by 2030 as the effect intensifies and the overall impact grows as a share of GDP. The bulk of all losses are estimated to be incurred in the United States, with European countries along the Rhine and Danube, such as Germany and the Netherlands, as well as Bulgaria and Romania, affected to lesser degrees. Mexico also shows high levels of vulnerability, linked to decline of the Rio Grande. Caution is suggested with regard to the assessment results, which may underestimate the vulnerabilities of several river basins if rainfall patterns were to evolve differently than expected, based on the research relied upon here.

THE BROADER CONTEXT

Many factors other than climate change—especially water withdrawals from rivers due to growth in agricultural, industrial, and municipal water demand—can play a central role in the level of rivers (Alcamo et al., 2003). Indeed, so-called “basin” closure—the inability of a waterway to meet local water demands for part of the year—currently affects 1.4 billion people in various river basins around the world (Falkenmark and Molden, 2008). Population growth exacerbates these issues when alternate resources are not adequately managed (Vösösmarty et al., 2000; Palmer et al., 2008). The transportation and logistics sector is a steady growth industry in a globalizing economy, with no expectation of declining demand, except for passenger transportation in some industrialized country settings (US DoT, 2010; Millard-Ball and Schipper, 2011). Therefore, losses are unlikely to lead to unemployment issues, but rather to generate additional costs for communities that have relied on highly efficient inland water-borne transportation, which can be a major economic benefit.

BIGGER PICTURE



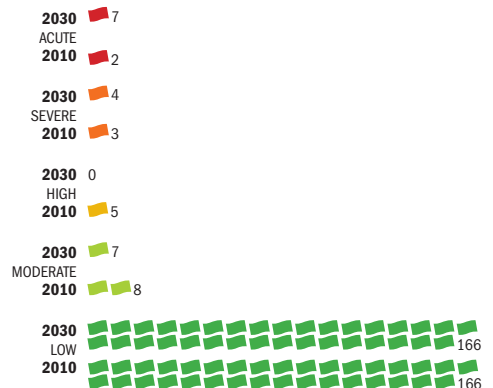
SURGE



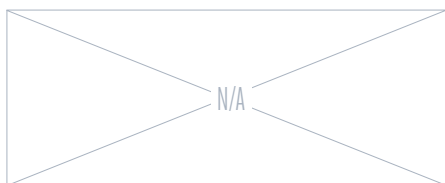
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Jonkeren et al., 2011; Nohara et al., 2006
 EMISSION SCENARIO: SRES A1B (IPCC, 2000)
 BASE DATA: UNECE (2012a)

➡ = 5 countries (rounded)

VULNERABILITIES AND WIDER OUTCOMES

In arid regions, water demand for irrigation has an amplified effect on river levels (Kang et al., 2004). Africa may be particularly vulnerable as a result (de Wit and Stankiewicz, 2006). Smaller rivers may also be asymmetrically affected (Pandey et al., 2010). Free-flowing rivers are more resilient than riverways with dams (Palmer et al., 2008). Deforestation or expanded agricultural and industrial activity can further lower resilience to any shocks and river-level decline brought on by climate change (Sahin and Hall, 1996; Conway, 2005). As the effects are currently interpreted, the narrow economic impact is not expected to have many discernable wider outcomes, aside from burdening a handful of countries/communities with additional costs.

RESPONSES

With glacial retreat, growing heat, and rainfall decline out of societal control, responses would likely include some form or combination of water resource management and the enhancement



of catchment potential (Palmer et al., 2008; Falkenmar and Molden, 2012). Water resource management could seek to minimize or reduce water withdrawals, especially during high summer or drought periods, as well as increase water re-use and reduce water contaminants from industrial or agricultural sources (Geng et al., 2001; Friedler, 2001; Asano, 2002). Government quotas

on irrigation could stimulate broader use of micro-irrigation and other water conservation actions (Pereira et al., 2002; Barret and Wallace, 2011). Water catchment potential can be enhanced through such measures as large-scale forestry expansion and conservation (Sahin and Hall, 1996). Limiting riverine infrastructure also improves resilience (Palmer et al., 2008).

THE INDICATOR

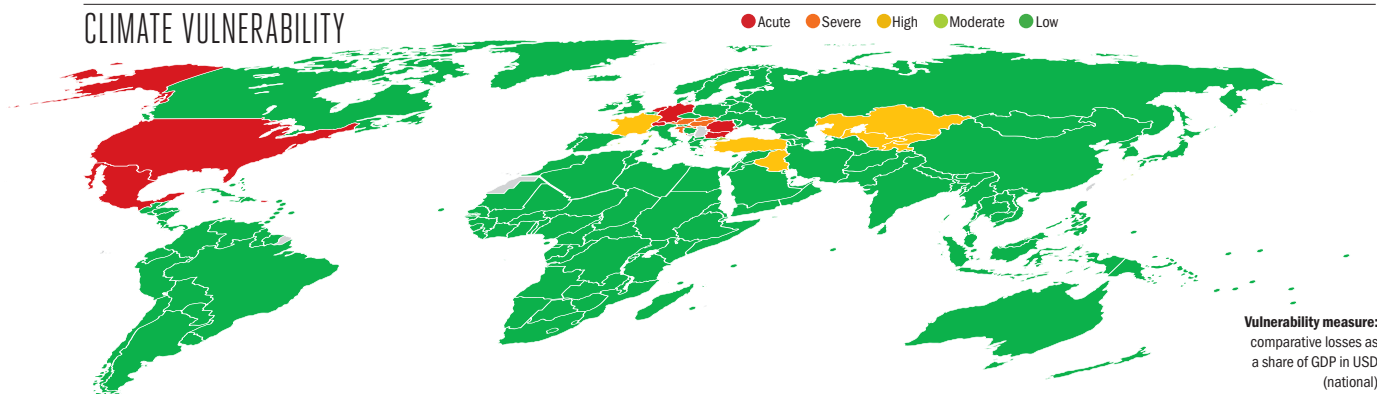
The indicator is considered uncertain and speculative for those countries assessed—provided projections for river flow and levels are accurate (Nohara et al., 2006). The economic effect of river decline relies on a study conducted in the Netherlands, not global research (Jonkeren et al., 2007). But the main limitation of the transport sector indicator relates to its scope, as increasing severity and variability of weather, growing heat stress, and other elements will likely affect the transport industry. Growing tire failure, increased delays and congestion, accidents, and port infrastructure damage have not been studied sufficiently to build even speculative indicators of global effects (Koetse and Rietveld 2009; Eisenack et al., 2012). The rapid opening of previously inaccessible Arctic passageways will likely benefit, but its dynamics are difficult to ascertain (Macdonald et al., 2005). Additional investigation is needed to better understand the global effects of climate change on the transport sector.

ESTIMATES COUNTRY-LEVEL IMPACT

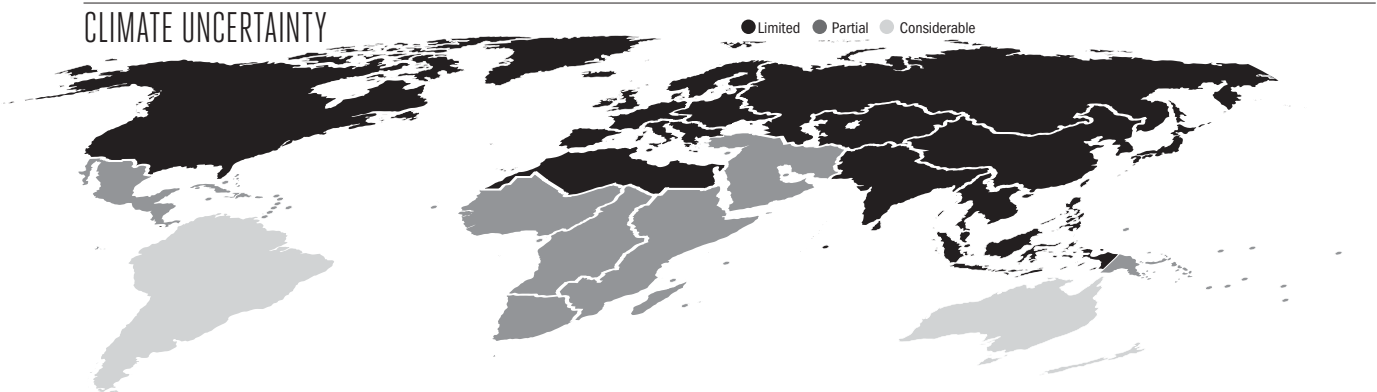
COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			Bahrain			Djibouti		
Bulgaria	5	65	Bangladesh			Dominica		
Germany	45	200	Barbados			Dominican Republic		
Mexico	75	950	Belarus			DR Congo		
Netherlands	35	150	Belgium			Ecuador		
Romania	10	100	Belize			Egypt		
Switzerland	5	30	Benin			El Salvador		
United States	1,000	5,750	Bhutan			Equatorial Guinea		
SEVERE			Bolivia			Eritrea		
Austria	5	15	Bosnia and Herzegovina			Estonia		
Croatia	1	10	Botswana			Ethiopia		
Hungary	1	25	Brazil			Fiji		
Slovakia	1	15	Brunei			Finland		
MODERATE			Burkina Faso			Gabon		
France	5	25	Burundi			Gambia		
Iraq			Cambodia			Georgia		
Kazakhstan			Cameroon			Ghana		
Kyrgyzstan			Canada			Greece		
Tajikistan			Cape Verde			Grenada		
Turkey			Central African Republic			Guatemala		
Uzbekistan			Chad			Guinea		
LOW			Chile			Guinea-Bissau		
Afghanistan			China			Guyana		
Albania			Colombia			Haiti		
Algeria			Comoros			Honduras		
Angola			Congo			Iceland		
Antigua and Barbuda			Costa Rica			India		
Argentina			Cote d'Ivoire			Indonesia		
Armenia			Cuba			Iran		
Australia			Cyprus			Ireland		
Azerbaijan			Czech Republic			Israel		
Bahamas			Denmark			Italy		



CLIMATE VULNERABILITY



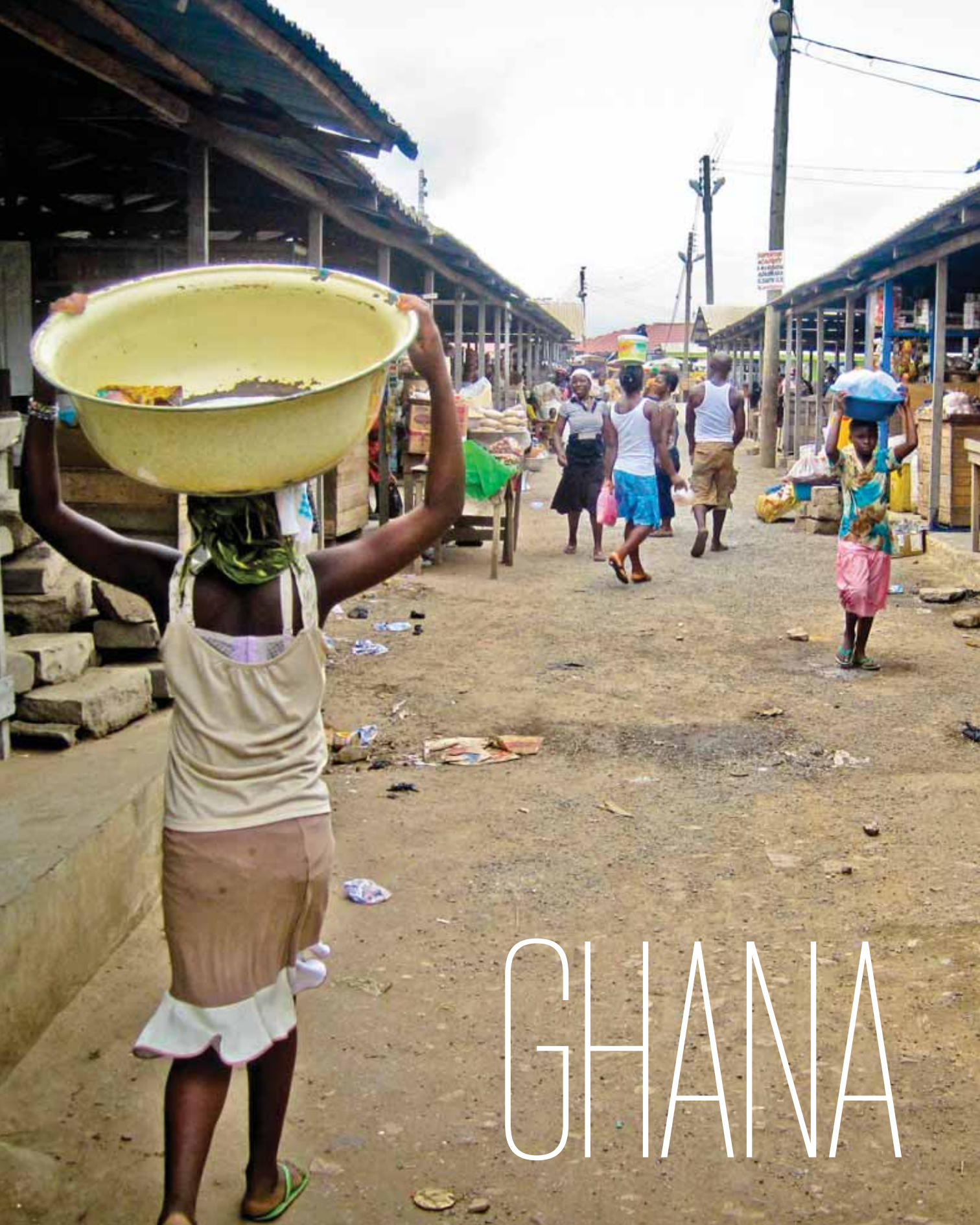
CLIMATE UNCERTAINTY



COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Jamaica			New Zealand			South Korea		
Japan			Nicaragua			Spain		
Jordan			Niger			Sri Lanka		
Kenya			Nigeria			Sudan/South Sudan		
Kiribati			North Korea			Suriname		
Kuwait			Norway			Swaziland		
Laos			Oman			Sweden		
Latvia			Pakistan			Syria		
Lebanon			Palau			Tanzania		
Lesotho			Panama			Thailand		
Liberia			Papua New Guinea			Timor-Leste		
Libya			Paraguay			Togo		
Lithuania			Peru			Tonga		
Luxembourg			Philippines			Trinidad and Tobago		
Macedonia			Poland			Tunisia		
Madagascar			Portugal			Turkmenistan		
Malawi			Qatar			Tuvalu		
Malaysia			Russia			Uganda		
Maldives			Rwanda			Ukraine		
Mali			Saint Lucia			United Arab Emirates		
Malta			Saint Vincent			United Kingdom		
Marshall Islands			Samoa			Uruguay		
Mauritania			Sao Tome and Principe			Vanuatu		
Mauritius			Saudi Arabia			Venezuela		
Micronesia			Senegal			Vietnam		
Moldova			Seychelles			Yemen		
Mongolia			Sierra Leone			Zambia		
Morocco			Singapore			Zimbabwe		
Mozambique			Slovenia					
Myanmar			Solomon Islands					
Namibia			Somalia					
Nepal			South Africa					



COUNTRY
STUDIES



GHANA

COUNTRY STUDIES

GENERAL PURPOSE

1

FEEDBACK FOR THE DEVELOPMENT OF THE MONITOR'S METHODOLOGY

2

EXPLAIN HOW THE ANALYSIS OF THE MONITOR CAN BE USED IN A NATIONAL SITUATION

3

SERVE AS A KNOWLEDGE-SHARING MECHANISM FOR BEST PRACTICE AND CHANGE MANAGEMENT FOR THE BENEFIT OF OTHER VULNERABLE COUNTRIES

4

PROVIDE AN OUTSIDE SUPPORTING ANALYSIS OF INTEREST TO NATIONAL POLICY-MAKERS AND DEVELOPMENT PARTNERS



KEY FIGURES

Population	24,965,816
2012 GDP PPP (Dollars)	
Total	\$82,571,000,000
Per Capita	\$3,312
Real Growth	8.8%

ECONOMY

GDP by Sector	
Primary/Extractive	28.3%
Secondary/Productive	21%
Tertiary/Services	50.7%
Key Sector(s)	Services

SOCIO-ECONOMIC DEVELOPMENT

Human Development (Rank)	Medium (135th)
Life Expectancy	64.2 years
Annual Population Growth	2.3%
Illiteracy	20.2%
Urban Population	52.2%
Access to Electricity	60.5%
Gender Development	122 nd
Undernourished Population (2006/08)	5%
Living below poverty line (\$1,25/day)	30%
Population without Improved Water Source	15.3%
Official Development Assistance (% of GDP)	6.1%
Public Health Expenditure	6.9%
Public Education Expenditure	5.4%

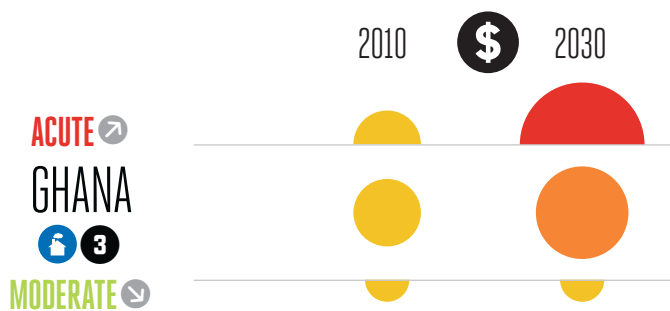
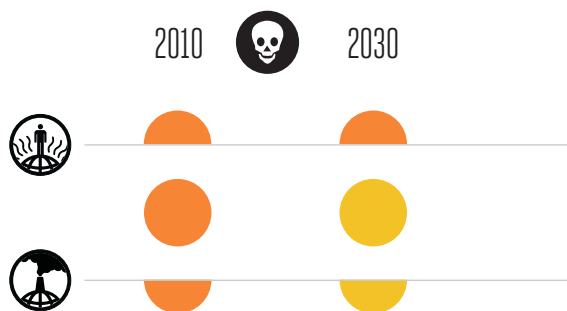
CLIMATE/GEOGRAPHY

Climate Zone	Dry and wet tropical
Projected Rainfall Change	20-30% reduction
Tropical Cyclones	No
Desertification	Yes
Low-Elevation Coastal Zone (10m and below)	1%
Forest Cover Change (1990-2008)	30.6%

MIGRATION/DISPLACEMENT

Emigration Rate	4.5%
Immigrants as Share of Total Population	7.6%
Internally Displaced People	None

Impact Areas	Indicator	Confidence	Bias	Vulnerability	
				2010	2030
CLIMATE	DROUGHT	✓		Yellow	Yellow
	FLOODS & LANDSLIDES	✓	♀	Green	Green
	STORMS	✓		Green	Green
	WILDFIRES	✓		Green	Green
	BIODIVERSITY	✓		Green	Yellow
	DESERTIFICATION	✓		Yellow	Yellow
	HEATING & COOLING	✓		Green	Yellow
	LABOUR PRODUCTIVITY	✓	♂♀	Red	Red
	PERMAFROST	✓		Green	Green
	SEA-LEVEL RISE	✓		Green	Green
	WATER	✓		Green	Green
	DIARRHEAL INFECTIONS	✓		Red	Red
	HEAT & COOL ILLNESSES	✓		Yellow	Yellow
	HUNGER	✓		Orange	Yellow
	MALARIA & VECTOR BORNE	✓		Yellow	Green
	MENINGITIS	✓		Yellow	Yellow
	AGRICULTURE	✓		Orange	Red
	FISHERIES	✓		Yellow	Red
	FORESTRY	✓		Yellow	Orange
	HYDRO ENERGY	✓		Green	Green
	TOURISM	✓		Green	Green
TRANSPORT	✓		Green	Green	
CARBON	OIL SANDS	✓		Green	Green
	OIL SPILLS	✓		Green	Green
	BIODIVERSITY	✓		Yellow	Yellow
	CORROSION	✓		Green	Green
	WATER	✓		Green	Green
	AIR POLLUTION	✓		Yellow	Yellow
	INDOOR SMOKE	✓	♀	Yellow	Yellow
	OCCUPATIONAL HAZARDS	✓	♂	Green	Yellow
	SKIN CANCER	✓		Green	Green
	AGRICULTURE	✓		Green	Green
FISHERIES	✓		Green	Green	
FORESTRY	✓		Green	Green	



“Unbearable” was a word commonly offered up by residents of rural communities in Ghana visited by the research team, emblematic of their view of the rising heat. Ghana was never a cool country, but an increase in average temperatures of 1 degree Celsius (1.8 degrees Fahrenheit) has been recorded over the past half-century. In comparison to Ghana in the 1960s, the effect of this seemingly small change in temperature is striking: there are now 50 more “hot” days and almost 80 “hot” nights every year (McSweeney et al., 2012). In addition to temperature, floods, wind and rain storms, as well as changes in the pattern of rainfall have become serious climate-related concerns for Ghana today (EPA-Ghana, 2011).

Most ecological zones of Ghana are hit by this rapid change in climate with effects already manifested in major sectors of the economy, such as agriculture, fisheries, and forestry, with some of these ramifications triggering severe economic and social decline, especially in rural areas. The success of Ghana is a beacon for Sub-Saharan Africa, which is plagued in many places by extreme poverty, hunger, suffering, conflict, and instability. As this report reaches publication, a humanitarian emergency across the Sahel is ongoing and extending through West Africa with some 20 million people in the grip of a major food crisis (Oxfam, 2012).

All of the drivers of climate change that harm: heat, unpredictable rainfall, changes in the timing and length of the crop season, sea level rise, ocean warming, to name only a few, will only intensify and hasten with each passing decade.

Few developing countries anywhere in the world offer meaningful models for tackling the climate problem at the national level. Even model adaptation options—such as planting medium heat-tolerant maize varieties and delaying sowing dates to minimize climate change impacts—present challenges related to everything from technology transfer to cultural beliefs (Tachie-Obeng et al., 2011). However, delaying investment to attenuate the losses and risks faced by climate change only leads to still higher costs, already estimated at several percentage points of Ghana's GDP.

Climate change and/or the carbon economy are far from being Ghana's only concerns. Indeed, with each climate-related issue, additional social, economic, and environmental problems combine to heighten vulnerabilities and the level of harm generated through the impact of climate change, which itself exacerbates economic, social, and environmental problems.

With limited resources, cost-effective solutions will have to explore the range of competing factors responsible for vulnerability and impact in the context of climate change. It is also an opportunity to revisit and address other longstanding problems, including gender inequality, deforestation, unsustainable fishing, and barriers that limit better use of technologies to drive social and economic activities and enhance resilience. Together with the affected communities, solutions can be found to the current challenges Ghana faces. The average temperature in Ghana has risen by around 1 degree centigrade (1.8° Fahrenheit) since the period from the 1970s to the 2000s. Should Ghana warm by another 3°C (5.5°F) in the 50–60 years to come, the human, economic, and environmental damage will be severe. What happens beyond the next few decades is now in the hands of national policymakers in the world's major economies.

Ghana could harness its successes to date by tackling climate change risks concertedly, and in doing so, not only improve the resistance of its own economy to these effects, but also serve as an inspiration in the coming decades to other countries in the region, which all face similar problems.



- 1 ACCRA
- 2 NEW NINGO
- 3 ADA FOAH
- 4 KETA
- 5 BOLGATANGA



MULTI-DIMENSIONAL CLIMATE VULNERABILITY: **ACUTE** ↗



MULTI-DIMENSIONAL CARBON VULNERABILITY: **MODERATE** ↘

CAPACITY: **RESTRICTED**

POPULATION 2010/2030: **24/32 MILLION**

GDP 2010/2030 (PPP): **65 BILLION/210 BILLION USD**

GDP PER CAPITA 2010/2030 (PPP): **2,650/6,500 USD**



BACKGROUND AND CONTEXT

BACKGROUND AND CONTEXT

With close to 25 million inhabitants, Ghana is a mid-sized and rapidly growing West African country. Now considered a middle-income country (lower-middle income) by the World Bank, Ghana is bordered to the north by Burkina Faso and to the east and west by Togo and Côte d'Ivoire, respectively. Ghana's climate is tropical monsoon, with relatively low-elevation geography, and clear regional differences in climate between the savannah (northern and east coast) and more humid southwestern forested areas along the Gulf of Guinea. Ghana is similar in size to the United Kingdom.

Ghana's real GDP grew at an average of 6% in the first decade of the 21st century and continues with growth for 2012 estimated by the IMF at almost 9% (IMF WEO, 2012). Ghana's per capita income is still very low, at around 3,000 dollars (PPP) or 1,700 US dollars (nominal). Income inequality is also high, with nearly half the urban population living in slums (UN-HABITAT, 2012). Ghana is not considered a Least Developed Country by the United Nations but its capacity is considered to be Intermediary, due to comparatively limited human and infrastructure assets, and despite relatively strong government effectiveness. The climate-sensitive agricultural sector still represents around 30% of GDP and employs nearly 60% of the workforce.

Ghana recently discovered large-scale new offshore oil and gas reserves, which are expected to boost national income further in the coming years. Ghana also produces large amounts of cash-yielding cocoa and gold that are mainstays of its economy. Heavy reliance on one type of crop may, however, represent a serious latent but systemic climate risk for Ghana's agricultural sector, where climate change to make plant diseases and pests more prevalent in the humid southern zone where much of the cocoa is grown (Bronzizio

and Moran, 2008). Nevertheless, continued national economic growth is well assured in the medium term. But whether or not Ghana's climate change policies are effective will be increasingly important in determining the extent and distribution of this growth, and the sustainability of its economic development as currently programmed.

GHG emissions remain very low at 3.2 tons per capita and are not expected to even exceed 3.5 tons per capita by 2020 (Climate Analytics, 2012). Deforestation is at very high rates and currently represents over 40% of total emissions; a little more than a decade ago, the forestry sector was acting as a net carbon sink, not an emitter (EPA-Ghana, 2011). Urban air pollution is beginning to become more serious, but household fuels are a much greater health concern, since indoor firewood stoves are still widely in use. Moreover, 40% of all homes lack access to electricity.

As is the case for many countries in close proximity to the equator, the environmental vulnerability of Ghana is extreme. Ghana is exposed to fisheries impacts, due to rising water temperatures and coastal erosion caused by the rising sea level; in the north, the increase in heat is occurring in a continental climate not restrained by the proximity of the sea. These effects are compounded by floods, drought, wildfires, land degradation, soil erosion, the threat of desertification, and the prevalence of diseases, such as cholera and meningitis. Major cash and staple crops, such as cocoa and maize will be affected in growing measure by climatic shifts, including increased temperature, the contraction of cropping seasons and changes in the distribution of rainfall.

In both urban and rural communities, socio-economic vulnerabilities are also extreme. Cities such as Accra have sprawling slums which form hazard-prone zones, exposing populations to unsafe water, restricted sanitation, and deadly flood

THE MONITOR'S ASSESSMENT OVERVIEW / CLIMATE CHANGE

risks—much of Accra was flooded in 2011, causing significant loss of life. In rural areas, subsistence farming is still widespread, and a lack of basic agricultural inputs and infrastructure, such as irrigation, roads and storage facilities make this group less adaptive to changes in climate.

THE MONITOR'S ASSESSMENT

OVERVIEW

Despite its relatively strong economic position in West Africa, Ghana is among the countries most vulnerable to climate change. According to the Monitor, Ghana's economic development will have already been significantly compromised due to changes in the climate that have already taken place.

The multi-dimensional vulnerability of Ghana to climate change is considered in the highest category of Acute, with vulnerability steadily increasing as global and local temperatures rise. Ghana's vulnerability to carbon impacts is considered Moderate and is actually declining, due mainly to the expectation that agriculture might benefit from carbon fertilization as CO₂ levels rise, and because economic development should lead households to adopt less hazardous cooking and heating practices over time. Both human (Severe) and economic (Acute) vulnerability are very high. Climate change is estimated to claim around 2,000 lives each year in 2010, while carbon-related mortality is at 13,000 deaths per year; each impact is expected to decline slightly by 2030 as a share of overall population, due to anticipated socio-economic gains between now and then. Losses due to climate change are estimated at 4% of GDP in 2010, rising to 9% of GDP in 2030. Carbon losses are stable at approximately 1.5% of GDP.

CLIMATE CHANGE

Following are the most serious climate change impact areas as assessed (for 2010/2030) in order of the scale of

GDP losses, from highest to lowest:

- LABOUR PRODUCTIVITY, **ACUTE/ACUTE** 3.0%/6.1% of GDP
- FISHERIES, **HIGH/ACUTE** 0.3%/1.1% of GDP
- AGRICULTURE, **SEVERE/ACUTE** 0.4%/0.7% of GDP
- SEA-LEVEL RISE, **MODERATE/MODERATE** 0.3%/0.4% of GDP
- BIODIVERSITY, **MODERATE/HIGH** 0.1%/0.2% of GDP

The most serious health effects are Diarrheal Infections, Hunger, Heat and Cold Illnesses and Meningitis. Heat and Cold Illnesses relate to the impact of heat waves on chronic disease sufferers, particularly the elderly. While mortality rates are not alarmingly high, more than 1 million people are estimated to be affected on average each year, due to the impact of climate change on diarrheal diseases, and over 400,000 people suffer from hunger.

The impacts for Labour and Sea-Level rise carry a relatively high degree of certainty, while other areas are more of an indication, due to the limitations of the models used and agreement on the signal of key changes, such as rainfall. Other areas of high vulnerability constituting serious concerns for affected communities include Desertification (High) and Drought (High), although these are not as significant in economic terms on a national level. Desertification is nevertheless estimated to already be affecting 75,000 people in Ghana, which could rise to 200,000 people at risk by the year 2030. By 2030, drought could cause 15 million dollars of damage on average each year to farmers, especially small-scale and subsistence farmers with low-resilience to these impacts. Floods and Landslides have been assessed as a Moderate concern; however, field research demonstrated that flooding is a major and growing concern in both urban and rural areas. For instance, recent large-scale floods in October 2011 inundated large parts of downtown Accra, reportedly killing 14 in the greater



CARBON ECONOMY

Accra region and 33 nationwide, according to Ghana's National Disaster Management Organization (NADMO). The international disaster database records 300 deaths due to floods for the whole of the last two decades since 1990, not including the 2011 floods (CRED/EM-DAT, 2012).

The only positive effect Ghana is estimated to experience on the basis of the Monitor's assessment is a less than 0.1% of GDP boost to Hydro Energy, as a result of small, although uncertain, increases in annual river flow that are projected by some models for this region of the world. Wildfires are a legitimate concern in Ghana and increased aridity and drought in certain areas will increase the likelihood of fires. However, since Ghana is projected to experience some increased rainfall, the final outcome of the role of climate change on wildfires is ambiguous, so vulnerability is assessed as Low.

CARBON ECONOMY

With respect to carbon economy costs, in human terms Indoor Smoke claims an estimated 10,000 lives each year today, followed by over 2,000 deaths associated with urban air pollution. Air Pollution deaths are expected to grow as a share of population to close to 4,000 deaths per year in 2030. However, Indoor Smoke is expected to decline to around 8,000 deaths per year by that time.

In economic terms, the largest carbon impact is to Biodiversity at 1% of GDP in 2010, growing to 2% of GDP by 2030. Health impacts are the next biggest loss to GDP at 0.8% of GDP, declining to 0.4% of GDP by 2030. The agricultural sector is still generally unaffected by pollution, but could benefit from higher CO₂ levels, in which case gains are estimated at 0.1% of GDP in 2010 and 0.8% of GDP in 2030. Thus, any current benefits of CO₂ fertilization are outweighed three times over by costs related to climate change. By 2030, scientists predict that all of the future impacts of climate change will be compensated by increases in plant growth due to CO₂

NATIONAL RESPONSE STATUS

fertilization. The very latest research is nevertheless more pessimistic than the Monitor's assessment on the possible extent of such benefits (Ainsworth et al., 2008; Leaky et al., 2009). This result should therefore be treated with much caution. Field research undertaken for the purpose of the Monitor in Ghana identified key agricultural regions already suffering severe stress and fundamental challenges relating to climate-tied shifts carrying serious humanitarian ramifications, including hunger and other diseases. Local research has also documented the climate-related challenges facing core staple crops, such as cocoa and corn (Tachie-Obeng et al., 2011). Carbon fertilization benefits are known not to accrue under stressed conditions (IPCC, 2007). Nonetheless, improving the resilience of Ghana's agricultural sector to climate change would certainly increase its chances of benefitting from any possible positive effects of high CO₂ levels, if they are ever to materialize; either way, adaptation to climate change remains a core priority. The health related impacts of Indoor Smoke and Air Pollution are considered relatively reliable, whereas Biodiversity and Agriculture should be considered more indicative or less certain.

NATIONAL RESPONSE STATUS

Policy development on climate change in Ghana is a new and rapidly advancing focus of energy for key government departments with competencies relating to the environment and disaster issues. The government has recognized climate change as a current concern for the country's economic output. It is viewed as a development challenge requiring action to address climate change so as to ensure that national progress is not derailed. This is at the core of ambitions to mainstream climate change into key planning processes at national, regional and district levels,

and into the Ghana Shared Growth and Development Agenda. In this spirit, an active consultation process is now underway aiming to develop a National Climate Change Policy. The National Policy has three core objectives: 1) effective adaptation to climate change, 2) social development, and 3) low carbon growth. The government has also identified the following seven pillars which it is planning to build upon in order to achieve those objectives:

- Governance and coordination
- Capacity building
- Research and knowledge management
- Finance
- International cooperation
- Education, communication and public awareness
- Monitoring and reporting

There exists a National Climate Change Committee grouping some 14 government entities together with development partners, including foreign assistance donors. It has been mandated to drive the climate change policy development work forward and is hosted by the Ministry of Environment, Science and Technology. A National Adaptation Strategy for Ghana has been completed following a detailed process of stakeholder inputs from multiple sectors, with the launch scheduled to take place before the end of 2012.

While the policy process is moving in a very promising direction, Ghana still lacks government policies specifically designed for responding to climate change. In particular, at the community level, district development plans viewed did not account for the additional stress resulting from climate change, nor did such plans contain climate change specific response considerations, whether to reduce carbon intensity or to address climate impacts. Nevertheless, several government entities are dealing with climate change issues as a part of their operational mandates and daily concerns, such as the Environmental Protection Agency-Ghana (EPA-Ghana) and the National Disaster Management Organization (NADMO). And there was evidence of active work on the part

CLIMATE FINANCE

of government, international, and local non-governmental organizations and foreign assistance partners in many climate change related areas of concern, from coastal defences, to food security, and health and sanitation issues.

CLIMATE FINANCE

In 2010, Ghana received close to 80 million US dollars in public climate change finance from foreign sources, making Ghana the 31st largest recipient that year among developing countries. This amount represented 0.25% of Ghana's GDP— compare this to the amount received by Vietnam (also studied in this report), which represented 0.5% of Vietnamese GDP in 2010. The largest bilateral donors of climate change finance in 2010 were Japan and France, which provided more loans for mitigation finance and only grants for adaptation. The component of those resources targeted to assist Ghana in adapting to the negative effects of climate change made up only about 10% of the total, or 10 million dollars. An order of magnitude increase in climate change finance for adaptation in Ghana would be needed, if a balance with respect to mitigation were to be achieved. Even such levels would likely fall far short of the actual requirement, considering the estimate that climate change already costs Ghana 4% of its GDP. Deserving of high praise are Ghana's development successes in high rates of real GDP growth and the progress achieved towards the Millennium Development Goals to-date. There is, however, a risk that foreign development partner donors view those achievements and the discovery of important fossil fuel reserves as reasons for withdrawing international support. The research team which visited various regions in connection with this project found that, in certain cases, foreign assistance programmes were already being withdrawn from some of the most vulnerable communities. Climate change impacts



ASSETS

are now expected to accelerate very quickly, putting the development gains of Ghana at greater risk, in particular where last-mile efforts to empower the poorest of the poor have not succeeded. Ghana's forthcoming National Adaptation Strategy should provide a vehicle for donors to ensure that adequate support is provided to the country as it seeks to address these serious and growing concerns.

ASSETS

Ghana faces a number of capacity constraints that are commonplace for lower-middle income countries in sub-Saharan Africa. But Ghana also has a number of important assets at its disposal as it gears up to tackle climate change locally:

- **Community Reach:** With the National Disaster Management Organization (NADMO), Ghana has centrally organized government officials or trained volunteers on the ground in every district, if not every village. NADMO volunteers are mobilized and actively working to respond to and reduce risks for communities dealing with climate change and other threats to safety and livelihoods and their responsibilities include advocacy and emergency assistance. Given appropriate strategies and resources, the NADMO apparatus will be invaluable for ensuring that community-level actions are carried out among the most vulnerable groups.
- **Technical Capacity:** the Environmental Protection Agency-Ghana (EPA-Ghana), the lead institution for UNFCCC-related activities, has been establishing important foundations of local expertise on core climate-related concerns, as it serves as the main Country Implementation Institution for the technical coordination of activities on climate change, including specialized working groups and expert climate change study teams, all of which support national policy development and the implementation of climate change project activities.
- **Fiscal Resilience:** Ghana is financially

stable with relatively low levels of public debt and surging economic growth. There are significant and important infrastructure investments that Ghana will be making over the next 5 to 10 years as it reinvests its growing wealth back into the economy. Ghana has yet to commit streams of public funds to a formal climate change policy, but should consider allocating some specific levels of resources to its own domestic climate change policies while the economy is strong.

- **Health Insurance:** In all communities visited as a part of the field research for the Monitor, participation rates in local health insurance schemes were very high, with annual fees very affordable, in some cases as little as 5 US dollars (10 Ghanaian Cedis). Health insurance did not, however, cover preventative measures, such as insect-repellent infused mosquito nets or vaccinations. Therefore, preventative measures remain a challenge for communities themselves, the government and foreign aid programmes.
- **Indigenous Knowledge:** The long cultural history and traditions of the people of Ghana represents a great wealth of indigenous knowledge relating to the environment. As climate change brings rapid change to that environment, much of this knowledge is not only not obsolete, but has become more important and useful. In one region for instance, crickets, still announced the end of the warm season, even when the timing of the season had shifted considerably. Documenting and disseminating the best of indigenous knowledge to supplement highly technical or costly infrastructure responses to climate change would help to lower costs and improve impact.
- **Sound Policy Environment:** From the capital in Accra to the remote villages of northern Ghana, community leaders, NGOs, entrepreneurs, farmers, experts, and other members of civil society consistently expressed deep concern and interest in climate-related issues. The government



GAPS

is benefitting from the attention and knowledge as a part of the consultative process leading towards the National Climate Change Policy and should continue to promote that interest, which will likely pay dividends in terms of fine-tuned policies and more robust implementation.

GAPS

- Ghana still lacks a dedicated climate change policy and never issued a National Adaptation Programme for Action under the UNFCCC since it is not a Least Developed Country. So policy gaps are large for now, but will progressively be filled, as different aspects of the government's policy project come online. Some gaps in the general policy approach can still be identified, and should be reinforced:
- **Leadership:** As evident from the more than one dozen government entities already participating in Ghana's National Climate Change Committee, the challenge of coordinating and ensuring sound implementation of cross-sector challenges is immense. The government has already recognized the need for a dedicated statutory body on climate change to oversee the government response, enhancing coordination and avoiding duplication. However, executive leadership on climate change has been largely absent and does not appear to be a planned component of a climate change body for Ghana. Ghana might do well to take a cue from successful national policy approaches of other vulnerable countries, such as the Philippines or Vietnam, where there is direct involvement of the government executive branch, which issues formal policy directives to all other relevant organs of government.
 - **Prioritization:** The research undertaken for the Monitor revealed that the government of Ghana has yet to flag climate change as a key priority area in its formal discussions with leading development partner donors. As such, several donors had the impression that climate change is not a priority



- for the government. A key step to mobilizing enhanced international support for Ghana's domestic climate change policies is for the government to be unambiguous regarding the importance of the climate policy project for Ghana when interacting with foreign assistance partners.
- **Fragmentation:** Experts also expressed concern over the potential fragmentation of national efforts to address climate change, as wide-ranging initiatives were being pursued in different directions. Fragmentation risks exhausting precious capacities, especially in central government, and favouring project-based pathways over strategic approaches more capable of tackling systemic issues.
- **Reference Scenarios:** Ghana plans to publish national reference scenarios for climate change as part of its National Adaptation Strategy. But to date, it has lacked truly comprehensive and highly specific reference scenarios for all key regions of the country across all main climate parameters, including river flow, rainfall/runoff, temperature, sea-level rise, sea temperatures and acidity, wind, fire risk, flooding, and drought/extreme aridity. For example, scenarios for rainfall cited in the most recent UNFCCC National Communication are at odds with the analyses of some other leading experts, which point to increases not decreases in rain, although seasonal, not annual, declines of rainfall may be extreme, including during growing periods (EPA-Ghana, 2011; McSweeney et al., 2012; Tachie-Obeng et al., 2011). The regular updating and publication of new national reference scenarios is critical for guiding the progressive calibration of adaptation investments as knowledge evolves. Establishing scenarios through wide consultation that all key stakeholders can have confidence in, despite intrinsic uncertainties, is an important component in building strong support for the national response to climate change.
- **Donor Support Group:** There is no formal group involving a wide range of key foreign donors that is operationally

OTHER CHALLENGES AND OPPORTUNITIES

focused on supporting Ghana to develop and implement climate change policies. Best practice from other country experiences such as Vietnam point to the clear value of a donor support group that could add to the policy implementation efforts of Ghana on climate change and help to harmonize aid, avoid overlap and drains on capacity, track progress and results, and ensure that financial commitments match government defined priorities and needs as effectively as possible.

OTHER CHALLENGES AND OPPORTUNITIES

- *Access to Markets and Industry:* All rural areas visited by the research team had in common a near total absence of any local light industry operations aimed at processing and packaging the raw products of farmers and fishermen into finished goods that could be transported to reach non-domestic markets. This led to the paradox of purchasing boxed South African mango juice from a food stall to be consumed under a fully laden local mango tree. In the Gulf of Guinea, fishing boats from China, Japan and Korea plied the waters and sent back home the fruits of Ghanaian seas. Tragic outcomes also resulted: an unusual bumper crop of tomatoes that was left to spoil on the road led some farmers to commit suicide when they realized that their superb crop was unable to reach any market. Yet none of the communities visited had development plans in place to give incentives to local entrepreneurs or to attract investment to set-up freezing works for seafood, canning facilities for tomatoes, packaging houses for fruit juice, or any other light industrial facilities that would enable farmers to achieve higher prices for their goods, receive more from the commercial value chain, and ultimately increase profits and disposable income.
- *Energy and Carbon Markets:* The abundant heat and sunshine that is now a concern for Ghana as temperatures continue to rise, underscores the existence of a latent

wealth of solar energy that is not being harnessed anywhere. Programmes aimed at distributing efficient and clean-burning indoor cooking stoves would not only reduce disease, but also help stem deforestation, land degradation, and desertification, since communities rely heavily on local wood as the primary fuel. Making the most of new opportunities in the renewable energy sector was a major theme expressed in interactions with experts during the research work undertaken as a part of the Monitor's development. Ghana has yet to gain meaningful access to international carbon markets and to the support mechanisms that drive renewable sector growth in other developing countries. With only one project registered with the CDM and a handful of others under development, virtually no investment has yet been leveraged (UNEP Risoe, 2012). Making the most of a potential future forest carbon market (via REDD+) would help reverse the rampant deforestation that caused Ghana's forestry sector to transition from a net carbon sink to a major source of GHG emissions since only the late 1990s (EPA-Ghana, 2011). Public and private sector capacity building would need to be actively fostered in order to break through and stimulate serious progress for Ghana's renewable energy and carbon sink sector.

- *Migration:* Hallmarks of a long-term rural decline whereby traditional livelihoods faced ongoing erosion were evident in many of the communities studied for this edition of the Monitor. Seeing limited opportunities for themselves, young adults were migrating on a seasonal basis to the larger centres, where they seek informal employment. Men or couples whose livelihoods in agriculture or fishing have been compromised were also moving on a more permanent basis, sometimes leaving children behind in the care of elderly relatives or single mothers; these "stranded" homes were reported to be particularly food insecure and vulnerable: if a remittance did not come in a given

month for whatever reason, the children would go hungry. The situation is fuelling the rapid urbanization of Ghana's metropolitan centres, where slums have been steadily growing, with settlements often developing in marginal or high-hazard zones, such as river flood plains, creating additional risks. It is difficult to attribute a specific proportion of that migration to climate change. However, the change in climate has had a negative affect on agriculture and fisheries—which determine income levels—and stifles economic activity in mainstay rural sectors. The heat, the extreme and erratic nature of rainfall, the rise in sea-levels, the stress on biodiversity and forests, are all set to increase dramatically in the decades ahead. With it, migration pressures will only increase considerably.

- *Women's and Youth Empowerment:* Ghana is known to have low levels of gender-related development or high degrees of gender inequality that disadvantage women (UNDP, 2007; UNDP, 2011). The research undertaken as a part of the Monitor's development highlighted the extent to which women are currently marginalized from decision making on community issues at multiple levels. Many of the men interviewed as a part of the research conducted autonomously suggested that greater involvement of women would lead to more sensible decision making and community action; it was emphasized that women are more receptive to change. The same issues were understood to also apply to youth. Gender development and inequality in particular are highly correlated to climate change vulnerability according to the Monitor's assessment; this suggests that gains across the full spectrum of gender-related development would reduce levels of vulnerability to climate change, since women are understood to be more vulnerable to climate change in Ghana (EPA-Ghana, 2011). The advent of climate change therefore only strengthens the urgency of overcoming gender equality challenges in Ghana.



NORTHERN GHANA: BOLGATANGA-BONGO-NAVRONGO

The Bolgatanga-Bongo-Navrongo areas of the Upper East Region of northern Ghana is close to the border with Burkina Faso. It is a primary agricultural region, raising livestock and cultivating staples such as rice and millet, market vegetables, and orchard trees. About one million people inhabit the upper east region of Ghana, which covers some 9,000km². Northern Ghana is the hottest part of the country, where the so-called “Harmattan” winds blow in from the Sahara desert, and where the increase in heat and the number of hot days and hot nights has been the most extreme. The relentless rise in temperature in the years ahead will also continue to be the most extreme here (McSweeney et al., 2012).

The serious increase in heat the area is experiencing has triggered a downward trend in its core economic sector, agriculture, with negative impacts on the health of the region's population. Key concerns range from extreme flooding, drought, desertification, growing energy needs for cooling, and a declining biodiversity. Concerns were also voiced about the nomadic Fulani herdsmen, who cross from Burkina Faso and are indiscriminately cutting and burning the savannah vegetation and causing other social issues, as their bonds with local farmers are increasingly severed along with rural decline. Occupational heat stress is also endemic, since large numbers of subsistence farmers, anxious to feed their families and unable to work in the relative cool of the night, are obliged to work during the intense heat of the day. All of these effects have serious social and economic implications: the rapid pace of development that Ghana has experienced in other regions has not been enjoyed by this part of the country: every one of the dozens of people interviewed in different villages and centres across this region insisted that life had become much harder. Social vulnerabilities were also extreme: no running water or sanitation facilities of any kind in many households, less than 50% of households with electricity or lighting, no cooling units

or fans virtually anywhere, too few mosquito nets, very few vehicles, and no insurance for houses damaged by flooding and wind or for crops destroyed in drought or floods.

HEALTH

With a significant share of the population living without electricity, refrigeration, running water, or sanitation facilities, the deleterious effects of climate change on health are a major concern. High rates of all of the main climate sensitive diseases were confirmed: diarrheal diseases such as meningitis, cholera, and malaria. In some areas, a majority of households were considered food insecure. People living without any form of climate control would often sleep outside on the hottest nights and in doing so expose themselves to mosquito bites and vector-borne disease, especially malaria, compounding the climate stresses on their health. One local expert explained that people often suffered malaria two or three times a year. Certain villages were able to report on the number of deaths due to meningitis over the preceding few weeks—accounting for more than 10 fatalities in one village alone. In another village, the funeral procession of a victim made its way past the research team's interview site. While health insurance is now high—reported to be around 80% coverage—vaccinations against communicable diseases common in the area are not covered by the insurance schemes, even though some vaccination campaigns were also reported to be in effect. School feeding programmes were in place in many areas, with the local government and international NGOs such as the World Food Programme responsible for providing one meal per day. Hunger deaths were understood to occur in remote areas or where children were not able to attend school, and significantly low school attendance rates were confirmed. To prevent malaria, more bed nets were needed,

but most local experts stressed that education was needed. People were apparently unaware of the importance of basic safety precautions in everyday life, such as personal hygiene, proper waste disposal, or the need to avoid being exposed out of doors at dusk and dawn when mosquitos are most active. Investment in education campaigns and schools is therefore a priority. Ensuring access to clean water for households was also understood to make a significant difference, as is clear from current international knowledge on the issue (Jamison et al. (eds.), 2006).

SEASON SHIFT

A clear erosion of the agricultural system in the Bolgatanga area was reported and manifest. Local experts reported that key causes of this erosion have been the growing length of the hot dry season—traditionally from November to April—and the contraction of the traditional rainy season—April through October. Although farming is done in both seasons, the rainy season is the mainstay of the harvest. In the dry season, it is only possible to grow crops where there is irrigation, while in the wet season, much of the land is available for cultivation. Thus, the contraction of the growing season lowers overall agricultural potential. Rains that reportedly once began in April are now not beginning until May. The new timing has a number of other consequences: one example provided was that butterflies have been slower to adapt their behaviour to the new season onset and caterpillar larvae now exit the cocoon when crops are at their most vulnerable early stages.

DROUGHT AND DRY SEASON HEAT

The dry season itself is now unbearably hot and even dangerous: people exposed outside in the heat are considerably more susceptible to deadly meningitis. It is more difficult for farmers to produce crops in the dry season, if only because of the extreme



levels of heat stress as they toil in the fields. Moreover, periods of drought are now very severe, since the heat is so much more intense, and crop productivity suffers whenever the heat is not offset by generous and evenly spread rainfall, reported to be rarely the case anymore. Rainfall in Ghana reached its lowest in the 1970s and early 1980s; although it has since increased from 2000, it is still below the 1960 baseline. But it is not keeping pace with the increase in temperature and so the evaporation rate of water for the region is increasing. As a result, rainfed agriculture is undergoing a transition away from optimal growing conditions, resulting in lower plant productivity and yield, while reservoirs that supply irrigation are becoming less efficient. Thus, most people migrate to southern Ghana during the dry season.

EROSION OF LIVELIHOODS

To cope with declining yields, farmers have begun to take measures, such as selling their livestock. Farmers who might have had five or six animals, might now have only one or two—others none at all—and may be worried about how they will cope with another difficult season. Such measures hardly constitute a sound long-term strategy, since the hope for a return to bountiful harvests of days gone by is unlikely, given the projections for climate change to come. Residents recalled times in the past when Bolgatanga area was once the breadbasket of Ghana. It is in this dead-end context that farmers were reported to have committed suicide, when their unusual bumper crop of tomatoes spoiled on the roadside for want of buyers.

These developments have upset the delicate balance of these rural communities. Since farmers now own less livestock, the relationship between farmers and nomadic people who settle in the less fertile surrounding areas has also been compromised. In the past, farmers would entrust the nomadic peoples from Burkina

Faso (Fulani herdsmen) with their livestock in return for payment, either in-kind or in the form of farm produce. Thus, the nomadic peoples have also been deprived of a source of income and livelihood, and are now being reported to be engaging in a growing number of criminal acts, such as theft, violence, and other social problems, not to mention destroying and burning savannah vegetation. The decline in livestock has also decreased the availability of local manure and therefore fertilizer, forcing farmers to rely more heavily on imported chemical fertilizers, the price of which has been escalating in recent years, together with the increase in gasoline prices. Finally, the chemical fertilizers available were said to be less effective for water retention than organic alternatives, so of declining utility as heat and water stress grew.

RESPONSES

Although heat is, indeed, rising and will continue to do so, the area is not condemned and could thrive. As mentioned earlier, the critical need is to prioritize local entrepreneurship, so that farmers can have better access to wider markets and higher prices for their goods. In reality, there has actually been only one tomato factory in the region, which apparently suffered from management problems. The skills required to oversee such operations are not yet present in the region, so people from outside have been brought in to run this type of industry. However, farmers were not guaranteed better prices, as the factory exercised a monopoly and would pay only low prices, despite being able to sell goods at much higher rates. Moreover, most farmers have no means to transport their goods to the factory. These problems could be solved by following the successful models of other communities which have already surmounted similar issues (Motiram and Vakulabharanam, 2007; Buse et al., 2008).

A range of other responses could

be taken to stem and reverse the steady erosion of rural livelihoods in Bolgatanga. Some promising programmes were ongoing in the promotion of Bolgatanga basket weaving to generate improved livelihood opportunities, especially during the relative downtime of the dry season. Bolgatanga baskets are a unique, indigenous handcraft woven by hand exclusively by women. The activity allows local women to earn respectable incomes, with immediate benefits for the promotion of maternal and child health for participating families. Handicraft activities, from basket weaving to leather goods and pottery, help to diversify the livelihoods and supplement subsistence farming, now increasingly at risk because of climate change.

Enabling the farmers to produce more crops during the dry season would also make a significant difference. There is enough rain over a year to ensure wider irrigation, but there were either not enough dams or reservoirs trapping the rain, or too many of these had silted up and become ineffective. Overhauling and building new dams is far beyond the means of local farmers and even the local government. International support can be extremely useful here—there are already some support programmes for dam rehabilitation, and these provide jobs during construction and beyond, representing a sustainable solution for the community. The same was true for less costly water wells, although it was not reported whether the pumping more water from the groundwater aquifer was sustainable or not. However, many did report that wells had dried up. Enlarging and linking an existing set of wilderness reserves already under conservation protection could help to strengthen biodiversity, with benefits for natural pest control, as well as water catchment. Local composting using on-site crop waste close to fields, and household food waste in vegetable gardens closer to houses, could help to offset the decrease in local fertilizer.

FLOODING AND THE BAGRÉ DAM

Evidence of excess rainfall is seen in the visible flood damage sustained to earthen buildings and is clearly documented with photographic evidence shown to the research team. One major issue is the release of water following heavy rains from the Bagré Dam in southern Burkina Faso; the area around the dam has experienced increasing rainfall in recent years (ICI, 2010). When the floodgates are opened, large areas of the plains in northern Ghana become inundated with water. The local community is defenceless as the water floods across the plains, unable to penetrate the densely packed, arid soil. Aside from damaging buildings, water that remains for several days destroys any crops that are submerged and increases the risk of malaria by greatly expanding the breeding ground for mosquitoes. Local experts suggested the problem could be addressed by building better drainage infrastructure, in combination with the construction or rehabilitation of feeder roads—small roads that are a sound investment under any circumstances (Stifel et al., 2012; Kingombe, 2011). Ensuring that waterways are not used for cropping, but for the planting of trees to reinforce embankments was another solution put forward. However, with declining fertility and scope for planting crops elsewhere, the fertile embankments with direct access to water are too attractive for farmers. Cooperation with Burkina Faso on infrastructure solutions that might help to release water gradually following heavy rains had apparently not been addressed.



EAST COAST: VOLTA DELTA

The east coast lies at the southeast extremity of Ghana, close to the border with Togo along the Gulf of Guinea. The researchers visited villages across the Greater Accra and Volta regions of Ghana, as well as Prampram, Ada Foah, and Keta. While the south of Ghana is less hot and more humid than the far north, the southeast coast itself has a dry climate within the coastal savannah zone of Ghana, which, according to EPA-Ghana, is due to “coastal alignment and upwelling of cold water” (EPA-Ghana, 2011). Not that it is cold here: truck drivers complained of more frequent tire and windshield explosions on the hottest days. Parents worried that teachers were becoming less effective in educating their children, as they struggled to work in the growing heat during school hours. The area is mainly a low-lying plain, interspersed with a number of lagoons and tributaries at the delta of the Volta River, which originates in Burkina Faso. It is predominantly a fishing and agrarian community, and the area visited is home to over half a million people (Ghana SS, 2010). The chief climate change concerns for the southeast coastal areas relate to coastal erosion/sea-level rise, fisheries, agriculture and health. Biodiversity, drought, energy for cooling and water are also concerns. As for much of the country, labour productivity and occupational heat stress are also important issues, and concerns over migration were additionally flagged by local experts, who emphasized a constant drain of men and families out of the area. Fisheries are in long-term decline in the area for a variety of reasons, including over-fishing, but research provides strong evidence for the negative impact on marine ecosystems of both rising sea temperatures and ocean acidity. The Gulf of Guinea is understood to be one of the zones worst hit by rising temperatures (Cheung et al., 2010). Coastal erosion in the area has a long history, with dramatic rates of degradation and residents asserting “several

kilometres” of land lost to the sea in certain places around the Volta Delta, where sea defences have not been put in place. The agricultural sector has been affected both by the heat and by salt intrusion and land erosion due to sea-level rise, although large areas of land are irrigated by the Volta River and are more resilient to the growing heat. In health terms, malaria was still a common health problem for residents of the area, and malnutrition was raised as a serious concern. Diarrheal diseases were apparently less prevalent than was the case for northern Ghana, since it was understood that plumbed/improved water sources and sanitation or latrines were more common in the coastal Volta area.

COASTAL EROSION AND SEA-LEVEL RISE

Analysis of Ghana’s coastline shows that over the last few decades the eastern coast has eroded at the fastest rate. Rates of annual erosion have been estimated in the range of 1-11 metres per year of land (Ly, 1980; Wiafe 2010; Appeaning Addo et al., 2011). Coastal erosion in the area has been noticeable for over a century, suggesting some degree of natural oscillations in delta growth and loss (Akyeampong, 2001; Oteng-Abbabio et al., 2011). In addition to claiming land and damaging coastal infrastructure, the erosion is also affecting water resources and soil quality from the penetration of salt from the sea as it seeps further inland. It has forced the relocation of residents who have abandoned their homes and properties along the coast and moved inland. Risks are particularly high during elevated seasonal tides or storm tides that can inundate tracts of land and severely damage infrastructure, livelihoods, and endanger lives. Sea-level rise due to climate change is a significant cause of concern in the coastal erosion of Ghana. However, research has highlighted several other important issues. These include the construction of the Volta/Akosombo


hydroelectric dam built in the 1960s, which withholds vital sediments that would otherwise be released into the delta from the Volta River; sediment to the littoral delta has been reduced by 10 times according to some estimates (Boateng, 2009). The erosion processes may have doubled since the building of the dam (Ly, 1980). Given that water flow is now controlled, the natural flooding patterns of the area have also changed and the flood plains now rely on irrigation and a reduced water supply (Corcoran et al., 2007). The hydro dam in itself is a positive response to the causes of climate change as a renewable energy generator, but it also presents a unique dilemma here because the dam exacerbates the consequences of climate change, in particular, sea-level rise erosion.

Other important concerns highlighted include the practice of sand mining and the construction of coastal infrastructure and sea-defences (Oteng-Abbabio et al., 2011; Appeaning Addo and Larbi, 2009). Sand removed from the shoreline obviously accelerates erosion, while the construction of coastal infrastructure affects sea-wave dynamics and concentrates energy on adjacent unprotected areas. Even if the entire Ghanaian coast were protected, Togo and Côte d’Ivoire on either side would be more exposed, since it is hard to imagine the possibility of protecting the entire Gulf of Guinea coastline. Residents and officials in Keta were insistent that the construction of the major seaport at nearby Tema during the early 1960s changed the velocity and energy pattern of the waves, further accelerating coastal erosion. A port further distant, on the border of Togo, was also a source of concern. Clearing and degradation of littoral mangrove forests has made matters even worse. Finally, the local practice of pumping out groundwater via “tube irrigation” was very common, even for fields close to the water’s edge. In other parts of the world, irrigation using ground-water has been shown

to accelerate land subsidence and perceived sea-level rise (Larson et al., 2001). Similar irrigation techniques were also common in the Mekong delta of Vietnam, also highly vulnerable to sea-level rise and studied in this report. In the context of all these varied and significant concerns, sea-level rise resulting from climate change is a very unwelcome new consideration for a community highly vulnerable and already having great difficulty coping with local coastal erosion. A series of large-scale coastal defences have already been built, and local experts have emphasized the sensible preference of “soft” approaches, such as re-vegetation of sand dunes or beach nourishment, over “hard” infrastructure coastal defence options (Oteng-Abbabio et al., 2011). Little information was obtainable about the feasibility of sediment pass-through retrofits to the Volta/Akosombo hydroelectric dam, although retrofitting options are available and would merit further investigation and investment given the scale of impact manifested (IPCC, 2012b). However, clearly the re-establishment of coastal mangrove forests and providing alternatives to ground-water pumping for irrigation would be less expensive than infrastructure-intensive solutions; for example, one single coastal defence construction near Keta cost 90 million US dollars (Armah, 2005). “Soft” approaches are also likely to cause less, if any, collateral damage. There appeared to be few mechanisms in place to compensate households that lost property and needed to relocate or who are subject to damage. If the sea level rises one or two metres during the 21st century—assuming that climate change is not sufficiently brought under control—the whole situation threatens to become quite dire (IPCC, 2007; RSNZ, 2010; Füssel in Edenhofer et al., 2012).

FISHERIES

Local observations of the rise in sea temperatures and some indications of decline in local marine life match global assessments (Wiafe et al., 2008). The


CLIMATE 	2010	2030
Contraction of biological zones (km ²) - yearly average	-3,000	-6,000
Additional land degraded due to climate change (km ²) - yearly average	750	1,500
Additional/reduced energy load due to climate change (GWh) - yearly average	350	900
Additional CO ₂ generated/reduced for heating and cooling due to climate change (kt CO ₂) - yearly average	60	150
Share of workforce particularly affected by climate change (%) - yearly average	55%	45%
Additional land lost due to climate change (km ²) - yearly average	15	35
Additional water losses/gains due to climate change (km ³) - yearly average	0.25	0.25

community was unanimous that there are simply fewer fish. This applies equally to inland and offshore fish stocks. As with sea-level rise, climate change driven sea temperatures and CO₂-related acidification of the oceans are not the only causal factors. As with many other social, economic, and environmental challenges, climate change is rarely, if ever, the only factor causing problems. Population growth increases the number of fishermen, resulting in damaging fish practices, such as the use of small gauge nets or even dynamite, and the practically uncontrolled intensification of large-scale commercial operations has not favoured sustainable management of fish stocks.

Two other climate change-related factors have also worsened the situation for fishermen. More volatile, unpredictable, and extreme weather is a serious safety hazard. Some fishermen cannot swim and the small fishing boats are often at serious risk on this high-energy coastline, especially in the case of fierce, unpredictable storms. Second, the retreat of the shore has pushed the blue-water shelf, where most fishing takes place, further away with each passing decade and add to labour, time, cost, and risks for fishermen in small craft.

Large and heavily equipped foreign fishing boats from China, Japan, and Korea ply the offshore waters of the region for fish that are explored from the port base in nearby Tema directly to Asia. In Keta, however, there is no fish processing industry, such as a freezing works, for packaging the catch of local fishermen. Locals rely only on “middle men” who truck the Keta catch back to Accra. Most of the fish leaving for Accra is sold smoked. Local fishermen stated that the smoking of fish used to be permitted by burning the less useful remains of the once bountiful catch. However, the falling fish harvest means that local trees and forests are instead used for fuel, and this has reportedly exacerbated local deforestation concerns. Moreover,

degradation of mangrove forests in the delta—with mangrove wood serving as firewood—damages marine and inland fishery biodiversity in an interlinked vicious cycle (Concoran et al., 2007). Responding to the full range of issues affecting the mainstay fisheries industry of the region is not a straightforward matter. Fishing is still a significant industry for the Ghanaian economy as a whole, and its rapid decline will clearly not add to the wealth and social cohesion of the nation. The only solution currently being explored seriously is the establishment of fish farms, for which a few select pilot projects were taking hold, to the great interest of the local industry. Regulation of foreign commercial fishing was dismissed as “unrealistic” under current circumstances, even if only to limit fish net gauge, so that the smallest fish would escape unharmed while promoting the continual replenishment of stocks. Once again, the preservation of the local mangrove forests represents an obvious positive response, with multiple benefits, even if steps towards implementation are unexplored and doubtful. Yet another avenue to be explored, which could lower the vulnerability of the community through expanded incomes is providing incentives and creating an enabling environment for local entrepreneurs to establish fish processing industries to generate value-added goods with broader market potential. Other options worthy of consideration are certified, sustainable fishing programmes and the establishment of marine reserves.

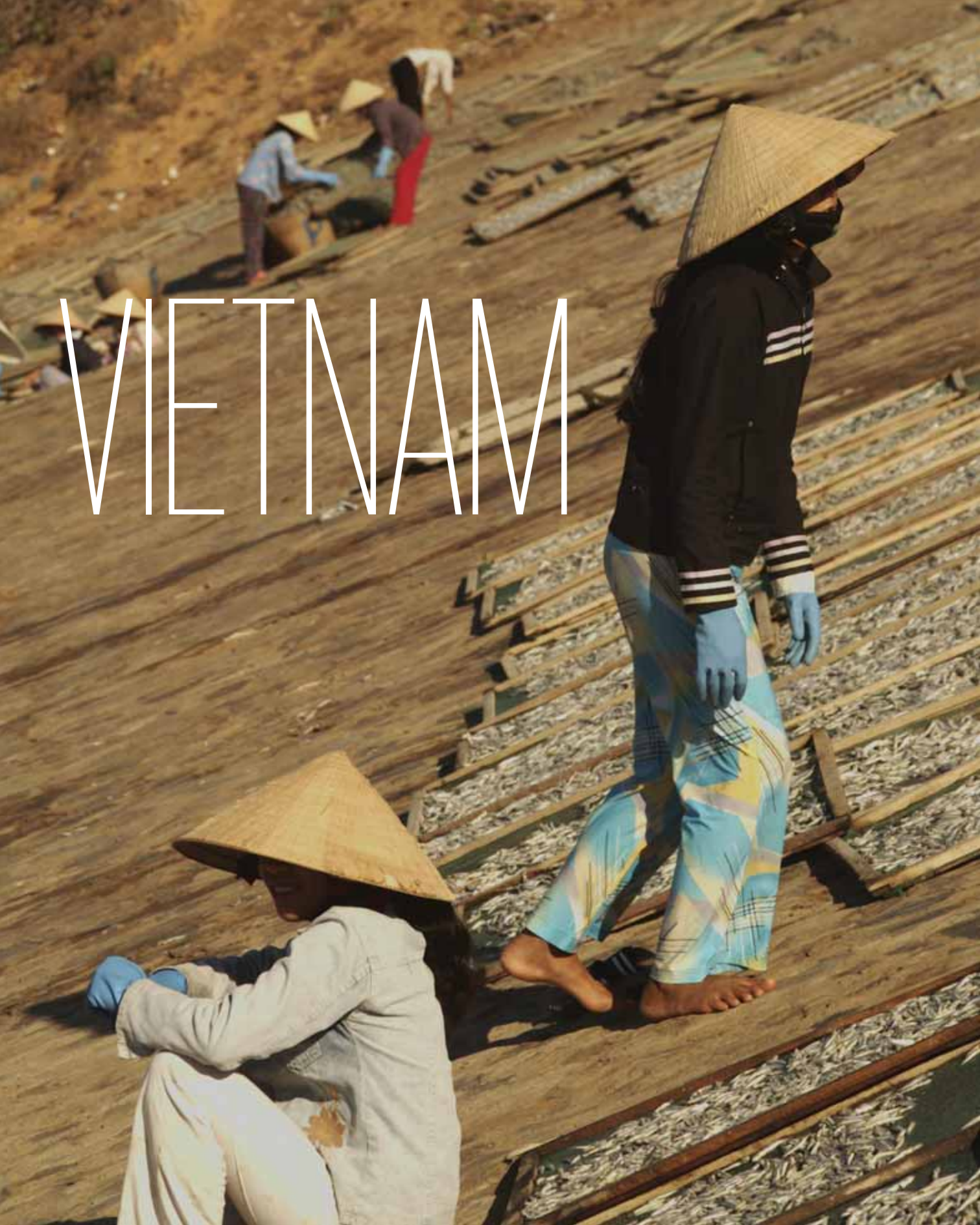
CARBON 	2010	2030
Volume of water to treat (millions m ³) - yearly average	250	350



CONCLUSION

The hallmarks of climate stress are clearly evident in the everyday life and the local environment of Ghana, whether in downtown Accra—recovering from unprecedented floods—or in coastal and northern savannah regions. More areas were not visited, but the National Workshop organized as a part of the research undertaken did highlight several other zones of the country facing still different and significant pressures characteristic of those areas, some of which are also documented in local research (Asante et al., 2010; EPA-Ghana, 2011; Tachie-Obeng et al., 2011). In every case, climate change stress met head-on with local issues not caused by climate change. In Accra, the floods were exacerbated by poor drainage and waste disposal methods. In the Volta delta, coastal infrastructure, unsound irrigation, and the upstream Volta hydro dam compounded one another in a context of growing climate-related sea-level rise. In the northern region of Ghana, local deforestation and savannah burning wove complex interrelationships with the extreme heat and water stress that was eroding the rural livelihoods in an area that in former times was the breadbasket for Ghana. With 50 additional days that could be considered “hot” in every current year, as compared with Ghana’s climate in the 1960s, the heat has nevertheless only just begun to increase; a doubling, trebling, or more of the temperature increase is expected over the next 20–30 years, given the inertia of the global climate system (McSweeney et al., 2012; Hansen et al., 2005). Thus, future climate stresses are likely to be extreme and will continue to exploit the economic, social, and environmental weaknesses of Ghana, and retard economic growth and social and human development potential, especially among the poorest communities. However, steps taken by the government are heading in a promising direction, and the success and relative stability of Ghana compared with other countries in the region make it an interesting candidate for a more concerted effort. United with the international community, Ghana has the potential to show the way in tackling the local impacts of climate change as they are increasingly coming to the fore.

VIETNAM



COUNTRY STUDIES

GENERAL PURPOSE

1

FEEDBACK FOR THE DEVELOPMENT OF THE MONITOR'S METHODOLOGY

2

EXPLAIN HOW THE ANALYSIS OF THE MONITOR CAN BE USED IN A NATIONAL SITUATION

3

SERVE AS A KNOWLEDGE-SHARING MECHANISM FOR BEST PRACTICE AND CHANGE MANAGEMENT FOR THE BENEFIT OF OTHER VULNERABLE COUNTRIES

4

PROVIDE AN OUTSIDE SUPPORTING ANALYSIS OF INTEREST TO NATIONAL POLICY-MAKERS AND DEVELOPMENT PARTNERS



KEY FIGURES

Population	87,840,000
2012 GDP PPP (Dollars)	
Total	\$320,874,000,000
Per Capita	\$3,549
Real Growth	5.6%

ECONOMY

GDP by Sector	
Primary/Extractive	22%
Secondary/Productive	40%
Tertiary/Services	37.7%
Key Sector(s)	Industry

SOCIO-ECONOMIC DEVELOPMENT

Human Development (Rank)	Medium (128th)
Life Expectancy	75.2 years
Annual Population Growth	1%
Illiteracy	3.1%
Urban Population	31%
Access to Electricity	97.6%
Gender Development	48 th
Undernourished Population (2006/08)	11%
Living below poverty line (\$1,25/day)	13.1%
Population without Improved Water Source	12.2%
Official Development Assistance (% of GDP)	4.4%
Public Health Expenditure	7.2%
Public Education Expenditure	5.3%

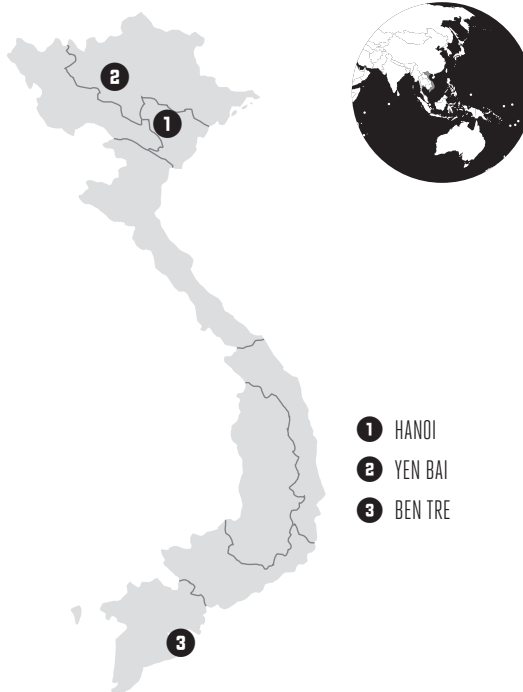
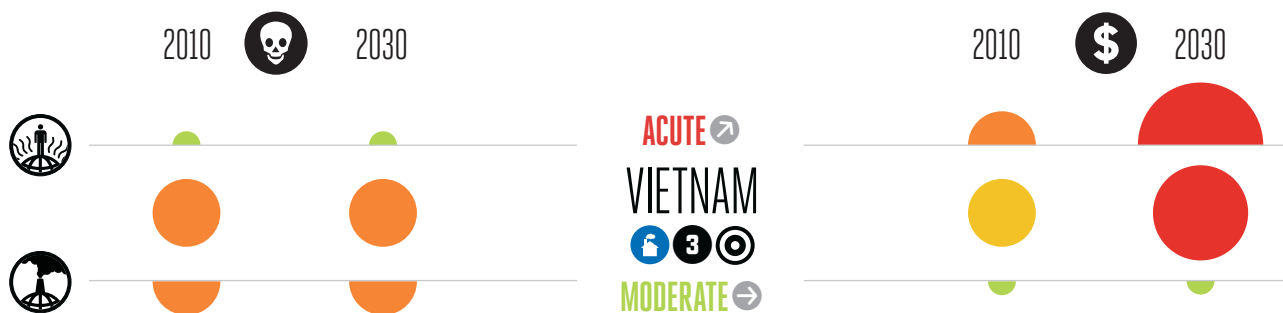
CLIMATE/GEOGRAPHY

Climate Zone	Monsoon tropical
Projected Rainfall Change	Likely to increase by 1.0-5.2% and 1.8-10.1%
Tropical Cyclones	Yes (decreasing trend)
Desertification	None
Low-Elevation Coastal Zone (10m and below)	20%
Forest Cover Change (1990-2008)	44.3%

MIGRATION/DISPLACEMENT

Emigration Rate	2.4%
Immigrants as Share of Total Population	0.1%
Internally Displaced People	None

Impact Areas	Indicator	Confidence	Bias	Vulnerability	
				2010	2030
CLIMATE	DROUGHT	✓		Red	Red
	FLOODS & LANDSLIDES	✓	♀	Red	Red
	STORMS	✓		Green	Green
	WILDFIRES	✓		Green	Green
	BIODIVERSITY	✓		Green	Green
	DESERTIFICATION	✓		Green	Green
	HEATING & COOLING	✓		Yellow	Orange
	LABOUR PRODUCTIVITY	✓	♂♀	Red	Red
	PERMAFROST	✓		Green	Green
	SEA-LEVEL RISE	✓		Yellow	Yellow
	WATER	✓		Green	Green
	DIARRHEAL INFECTIONS	✓		Green	Green
	HEAT & COOL ILLNESSES	✓		Yellow	Yellow
	HUNGER	✓		Green	Green
	MALARIA & VECTOR BORNE	✓		Green	Green
	MENINGITIS	✓		Green	Green
	AGRICULTURE	✓		Yellow	Orange
	FISHERIES	✓		Orange	Red
	FORESTRY	✓		Green	Green
	HYDRO ENERGY	✓		Green	Green
	TOURISM	✓		Green	Green
TRANSPORT	✓		Green	Green	
CARBON	OIL SANDS	✓		Green	Green
	OIL SPILLS	✓		Green	Green
	BIODIVERSITY	✓		Green	Green
	CORROSION	✓		Yellow	Yellow
	WATER	✓		Yellow	Yellow
	AIR POLLUTION	✓		Yellow	Orange
	INDOOR SMOKE	✓	♀	Orange	Yellow
	OCCUPATIONAL HAZARDS	✓	♂	Orange	Yellow
	SKIN CANCER	✓		Yellow	Yellow
	AGRICULTURE	✓		Green	Green
FISHERIES	✓		Red	Red	
FORESTRY	✓		Green	Green	



The Monitor research team held a nationally-focused policy workshop in the Vietnamese capital of Hanoi and undertook field research in two provinces: Bến Tre, in the extreme south of Vietnam, at one of the outlet points of the Mekong Delta, and Yên Bái, in the highlands to the north-west of Hanoi in northern Vietnam.

In recent years, Vietnam has consistently been one of the world's fastest growing economies and is an important contributor to global growth (IMF WEO, 2012). Getting climate policy right will enable Vietnam to grow even faster and to accelerate its already impressive strides in reducing poverty and safeguarding the health of its people, as evidenced by the significant progress it has achieved with respect to the Millennium Development Goals (ODI, 2010). Among the countries most vulnerable to the effects of climate change, especially in economic terms, Vietnam also suffers serious health impacts from carbon-intensive urban industrial and transport-related air pollution and, especially in rural and highland areas, hazardous household cooking and heating practices from the indoor burning of wood, coal, and other materials. The full range of climate-related effects is harming last mile efforts to reduce poverty. The government has clearly recognized the benefits of a strong response to climate change and embraced efforts to begin low-carbon transition as a means of increasing competitiveness. It has unequivocally prioritized these steps in its policy directives and foreign relations. As a result, it is taking concrete steps to safeguard and enhance the economic, social, and environmental dividends of its growth. This in itself is a compelling message to the world, given that Vietnam is anticipated to be among the largest economies of the 21st century (O'Neill et al., 2005).

The country's policy stance on climate change is path-breaking for one with low-emissions and limited responsibility for climate change experienced to date. However, new research aggregated for the Monitor's assessment in this report suggests that there is still further scope for enhancing these policies. Nevertheless, the approach adopted serves as an important example of success that other vulnerable countries around the world would be well advised to examine in detail.



MULTI-DIMENSIONAL CLIMATE VULNERABILITY: **ACUTE** ↗



MULTI-DIMENSIONAL CARBON VULNERABILITY: **MODERATE** →

CAPACITY: **INTERMEDIARY**

POPULATION 2010/2030: **88/102 MILLION**

GDP 2010/2030 (PPP): **280 BILLION/1.5 TRILLION USD**

GDP PER CAPITA 2010/2030 (PPP): **3,000/14,000 USD**



BACKGROUND AND CONTEXT

BACKGROUND AND CONTEXT

With a population of over 90 million today, Vietnam is a populous and fast-growing lower-middle-income South East Asian country, bordering China to the north and Laos and Cambodia to the west (CIA, 2012). Vietnam is similar in size to Germany or Japan. Its climate is tropical monsoon and varies from warm in the south to cool in parts of the sub-tropical north; its climate also changes depending on elevation in the many mountainous parts of the country.

Although economic growth has been consistently fast in the last decade, GDP per capita is still very low at 3,000 US dollar (PPP), or 1,200 dollars per capita in nominal terms, but could increase ten times by 2030, as anchored in IPCC marker scenarios (IPCC, 2000). The affluent and international urban centres of Hanoi and Ho Chi Minh City contrast with the less developed rural areas with their still excessive poverty levels. A strong education system and human capital, as well as relatively robust institutional governance and infrastructure indicate that Vietnam's capacity is not among the lowest. For similar reasons and due to its population size, the United Nations has never considered Vietnam a Least Developed Country. The country carries relatively high macroeconomic climate risk compared with more advanced economies, since the agricultural sector represents 20% of GDP and employs over half of its workforce. Reducing risks will involve diversification of the labour force into the industrial and service sectors, as well as modernizing farming through irrigation systems.

As the Vietnamese economy experiences sustained high growth, it will be a priority to limit the negative effects of the industrialization process associated with its structural progression to higher income levels. While Vietnam's GHG emissions are low at 3.5 tons per capita and are expected to remain below 4 tons per capita into the 2020s. Vietnam's industrial,

THE MONITOR'S ASSESSMENT OVERVIEW

urbanizing, power generation, and socio-economic profiles mean have led to high concentrations of fine particles, which are extremely toxic. Moreover, heavy reliance on firewood for domestic cooking and heating poses serious health risks (Climate Analytics, 2012). Despite its strengths, the environmental vulnerability of Vietnam to climate change is extreme. Its mountainous geography and coastal frontage combine with exposure to tropical cyclones (typhoons) and storms which form in the western Pacific Ocean, leaving the country prone to extreme floods, landslides, heavy rainfall, and high winds. The low-lying Mekong delta is one of the largest flood-prone zones of the world. Most of the southern tip of the country, including much of nearby Ho Chi Minh City, are at less than one metre above sea level. Vietnam's tropical climate will continue to heat up, bringing more drought spells and fishery losses as thermal conditions increasingly exceed already elevated historical levels. Social and economic vulnerabilities are also high, especially in remote highland communities. Insurance exists for health care, but is rarely available for farmers, fishing operations or even infrastructure. Electricity grid access is very high for the country as a whole, but in some of the poorest communities, it reaches just over half of all households, where plumbed water sources are also absent and malnutrition rates and the associated stunting of children can be commonplace.

THE MONITOR'S ASSESSMENT OVERVIEW

On the basis of the Monitor's assessment, the impact of climate change is estimated to have already held back to a significant degree the economic prosperity of Vietnam's fast-growing economy, effects which are estimated here to grow steeply in severity in the next 20 years. Certainly, the top 10% of days and nights previously considered "hot,"

CLIMATE CHANGE

a key indicator of climate change, has increased in number by 30 and 50 respectively for a given year, as compared with Vietnam's 1960s climate. Both are set to increase even more substantially through to mid-century and potentially beyond (McSweeney et al., 2012). The multi-dimensional vulnerability of Vietnam to climate change is considered in the highest category of Acute and rising. Vulnerability to the carbon economy is estimated as Moderate and stable. Economic impacts are the main sources of Vietnam's vulnerability, with human or health effects being less extreme in comparison with other countries. Total economic losses are estimated to cost Vietnam 5% of its GDP in net terms in 2010, growing to 11% of GDP by 2030, as the country's vulnerability shifts from Severe to Acute over this period. The economic cost of the carbon economy is estimated at a much lower 0.8% and is set to remain stable relatively through to 2030. However, the human cost of the carbon economy is considered Severe and estimated already to cause over 50,000 deaths per year, increasing to over 60,000 deaths per year by 2030.

CLIMATE CHANGE

The following most serious climate change impact areas are assessed (for 2010/2030) in order of the scale of GDP losses from higher to lower:

- LABOUR PRODUCTIVITY, **ACUTE/ACUTE** 4.4%/8.6% of GDP
- SEA-LEVEL RISE, **HIGH/HIGH** 1.5%/2.7% of GDP
- FISHERIES, **SEVERE/ACUTE** 0.5%/1.6% of GDP
- AGRICULTURE, **HIGH/SEVERE** 0.2%/0.4%
- HEATING AND COOLING, **HIGH/SEVERE** 0.1%/0.3% of GDP
- FLOODS AND LANDSLIDES, **ACUTE/ACUTE** 0.1%/0.1% of GDP
- BIODIVERSITY, **MODERATE/MODERATE** 0.1%/0.1% of GDP
- DROUGHT, **ACUTE/ACUTE** 0.1%/0.1% of GDP

The most serious health impacts

CARBON ECONOMY

related to climate change are estimated to be Heat and Cold Illnesses and Hunger. Heat and Cold Illnesses, or mortality among chronic disease sufferers during heat waves, present particularly severe challenges to the elderly, whereas Hunger predominantly concerns young children. While mortality is low in each case, an average of over 800,000 people is estimated to be affected each year by the aggravating effect of climate change on hunger. The assessment used for Labour Productivity and Sea-level Rise are considered relatively reliable, whereas other main impacts are more indicative or less certain due to the limitations of models relied upon for these indicators. In terms of positive impacts due to climate change assessed here, Vietnam is understood to benefit very slightly from additional water supply as a result of additional rainfall, overcompensating for heightened evaporation as the heat increases. For similar reasons, Vietnam is also estimated to experience a slight decline in aridity in the driest zones which could become more humid. However, these findings are based on global models (or IPCC model ensembles) and their results contrast with Vietnam's own reference scenarios, which project higher rates of evaporation than rainfall, and large declines in rain and river flows during dry spells, which are not always offset by increases in flood flows (Nohara et al., 2006; Hansen et al., 2007; Vietnam MONRE, 2010).

CARBON ECONOMY

Regarding carbon economy cost in human terms, Indoor Smoke is the most serious concern, accounting for just over 40,000 deaths per year in 2010 and similar mortality levels by 2030, as a result of disease from exposure to smoke from indoor fires for cooking and heating. Deaths due to indoor smoke are stable, because despite a fast expanding population, economic growth is expected to see many households adopt cleaner burning fuels and stoves. Air Pollution

NATIONAL RESPONSE STATUS

is estimated to claim 10,000 casualties a year in 2010, rising to over 20,000 deaths per year in 2030 as pollution levels rise. The northern Red River basin around Hanoi has significant, excessive levels of fine air particulates from traffic and industrial emissions which are highly hazardous to human health. The country's current growth pathway would see that worsen as economic growth and industrialization expand (World Bank, 2012; Donkelaar et al., 2010). In economic terms, the most significant economic losses due to the carbon economy concern Biodiversity (2010/2030: 0.3%/0.6% GDP), Human Health (2010/2030: 0.3%/0.3%) and Fisheries (2010/2030: 0.2%/0.2% GDP). The carbon economy effects for Agriculture constitute a 0.2% loss to GDP in 2010, but are converted into a 0.1% gain to GDP by 2030, due to the expected realization of carbon fertilization benefits for crop productivity. However, this gain to GDP is more than offset by the expected 0.4% of GDP losses due to climate change. The human health impacts are considered relatively reliable, whereas impacts for Biodiversity, for instance, are considered more indicative. Fisheries impacts are labelled here as speculative, due to the limited scientific research currently available, especially as regards the effects of various pollutants, such as acid rain on key species of fresh or brackish water fish and aquatic life. The acidification of the oceans as it absorbs CO₂ is however a well established area of concern (Sabine and Feely in Reay et al. (eds.), 2007; IPCC, 2007).

NATIONAL RESPONSE STATUS

Policy development on climate change in Vietnam has been a serious and active field of activity for many years. The 2007/8 "National Target Programme to Respond to Climate Change" (NTP-RCC) carved out the



CLIMATE FINANCE

first major national policy framework and committed over 50 million USD of domestic resources to tackling climate change, in particular to respond to the impacts of climate change (Vietnam MONRE, 2008). In 2012, Vietnam launched its “National Climate Change Strategy” (NCCS), which covers a range of vulnerability and low-carbon issues (Vietnam NCCS, 2011). The NCCS is also fundamentally different from the earlier National Target Programme, in that it conveys firm directives of the Executive to all relevant government offices to bear responsibility for implementation. The Strategy outlines the following ten priority task areas for implementation, which provide a useful insight into the foundations of Vietnam’s national response to climate change:

1. Disaster preparedness and climate monitoring
2. Food and water security
3. Sea-level rise
4. Protection and sustainable development of forests (carbon sinks and biodiversity)
5. GHG reductions
6. Increase of the role of government
7. Community capacity development
8. Scientific and technological development
9. International cooperation and integration
10. Diversification of financial resources and investment effectiveness

Furthermore, concerted efforts to implement climate change policy at the regional level are also underway, with one of the initial target provinces, B n Tre, visited as part of the field research for the Monitor.

CLIMATE FINANCE

In 2010, Vietnam attracted the sixth largest volume of international climate change finance among developing countries, totalling over 500 million USD. Only Brazil, Egypt, Kenya, India, and Indonesia received more funds. However, with 200 million USD targeting adaptation, Vietnam was the single largest recipient of Adaptation funds, and has a very balanced allocation of international

resources between adaptation and low-carbon investments. These funds represent monies announced by donor governments or multilateral institutions to the main database of the Organization for Economic Co-operation and Development as principally targeting climate change (OECD CRS, 2012). They do not necessarily represent funds supporting the government of Vietnam’s climate change policies and programmes, although a share of these funds may, indeed, be applied in this manner. In the case of Vietnam, climate finance is almost exclusively bi-lateral with Japan as the largest climate donor, followed by Germany and France. The split of bilateral funds between loans and grants is almost 90:10, so most of the finance is in the form of concessional loans.

All other factors remaining equal, the high levels of vulnerability in Vietnam and its relatively significant capacity make the country a sensible early priority destination for climate finance. Vietnam is developing a robust climate change policy and implementation model that will be of interest and use to other countries in similar income and vulnerability strata, but which, unlike Vietnam, have farther to go in making progress on building their multi-dimensional capacity for implementation. Despite being the largest contribution worldwide, the 200 million USD of external support for adaptation is well below 0.1% of Vietnam’s GDP and therefore pales in comparison to the scale of economic losses estimated at over 5% of GDP in 2010. In ideal circumstances, greatly enhanced international support should be forthcoming to assist Vietnam in dealing with such large-scale impacts. However, given the possible scale of the shortfall and the low-end prospects for large-scale increases in foreign assistance, Vietnam will likely come under increasing pressure to invest available domestic resources in order to preserve the resilience and ensure the ongoing competitiveness of its economy.

ASSETS

ASSETS

Several strong points are notable hallmarks of Vietnam’s response to climate change:

- *Strong Executive Leadership:* The clear support of the Prime Minister behind the climate policy project of Vietnam will be essential for meaningful vertical (central, provincial, district/municipal) and horizontal (across multiple ministries/departments) collaboration, necessary to strengthen the country’s resilience to climate change and seize key opportunities for low-carbon development.
- *Governance Mechanism:* A clear and comprehensive policy framework and coordination mechanism has been established with executive authority and provides the substantive and operational mechanism with phasing, responsibilities, and financial parameters outlined for implementing Vietnam’s climate policy response. The National Workshop held in the context of the country research undertaken highlighted how moving from governance to effective implementation and monitoring is now becoming the overriding challenge for Vietnam.
- *National Reference Scenarios:* Vietnam has regularly updated and communicated national climate change scenarios with a high resolution of sub-national information across a range of key concerns such as rainfall and evaporation, sea-level rise, and others. Clarity on an agreed set of reference scenarios is essential to calibrating policy responses, allocating/prioritizing resources and anchoring expert debate; regular updating is essential, given the fast pace of knowledge development in the field of climate change. In light of this assessment for instance, Vietnam might consider adding sea and pond temperature and acidity reference measures of concern to the fisheries industry, and Wet Bulb Globe Temperature (WBGT) of interest to businesses, occupational safety specialists, and economists.
- *Vibrant National-level Civil Society:*

GAPS

Engaged and concerned groups of academics, non-governmental organizations, international actors, and other civil society actors especially active in the nation’s capital are a valuable resource for the Government to draw upon, as it refines and advances its climate change policy project in the years ahead. The group should be fostered and relied upon to support the fine tuning of policy development, implementation, and monitoring.

- *Buoyant International Support:* The Government has clearly indicated to development partners the importance of climate change as a national development priority. International development partner donor governments, such as Japan and France, and international financial institutions including the World Bank have responded by forming a “Support Programme to Respond to Climate Change” (SPRCC) coordination group to assist Vietnam in its development and implementation of climate change policy; an evaluation mechanism fiscal/loan support, including financial resource commitments form a growing share of Vietnam’s Official Development Assistance (ODA), all of which promote harmonization, cooperation, action, and results.
- *Public Financial Commitments:* Vietnam has committed substantial government mobilized funds to the project, initially amounting to approximately 50 million USD over a 5–6 year period.
- *Key Sector Effects Addressed:* The existing climate change strategy and policies of Vietnam already address the majority of the key issues, including sea-level rise, agriculture/food and water security, heating and cooling (through urban energy efficiency), as well as disasters, such as flooding and landslides.

GAPS

Some gaps can be identified on the basis of this Monitor’s innovative assessment methodology. In 2010, the first Monitor would have identified



OTHER CHALLENGES AND OPPORTUNITIES

very few gaps, testifying to the quickly evolving nature of our understanding of climate change. Gap areas which merit further exploration by stakeholders include:

- **Labour Productivity:** The most significant impact for Vietnam as assessed by the Monitor. It is to be expected that it is not addressed by current policies, since the effect has not been included in any IPCC reports to date (IPCC, 1990, 1995, 2001, and 2007). However, in noting in its 2008 NTP that mines would require more energy for cooling, Vietnam did recognize the important relationship between worker productivity and rising heat (Vietnam MONRE, 2008). Experts also noted ongoing inquiry by the Vietnamese Ministry of Labour – Invalids and Social Affairs (MOLISA) into climate change effects. With nearly half of its workforce currently vulnerable to extreme forms of occupational heat stress, incorporating a response to this large-scale economic impact would be advisable for future climate policy iterations (Kjellstrom et al., 2009a).
- **Fisheries:** The impact of climate change on fisheries was recognized in the 2008 NTP, but has yet to find its way into an operational strategy or response. On the basis of the Monitor's assessment, Vietnam has the largest total losses in the fisheries sector due to climate change of any country in the world. Losses from climate change and the carbon economy are over 0.7% of GDP in 2010, growing to nearly 2% of GDP by 2030. This is in part due to the sheer scale of the country's fishing sector, and the vulnerabilities of its tropical waters and unsustainably managed fish stocks (UoC and Vietnam MPI, 2010). Therefore, building resilience or limiting impacts in the fisheries sector through improved fisheries management would help to reinforce any future climate policies.
- **Low-carbon Objectives:** The current national policy includes increasing energy efficiency across different sectors, carbon sinks through forests

and the share of renewable energy in the power generation sector to 5% by 2020 and a modest 11% by 2050. It also involves reducing emissions from agriculture and waste disposal in a comprehensive low-carbon strategy. With carbon economy losses representing 0.8% of GDP and quite significant human impacts particularly due to indoor smoke, providing incentives for the use of clean burning household fuels/stoves and emission reductions that also yield clean air benefits could help Vietnam to maximize the social and economic benefits of low-carbon development. The Clean Development Mechanism (CDM) should continue to be drawn upon in order to maximize low-carbon technology saturation that will increase energy and economic resilience and competitiveness, in addition to their potential health, social and environmental benefits. A "Green Growth" strategy is set to be adopted in 2012, which may provide additional impetus to the work of Vietnam in this area.

- **Regional/Transnational Dimensions:** Vietnam's interests are directly affected by the policies of neighbouring countries. In particular, increased water withdrawals and sediment withholding infrastructure in the upstream Mekong, such as in neighbouring Laos and China, have direct impacts on biodiversity, fisheries, coastal erosion, and saline intrusion in the downstream delta region in Vietnam. Vietnam's national policies could, therefore, consider raising these concerns in the context of the intergovernmental Mekong River Commission, and seeking to stimulate domestic policy responses in other countries that are favourable to its interests.

OTHER CHALLENGES AND OPPORTUNITIES

- **Awareness:** Country research stressed the level of public awareness on the issue of climate change as both a challenge and an opportunity at various levels, national, provincial, and municipal. So much can be achieved through awareness alone, from flood

safety to forest protection or farming knowledge, that it was seen as a key priority and features prominently also in the National Strategy. However, explaining complex concepts and responses in terms accessible and meaningful to different communities was seen as a challenge. Wide-ranging media: TV, radio, and the Internet, could provide a range of possibilities for reaching target audiences. Efforts to raise awareness should focus on options for practical action that people can relate to and become involved in implementing.

- **Forestry and Payment for Ecosystem Services/REDD+:** Forest covers almost half of the surface of Vietnam, but land-use conversions, such as wetlands to productive zones for fisheries or agriculture, as well as deforestation and forest degradation, are all clearly at significant levels, as evident from the country's national carbon inventory, where land usage and change (LULUCF) make up 15% of all emissions (Climate Analytics, 2012). Deforestation exacerbates fresh water scarcity, flash flooding and landslides, depletes natural carbon sinks, pollutes the air, and contributes to the erosion of biodiversity, all impacts that drain GDP and inhibit economic growth. The National Strategy aims to stabilize or increase forest cover, but given the macroeconomic risks involved, it may make sense for the Government to give incentives to land holders or local custodians to ensure sustainable forest management through a payment for ecosystem services scheme. Efforts to maximize the potential of the UN deforestation programme (REDD+) should also be prioritized as a central component in future climate strategies.
- **Monitoring and Evaluation:** Policymakers and the climate change community in Hanoi expressed an interest in enhancing monitoring and evaluation efforts in order to promote learning and improve the mobilization and prioritization of resources towards higher impact outcomes. Better criteria for evaluation were seen as

vital to ensuring quality control of implementation projects.

- **Safety Nets:** In some of the poorest parts of Vietnam, health services are made available free of charge to the lowest income groups including ethnic minorities, with progressive cost schemes depending on income level for health services or insurance. Emergency teams as state or volunteer services are mobilized for on-the-spot responses to extreme events.
- **State Education System Reach:** Vietnam's public school system is present in every municipality and is a major asset for responding to climate change in vulnerable communities around the country. The potential for expanding awareness and education programmes is high, while schools can also support health monitoring and food security among children, who are a high-risk demographic group.
- **Sustainable Fishing:** Fishing is a large industry, but facing growing concerns about overfishing and fish stock depletion due to unsustainable practices (UoC and Vietnam MPI, 2010). Losses due to climate change could be attenuated in part by improving the sustainability of fishing practices, and in this way the resilience of fish stocks. Enforcing simple regulations on fish net size (large gauge) and promoting sustainable produce certification for fishing operations are just two examples of compelling and simple options for addressing unsustainable fishing.
- **Pollution Controls:** In all regions visited, industrial, domestic and agricultural pollution was highlighted as a major concern. From mining refuse to coal plant slurry, pesticides, domestic sewage and the use of poison to catch fish, water resources were being polluted, with negative effects for fishing, biodiversity, and water availability. The finding implied that increasing resilience to climate-induced water stress could be addressed in part through improved waste management across different sectors.



BẾN TRE – MEKONG DELTA

The Mekong delta of Vietnam is almost identical in area and population size to The Netherlands in Europe including the Rhine and Meuse, Schelde Delta, each spanning some 40,000 km² with around 18 million inhabitants. Bến Tre itself is one of a number of low-lying coastal provinces in the area and is heavily dependent on the fishing industry, including intensive aquaculture such as shrimp farming. Hallmark concerns for the area relate to sea-level rise, such as salt intrusion into water and soils, fisheries impacts due to warming waters and to a lesser extent, air pollution. Drought as well as heavy and unpredictable rains were further concerns raised by the community and these are highlighted in the Monitor's assessment. Sea-level rise causes a range of effects, including erosion of sea frontage and isolated flooding especially during record tides when the estuaries of the delta begin to inundate the surrounding land. The most serious current effect, however, relates to the increasing salinity of the waters as the sea pushes further upstream the Mekong. Bến Tre's many downstream waterways are undergoing a transformation as salty water progressively replaces previously fresh water, ultimately restricting the availability of water for domestic and agricultural purposes, and effectively drying up this coastal community.

RESPONDING TO SEA-LEVEL RISE

Needless to say, the very serious impacts and imminent risks linked to sea-level rise are of great concern. Local adaptation plans aim to gradually transform the Mekong delta into a South-East Asian version of The Netherlands, with a long list of intended actions costing over 100 million dollars in near-term investments for the province of Bến Tre alone, only one of 58 provinces in Vietnam. Although 50–60% of the plan is aimed at crucial infrastructure investments, such as dykes, polders, water supply works and dams, including 65kms of concrete sea walls and coastal defences reminiscent

of the Maginot Line, it nevertheless represents a bargain, if compared to the unthinkable costs such enormous infrastructure investments might incur in a developed country. A long-term Mekong Delta “Master Plan” is also under development with the involvement of a Dutch consortium (NWP, 2012). Local officials were open about the fact that investment needs far exceed what the community could conceivably afford to invest, and hoped that 90% of funds would be forthcoming from the international community and the central government. The ability of the community to take on loans to pay for all the intended construction was also severely limited. However, certain projects were reported to be potentially justifiable as loans, in light of the anticipated increases in agricultural production that would result from implementation. This suggests some scope for communities and businesses to pay for construction costs of water infrastructure later on the basis of expanded incomes. With almost the entire province lying below only one metre above sea-level, the whole area would be underwater by the end of the century according to the mid-point of the IPCC's estimates (IPCC, 2007). Since the last IPCC report, much higher estimates have been consistently put forward, suggesting that the IPCC is at the low-end of possible outcomes (RSNZ, 2010; Füssel in Edenhofer et al. (eds.), 2012). At the moment, however, sea-level rise is a more manageable 2–3mm per year, or 1 cm every 3–5 years (Vietnam MONRE, 2010; NASA Climate, 2012). Given that it is not likely that international resources will ever be made available to fund infrastructure for an expanse of over 60kms of coastline over the next five years, a diversification of the response strategy is likely called for.

In a broader context, it is evident that climate-driven sea-level rise is not the only factor aggravating Bến Tre's water-related concerns. Two important issues are equally worrisome. If adequately addressed, they might well

help to alleviate or offset some of the climate-related stress being felt and at a lower cost than solid infrastructure responses.

First, an intensification of agriculture in the area has used water pumped from underground or from canals to meet growing irrigation needs. The water volume removed from local supplies is therefore increasing in a context of growing water scarcity. Increasing heat and drought due to climate change remain a likely exacerbating factor. However, withdrawal of ground water contributes to land subsidence, or sinking land, which heightens inundation vulnerabilities and can result in perceived sea-level rise (Larson et al., 2001).

Rainfall, especially in heavy concentrations, is predicted to increase for much of Vietnam due to climate change, as the Earth's hydrological system is accelerating (Vietnam MONRE, 2010). An alternative to expensive large-scale water generation facilities are low-cost, locally produced water catchment and storage units that harvest rainfall for subsequent use for domestic purposes; however, the available area for artificial catchment would likely fall short of meeting the needs of the agricultural industry. The second key factor is also linked to the booming agricultural industry of the broader region. From the ocean frontage of Bến Tre back through the Mekong across Vietnam and reaching to the hinterlands of Cambodia, the agricultural boom has been sustained by large-scale irrigation systems that are fed by the Mekong itself. Upstream, not only in Vietnam but also in Cambodia, this is often accomplished through the construction of dams or dikes that help ensure a predictable water supply at specific points. On the whole, however, the Mekong's flow rate may be affected by a large-scale diversion of its water for irrigation (Fredén, 2011). Furthermore, dams built for irrigation purposes also trap riverine sediment upstream, depriving the downstream river delta of crucial alluvial deposits vital to its



CLIMATE ★

	2010	2030
Contraction of biological zones (km ²) - yearly average	-150	-300
Additional land degraded due to climate change (km ²) - yearly average	-3,500	-7,250
Additional/reduced energy load due to climate change (GWh) - yearly average	1,500	6,000
Additional CO ₂ generated/reduced for heating and cooling due to climate change (kt CO ₂) - yearly average	550	2,500
Share of workforce particularly affected by climate change (%) - yearly average	48%	37%
Additional land lost due to climate change (km ²) - yearly average	150	300
Additional water losses/gains due to climate change (km ³) - yearly average	-1	-1

environmental integrity (Baran, 2010; Yang et al., 2005). A slowing river flow might therefore also be responsible for increasing contamination of downstream zones in water with a high salt content as the Mekong's ability to force back oceanic tidal movements is compromised. It is unclear whether or not an expected increase in river flow due to climate change would offset a growing intensification of water withdrawals (Vietnam MONRE, 2010). The retention of sediment also has a further negative impact on marine and freshwater biodiversity and fisheries by reducing the nutrient content of the lower Mekong, as experts confirmed. Nor is does the question concern the suffering of downstream Bến Tre alone. The ecosystem of all parts of the delta system being tightly interlinked, local experts stressed the interdependence of fish movements. With the local biological richness of Bến Tre declining, its ability to serve as a corridor for fish migrations upstream is compromised and is leading to a decline in fish stocks in non-coastal delta provinces. Therefore, there is a strong incentive for inter-provincial cooperation to ensure that common resources are managed effectively and for the benefit of all. However, according to experts, this type of cooperation was still at the exploratory phase. The upstream provincial university at Can Tho for instance had recently formed "MekongNet," to foster greater understanding and cooperation around shared Mekong river interests. At a national level, the long-term development objectives of neighbouring Cambodia have direct implications for the prosperity and risks facing the downstream delta communities of Vietnam, such as Bến Tre, Can Tho, and others. Therefore, transnational cooperation on issues affecting the Mekong river are a serious economic, environmental, and livelihood concern for Vietnam—even more so considering the growing array of considerations linked to climate change. Working more actively with the Mekong River Commission, prioritizing the issue

in formal bilateral relations with Cambodia and clearly spelling out the concern in future national policies, would constitute steps forward in addressing these challenges.

SUSTAINABLY MANAGING AQUACULTURE AND FISHERIES

Catch fisheries and aquaculture, particularly shrimping, are the dominant industries and sources of livelihood in Bến Tre. Serious exposure of the fisheries industry to climate and carbon risks did not, however, appear to be a major local consideration. And at the same time that the industry is a major income earner, it is also capital intensive and highly risky. If disease breaks out in a shrimp pond, the entire harvest is compromised, and possibly also in the neighbouring ponds. So, while the industry is an important income earner, it is also the sector that incurs frequent losses. No insurance was reported to be available for such high-risk activities as commercial pond shrimping.

Furthermore, experts confirmed that water temperature and acidity (pH) were fundamental concerns for controlled fish or shellfish ponds and directly linked to disease outcomes. Increasing heat and pollution-related water acidity would only heighten the risk of disease. Government intervention appeared to be limited to issuing guidelines during periods of extreme heat, to try and limit the loss of fish or shellfish from farms.

One systemic vulnerability identified for the aquaculture/shrimp industry was the quality of hatcheries. High quality disease-resistant seedlings are bought at extra cost that is hard to justify when a neighbouring pond might purchase the low-cost version and contract and pass on disease anyway. Improving seed supply for shrimp is an important response to this concern: Stricter regulation ensuring highest quality control for all hatcheries could ensure that all farmers use disease resistant seedlings to begin with, reducing

CARBON ★

	2010	2030
Volume of water to treat (millions m ³) - yearly average	2,000	3,000



system wide risks and losses. The increased resilience should help offset to some extent the mounting concerns over water temperature and acidity. In terms of catch fishing, there did not appear to be any serious regulation targeting overfishing and experts referenced the use of poison for fishing and the harmful effect of sewerage and aquaculture pond refuse on free-roaming fish stocks. Higher prices were reported for fish or shellfish produced under certified sustainable conditions. They provide an economic advantage, which, in most cases, outweighs the extra capital required to ensure compliance with certification schemes, such as MSC. However, many fishermen could not afford the additional financial outlay. With sustainable fishing programmes only beginning to appear, the full possibilities for such programmes were understood to be high. Building the capacity of producers by offering detailed training programmes was seen as an important step for promoting wider adoption of sustainable fishing activities. Financial stimuli or incentives are also likely to be necessary to help operators make the transition to certified operations.

Establishing and enforcing strict regulations on net size (gauge) was another important measure that helped to avoid depletion of young fish stocks and support the sustainable replenishment of fish. Finally, the preservation of coastal mangrove forests was viewed as an important priority for enhancing biodiversity that could improve the quality and quantity of local fish stocks. Mangrove swamps serve several functions: naturally accreting sediment that stems coastal erosion and warding off sea-level rise and the contamination of coastal water lenses due to salt intrusion. Mangroves also reduce sea-to-land wind speeds during severe storms, and help to limit the damage caused by extreme weather. According to local experts, some preservation zones had been established, but in areas where mangroves were not protected, the forests were in decline, due to a combination of local plundering and coastal stress. There seemed to be few if any arguments for not protecting and seeking to expand the entirety of the remaining mangrove forests. The main driver for degradation of the forests is pressure to enlist more space for agriculture or aquaculture.



YEN BÁI – NORTH-WEST HIGHLANDS

Therefore, regulations and monitoring would be required to ensure protection. Yen Bái is a large and relatively populous province in the north-west highland region of Vietnam. It is a heavily forested area with an agriculture-based economy active in the valley zones, with several hydro-energy installations in place. Farmers produce staple crops, such as rice and cassava, and, depending on the zones, cultivate plants ranging from tea to fruit trees, and in certain areas, also raise livestock. The dominant form of energy for cooking and heating is wood and biomass for indoor fires/stoves, with all the health risks that this practice implies.

The area of Yen Bái visited by the project researchers has a very low per capita income and high proportions of minority ethnic groups, living at the socio-economic margin. No specific climate change adaptation plans were in place or under development for that area. However, a number of government-led initiatives address key climate-related vulnerabilities and local officials had participated in workshops on climate change policies as a part of recent provincial and central government initiatives.

SOCIAL VULNERABILITIES

The main climate change risks for the region are extreme weather and shifting climate patterns, with flooding, drought, and agricultural concerns emphasized. Levels of socio-economic vulnerability were very high, with child malnutrition rates and stunting at 10–20% or higher in certain villages. Although mortality was reportedly very low, children and the elderly are the high-risk groups. Some 40% of households were without electricity, and similar levels of households, especially in poorer villages, were without an improved or plumbed water source. Other climate-related health concerns included a recent cholera outbreak in a remote community. However, programmes promoting personal hygiene and other education

initiatives had apparently made strides in reducing a variety of health concerns in recent years. In the poorest communities, refrigeration was unusual, and air conditioning was to be found only in upscale restaurants or hotels.

EXTREME WEATHER AND IMPACTS

Experts reported a clear shift in the last 5–7 years in weather patterns. The abruptness and timing of season changes was a hallmark alteration. One school visited by the research team had 60 children absent for reasons of illness, attributed to the sudden arrival of warm weather. Large amounts of stone debris brought downstream in recent flooding were visible in most main waterways. Tractors were in some locations clearing the debris and locals attested to the expense of flood cleanup operations. Prolonged hot and dry spells were widely reported to be more common and had led to livestock and crop losses and reductions in stream-flow during these periods. Higher temperatures were a concern for agriculture and forestry due to water stress and insect and plant disease outbreaks. A hotter climate was forcing farmers to abandon some traditional crops—one form of cabbage was cited as no longer able to grow effectively. Although winters were now shorter and the hot periods of the year longer, the area had also experienced several extreme cold snaps that had caused health concerns and livestock losses, testifying to the volatility of weather in this area. No insurance schemes were available for crop or livestock losses due to such extremes of weather or drought. But public irrigation works were ensuring wider access to reliable water sources and it was hoped these would be further expanded. A number of government-linked rural extension programmes were operational in the region, assisting farmers to grow new varieties of crops, such as those promising to be more suitable to warmer conditions, and to

bring higher yields and higher market prices. However, improved varieties of rice required more attention and technical care from farmers, indicating the importance of access to training and knowledge, as farmers made the shift in their crops and cultivation. The timing of planting and harvesting was cited as particularly important. Weather forecasting information was made readily accessible and was regularly consulted by local farmers, with rural extension officers also promoting the practice.

SCHOOLS AND EDUCATION

Disaster education programmes were being successfully piloted in a number of schools, although the focus was mainly on personal safety, such as avoiding riverbanks during heavy rains. However, environmental and climate issues were set to be introduced in two schools visited, following training sessions for teachers on these issues. Schools were already active in teaching children to help preserve forests, to cultivate climate-resistant vegetables outside their homes as a food supplement, and to follow basic sanitary guidelines. Children from the poorest remote communities were also lodged and fed at the school during term time for minimal fees. Evidence of behavioural change as a result of these initiatives was cited and teachers confirmed that children also passed on what they learned to their parents and relatives. The importance of education was underscored by the number of houses in some of the lowest-income villages that lacked any improved water source, but did possess colour televisions with satellite dishes. There were also limits to knowledge: hardship was cited as one of the main causes of local forest degradation, since people with no other alternatives would rely as a last resort on the forests by chopping down trees in order to sustain their livelihoods. Teachers suggested that the impact of educational programmes might nevertheless be improved by offering

prizes in extra-curricula student competitions on environmental/climate issues; even very low-cost items such as sun caps could make the programmes more attractive, well attended, and broaden results. Schools also worked in close cooperation with health stations monitoring children and their families and alerting and referring sick children who needed early intervention. In several schools, children whose families could not feed them would also receive free meals.

HYDRO-ENERGY

On the basis of the Monitor's assessment, Vietnam is expected to experience modest benefits for its Hydro-Energy sector as a result of higher levels of rainfall. Local experts explained that more dry spells during the hotter seasons would not affect production for energy installations with reservoirs, if annual rainfall (or runoff) were to increase. However, installations without reservoirs which relied instead on a constant stream-flow would be negatively affected. Increasing the immediate water catchment potential and quality of surrounding land could potentially offset any losses. In particular, the high-altitude forests absorb more water (by "cloud catching") and also release it more slowly and regularly, which helps to diminish the severity of droughts (Postel and Thompson, 2005). On the whole, the bulk of hydro energy in Vietnam is being produced from reservoir type installations. Local hydro-energy producers had also successfully accredited projects with the Clean Development Mechanism (CDM) and were able to confirm that the additional income stream provided by the sale of carbon credits as Certified Emission Reductions (CER) was the determining factor in making the installations commercially viable. Therefore, local entrepreneurs planned to undergo the 1–2 year registration process as a part of all future business



expansion efforts for new energy installations.

TOWARDS COMMUNITY RESILIENCE

A boost to the resilience of Yen Bái as it comes to grips with a warmer and more volatile climate could expand on and reinforce various initiatives already under way as described above. Schools and health stations are active institutions at the centre of the poorest communities doing crucial work but severely lacking in resources. Reinforcing the ability of schools and health centres to deliver social support would likely yield immediate results for the most vulnerable communities. Supporting farmers as they make the transition to higher-yielding, higher-value crops is an ongoing priority, as is the expansion of irrigation works. Preserving, growing and sustainably managing the forests of Yen Bái is also a public good that will reinforce the environmental resilience of the region with positive benefits for farmers and their families, and advantages for hydro-energy installations. The CDM is already being used to support large-scale energy projects in the region. However, CDM projects could also be developed as bundled programmes of activity, in particular to promote the dissemination of clean-burning or low-emission cooking/heating stoves (UNDP, 2011). This would help to address both the indoor smoke health risks and the forest degradation concerns of the region. Local manufacturing of appropriate and low-cost stoves may yield an additional economic dividend. Policymakers may also be interested to consider offering lifeline payments to forest holders or custodians, especially ethnic minority groups for forest stewardship, giving them incentives to preserve and sustainably manage the region's forests.

Finally, the very limited access to either crop/farm and infrastructure insurance or finance for small-scale farmers also

merits attention. The government has an interest to increase the transfer of risks to the insurance industry and to expand access to finance in order to support enhanced economic growth. Microfinance and micro-insurance schemes have met with success in other countries in communities of similar income levels, and these could provide inspiration for applying such tools in Yen Bái and other parts of rural Vietnam (Jansson, 2010).

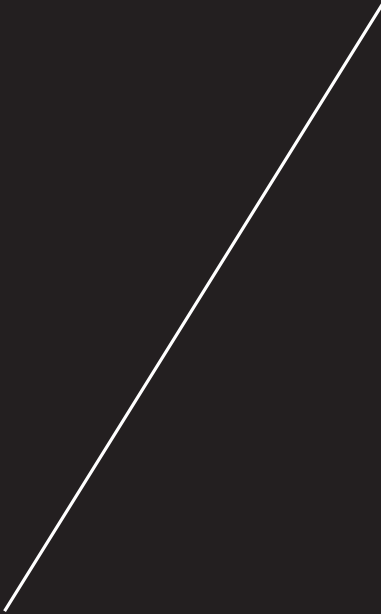
Micro-insurance is of interest for a number of reasons. First and foremost, because communities with the highest levels of vulnerability, such as the subsistence farmers of Yen Bái, risk much more of their livelihoods to extreme weather events than any other segment of the population. Since micro-insurance is by definition affordable and should be offered on a sustainable and equitable business model for all concerned, it offers the prospect of breaking part of the cycle that links poverty so closely to vulnerability (Churchill and Matul, 2012). The fact that health care insurance is widespread, even among the poorest communities in Vietnam demonstrates the viability of the concept for other concerns, particularly in the agricultural context, such as for crops and livestock. If farmers have income protection from year to year, their productivity can be regularized and enhanced. When farmers are insured, they are also more likely to be able to access finance to enhance their yields and income further (Zeller and Sharma, 2000). Ultimately, all this will boost economic growth and public finances, which can, in turn, be reinvested in more sustainable growth and should more than justify any outlay to provide incentives in partnership with competent organizations.

CONCLUSION

Vietnam has made an impressive beginning in tackling climate change, in particular from a government policy perspective. The country serves as a case of interest for other developing countries now considering how to meet the national climate change policy challenge. It has consolidated helpful assistance from foreign partners and, with pilot activities in select provinces, has begun to tackle the larger task of implementing its policies on the ground. As climate change is estimated in the Monitor to cause significant negative externalities for Vietnam, tackling the problem effectively should provide an economic boost for the country. Raising community level awareness, while fostering local sources of knowledge and the people's capacity to engage with climate change and take actions at the community level will enhance their impact. Likewise, focusing on monitoring and evaluating project performance will lead to higher-quality projects and better results.

Vietnam would do well to focus energies on core macroeconomic risks, such as improving resource management in the fisheries sector and responses to labour productivity exposure, as well as promoting ongoing diversification of the economy onto a lower-risk service and industrial sector-orientated footing. Opportunity should also be taken to help those remaining vulnerable communities to become more resilient through programmes such as education campaigns or encouraging the use of agro-insurance. Developing the interlinkages with low-carbon concerns on forestry, wetland or mangrove preservation and indoor household fuel use, and taking advantage of technology transfer and financing through the Clean Development Mechanism will all help to maximize economic, social and environmental benefits. With the anticipated intensification of climate change stresses in the immediate years and decades ahead, early action and investment will surely guarantee the highest dividends.





CARBON



ENVIROMENTAL DISASTERS



OIL SANDS



OIL SPILLS

↓ **\$** 5 BILLION LOSS 2010
25 BILLION LOSS 2030



↓ **\$** 10 BILLION LOSS 2010
40 BILLION LOSS 2030



OIL SANDS



ESTIMATES GLOBAL CARBON IMPACT



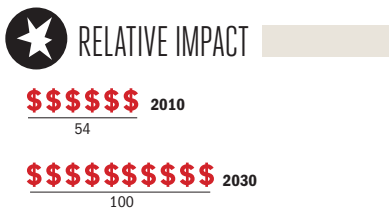
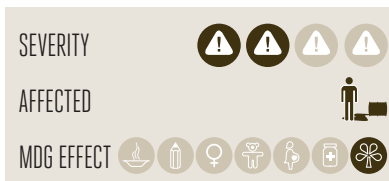
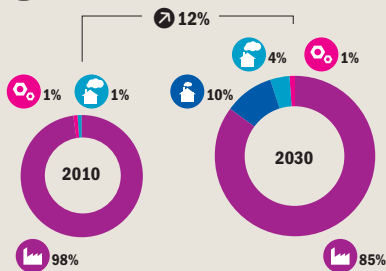
2010 EFFECT TODAY

5 BILLION
USD LOSS PER YEAR

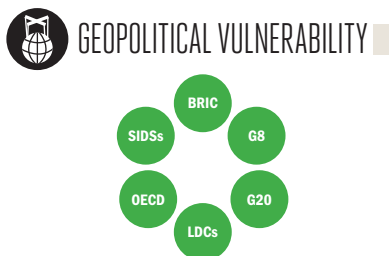
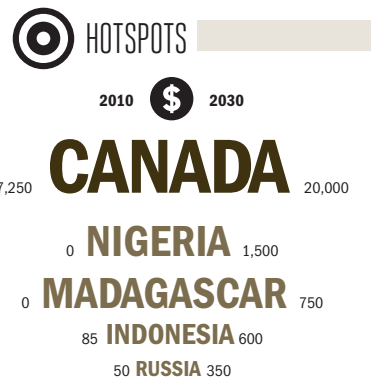
2030 EFFECT TOMORROW

25 BILLION
USD LOSS PER YEAR

ECONOMIC IMPACT



- Oil sands, or tar sands, are an unconventional source of petroleum extracted from an asphalt bitumen sand-like substance
- With the projected expansion of oil demand over the next twenty years, unconventional fuels, like synthetic crude from oil sands, will make up a significant proportion of the new supply
- Oil sands involve large scale localized ecological damage that is costly to remedy: some environmental damage is thought irreversible
- Oil sand exploitation is highly concentrated with over 90% of all today's production in Canada, although a small number of mainly developing countries also have important reserves



\$ Economic Cost (2010 PPP non-discounted)

i Developing Country Low Emitters **f** Developed

h Developing Country High Emitters **o** Other Industrialized

★ **\$** = Losses per 10,000 USD of GDP

↗ Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

So-called “unconventional fuels”, including oil sand-derived synthetic crude as well as shale oil and gas, make up an increasing share of the global energy mix and are poised to contribute significantly to meeting the surging global demand for fossil fuels expected in the two decades ahead (US EIA, 2011). Unconventional fuels are more costly to extract than ordinary crude oil or natural gas because they involve separating out the hydrocarbon fuels from rocks, sand and other debris. The extraction process is water, energy and emission intensive, and generates large volumes of environmental debris and toxic sludge waste (Severson-Baker and Reynolds, 2005; Tenenbaum, 2009; Giesey et al., 2010). Over 600km² of land in Canada has now been disturbed by oil sand exploitation with 600 million tons of toxic waste by-products from this process now held in over 100km² of “slurry” ponds (Reuter et al., 2010). The potential growth in environmental risks is significant: proven recoverable reserves are 300 times today’s annual production and bitumen deposits that could become recoverable, given technological advances, lie beneath some 140,000 km² of land, an area almost the size of Bangladesh (GoA,

2012). The Canadian government aims to make Canada an “Energy Superpower” on the back of its oil sand production. Prime Minister, Stephen Harper, has likened this aspiration to “the building of the pyramids or China’s Great Wall. Only bigger” (Canada OPM, 2006). Oil sands are expected to more than double in production scale over the next 20 years, with a handful of countries outside Canada also having important deposits of the resource (CAPP, 2011; World Energy Council, 2010).

HAZARD MECHANISM

There are two main types of oil sands exploitation: open pit mining, which involves digging and excavation of bitumen sands containing oil, and various forms of pumping, termed “in situ” extraction. Both processes involve large quantities of water and often solvents to aid the extraction by increasing the fluidity of otherwise highly dense and viscous bitumen sands (Canada NEB, 1996). In order to access the sands via mining, as much as 75 metres of ground soil including all vegetation, usually boreal forests, is removed. On average some two tons of land is removed per barrel of oil extracted (Reuter et al., 2010). Pumping

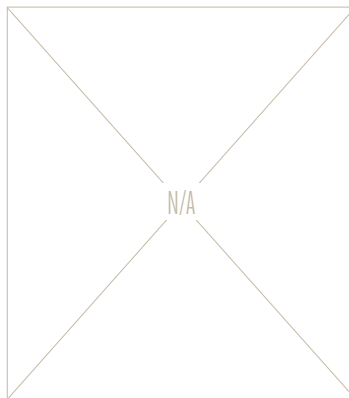
out bitumen oil in situ involves injecting steam and industrial solvents into the ground before pumping out liquefied bitumen (OSDG, 2009). Each barrel of oil produced generates eight barrels of waste slurry (so-called “fine tailings”) with current production at around 1.5 million barrels of oil a day (Reuter et al., 2010; CAPP, 2011). The refuse slurry generated by extraction is highly acidic and acutely toxic to aquatic life (Allen, 2008). Numerous different types of pollutants from these processes, including cadmium, copper, lead and mercury, have been released into adjacent waterways, exceeding in many cases local concentration guidelines for fresh water in nearby populated areas (Kelly et al., 2010). To date there has only been minimal reclamation of land to remedy the degradation caused. Experts have estimated that around two thirds of all peatlands damaged by oil sand exploitation would be permanently impaired and irrecoverable (GoA, 2012; Rooney et al., 2012). If action is not taken to treat open waste ponds, through steps such as “bioremediation”, which accelerates natural processes to reduce their toxicity, the environmental damage in terms of human health, water, ecosystems and

otherwise, is very likely to exceed any treatment costs (Reuter et al., 2010).

IMPACTS

The environmental impact of oil sands is estimated at over seven billion dollars a year today. As oil sand production is expected to expand, including into other countries, the total environmental costs are set to grow to nearly 25 billion dollars a year in 2030, assuming that much of the world’s known reserves have been brought into production (World Energy Council, 2010). Current and prospective oil sand reserves outside Canada include those found in Angola, China, Congo, Indonesia, Italy, Madagascar, Nigeria, Russia, Trinidad and Tobago and the US. Indonesia, Russia and the US have already commenced small-scale levels of production. Canada is, and will continue to be, worst affected by the environmental impact of oil sands. By 2030, however, Madagascar, Congo and Nigeria are also expected to suffer significant costs linked to the exploitation of this resource, provided exploitation is carried out. The costs for Canada would grow from seven to 20 billion dollars a year by 2030.

BIGGER PICTURE



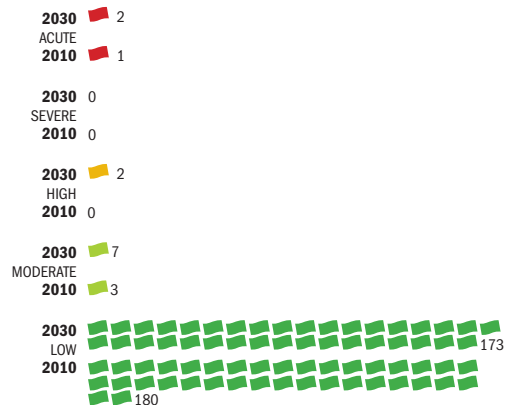
SURGE



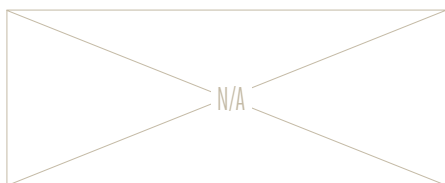
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: CAPP, 2011; CERES, 2010
 BASE DATA: World Energy Council, 2010

➡ = 5 countries (rounded)



THE INDICATOR

The indicator measures the environmental costs of oil sands exploitation by the proxy of measuring the costs of accelerated clean-up, through “bioremediation”, of toxic wastes generated. It is assumed that remediation costs are less than or equal to the environmental and health damages that would result if no measures were taken to protect the environment. Currently Canadian oil firms are subject to regulations that could be more forceful in ensuring strict environmental protection measures are complied with: to date the vast majority of toxic waste is untreated (Reuter et al., 2010). Only a small group of countries with significant reserves (four with existing production) are taken into account (World Energy Council, 2010). Environmental “bioremediation” costs per barrel of oil are assumed to be equal for all countries concerned, which could prove an estimation limitation. However, there are few precedents against which to assess the costs.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		☢	
	2010	2030	2010	2030
ACUTE				
Canada	7,250	20,000	150,000	300,000
Madagascar		750		2,000
HIGH				
Congo		150		650
Nigeria		1,500		5,000
MODERATE				
Angola		150		600
China		95		200
Indonesia	85	600	1,250	2,250
Italy		20		250
Russia	50	350	700	1,250
Trinidad and Tobago		30		100
United States	60	150	1,250	2,250
LOW				
Afghanistan				
Albania				
Algeria				
Antigua and Barbuda				
Argentina				
Armenia				
Australia				
Austria				
Azerbaijan				
Bahamas				
Bahrain				
Bangladesh				
Barbados				
Belarus				
Belgium				
Belize				
Benin				

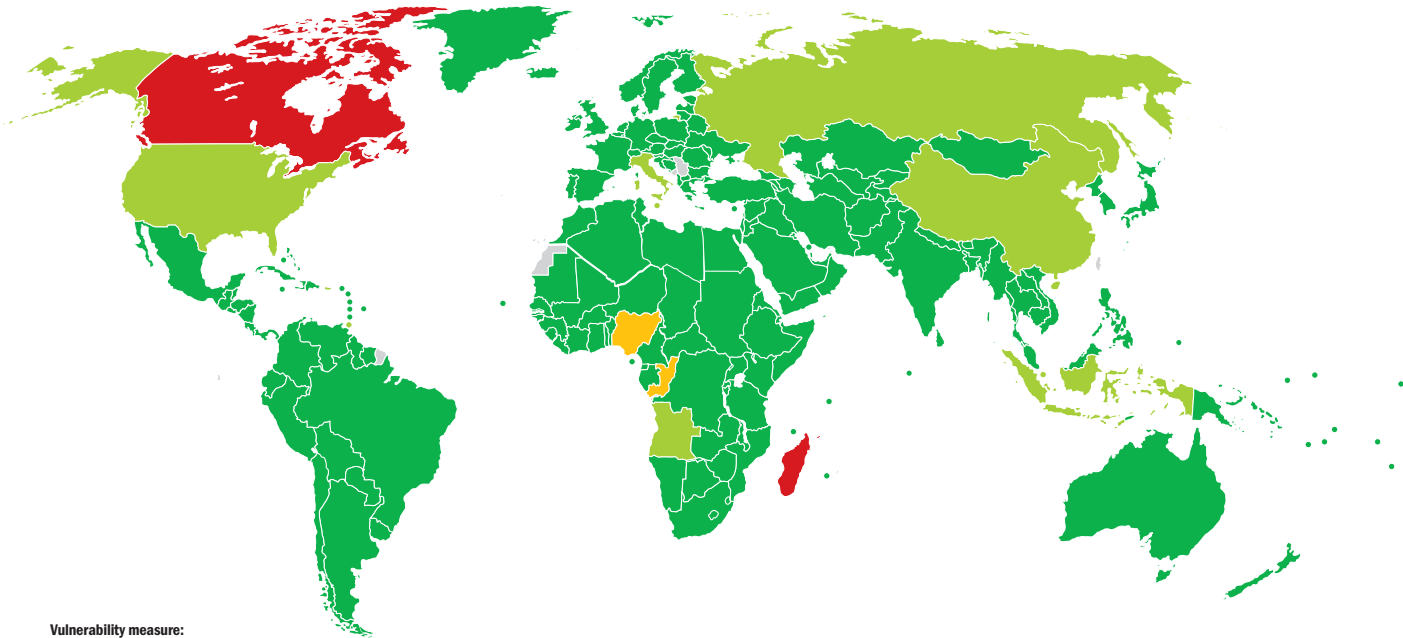
COUNTRY	\$		☢	
	2010	2030	2010	2030
Bhutan				
Bolivia				
Bosnia and Herzegovina				
Botswana				
Brazil				
Brunei				
Bulgaria				
Burkina Faso				
Burundi				
Cambodia				
Cameroon				
Cape Verde				
Central African Republic				
Chad				
Chile				
Colombia				
Comoros				
Costa Rica				
Cote d'Ivoire				
Croatia				
Cuba				
Cyprus				
Czech Republic				
Denmark				
Djibouti				
Dominica				
Dominican Republic				
DR Congo				
Ecuador				
Egypt				
El Salvador				
Equatorial Guinea				

COUNTRY	\$		☢	
	2010	2030	2010	2030
Eritrea				
Estonia				
Ethiopia				
Fiji				
Finland				
France				
Gabon				
Gambia				
Georgia				
Germany				
Ghana				
Greece				
Grenada				
Guatemala				
Guinea				
Guinea-Bissau				
Guyana				
Haiti				
Honduras				
Hungary				
Iceland				
India				
Iran				
Iraq				
Ireland				
Israel				
Jamaica				
Japan				
Jordan				
Kazakhstan				
Kenya				
Kiribati				



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		☢		COUNTRY	\$		☢		COUNTRY	\$		☢	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Kuwait					North Korea					Sudan/South Sudan				
Kyrgyzstan					Norway					Suriname				
Laos					Oman					Swaziland				
Latvia					Pakistan					Sweden				
Lebanon					Palau					Switzerland				
Lesotho					Panama					Syria				
Liberia					Papua New Guinea					Tajikistan				
Libya					Paraguay					Tanzania				
Lithuania					Peru					Thailand				
Luxembourg					Philippines					Timor-Leste				
Macedonia					Poland					Togo				
Malawi					Portugal					Tonga				
Malaysia					Qatar					Tunisia				
Maldives					Romania					Turkey				
Mali					Rwanda					Turkmenistan				
Malta					Saint Lucia					Tuvalu				
Marshall Islands					Saint Vincent					Uganda				
Mauritania					Samoa					Ukraine				
Mauritius					Sao Tome and Principe					United Arab Emirates				
Mexico					Saudi Arabia					United Kingdom				
Micronesia					Senegal					Uruguay				
Moldova					Seychelles					Uzbekistan				
Mongolia					Sierra Leone					Vanuatu				
Morocco					Singapore					Venezuela				
Mozambique					Slovakia					Vietnam				
Myanmar					Slovenia					Yemen				
Namibia					Solomon Islands					Zambia				
Nepal					Somalia					Zimbabwe				
Netherlands					South Africa									
New Zealand					South Korea									
Nicaragua					Spain									
Niger					Sri Lanka									

OIL SPILLS

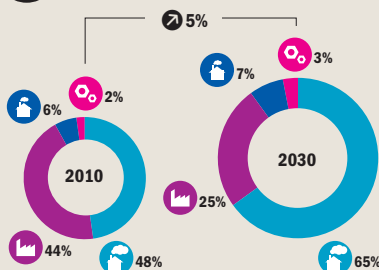


ESTIMATES GLOBAL CARBON IMPACT

2010 EFFECT TODAY
 USD LOSS PER YEAR **10 BILLION**

2030 EFFECT TOMORROW
 USD LOSS PER YEAR **40 BILLION**

ECONOMIC IMPACT

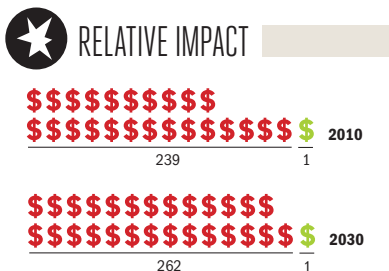


CONFIDENCE INDICATIVE

SEVERITY

AFFECTED

MDG EFFECT

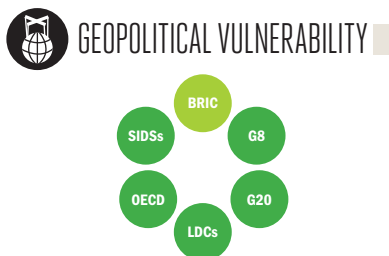
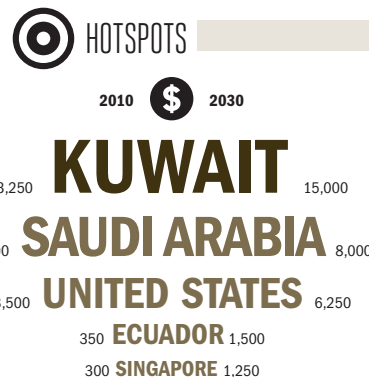


Oil spills are one of the most graphic manifestations of the environmental risks run by a carbon economy reliant on fossil fuels

Oil is expected to remain the world's principal fuel well beyond 2030: by then consumption is expected to be some 25% higher than today

Despite the 2010 Gulf of Mexico disaster an increase in deep-water oil drilling is foreseen as the frontier for new petroleum reserves advances, pushing up against the limits of exploration and exploitation

The dangers associated with deep-water drilling are expected to cause considerable further increases in the environmental and economic costs of oil spills



Economic Cost (2010 PPP non-discounted)

Developing Country Low Emitters Developed

Developing Country High Emitters Other Industrialized

= Losses per 10,000 USD of GDP

= Millions of USD (2010 PPP non-discounted)

Change in relation to overall global population and/or GDP

Improvements in operating safety leading to decreased risks of oil spills in recent decades have occurred in parallel to increases in consumption and new risks associated with deep-water drilling now expected to lead to even greater damage in the years to come in spite of progress made. The April, 2010 BP Gulf of Mexico oil disaster, triggered by an explosion on the ultra deep-water Macondo Well rig, released five million barrels of crude oil into the sea. The unabated stream flowed for months and led to tens of billions of dollars of direct economic damage and profound ecological consequences. Half a year after the spill 32,000 square miles of sea remained closed with much of the American fishing industry unable to operate (Graham and Reilly, 2011). The oil firms themselves and their shareholders also suffered: BP saw its share price fall by more than half in a matter of months and is still to recover as tens of billions of dollars in value were erased forever (Grant, 2010). Analysis has shown that similar incidents cause affected companies roughly 10% losses in market value six months after such accidents (Laguna and Capelle-Blancard, 2010). From 2002 to 2015,

deep-water oil exploitation is expected to emerge as a major source of fuel, growing from 2% to around 12% of all global oil production (Douglas-Westwood, 2010). With it the danger of repeats of the Gulf of Mexico disaster will only increase: the risk of abnormal incidents on offshore facilities triples for deep-water oil platforms operating in water depths below 300 metres or 1,000 ft (Cohen, 2011).

HAZARD MECHANISM

The vast majority of oil spills occur in the world's oceans as the principal global energy source – oil – is transported to feed a worldwide demand for a product with highly restricted geographical availability (ERC, 2009; US EIA, 2011). Oil spills occur along global supply chains between key source and destination nodes. When an oil spill occurs there is a predictable and measurable relationship between the amount of surface water contaminated and a corresponding economic loss divided between environmental or biodiversity costs, such as the decimation of birds and other local wildlife populations, socio-economic costs, such as the loss of fishing revenues, and spill

response costs, which include the cost of clean-up (Etkin, 2004). The level of economic costs ultimately experienced is determined by factors such as the location of the spills (far offshore, or in a coastal area), the type of oil released into the environment (more viscous and therefore more costly to remove, or vice versa), and environmental conditions prevailing in the days and weeks following the incident (such as ocean currents that disperse or concentrate oil slicks) (McCay, 2004).

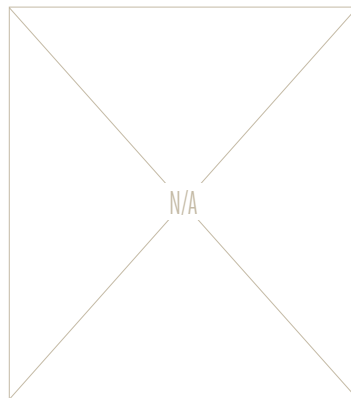
IMPACTS

The global impact of oil spills on the world economy is estimated at 12 billion dollars a year today, and is expected to nearly triple to more than 30 billion dollars a year in 2030 but with losses remaining stable as a share of GDP.

On the basis of historical trends in oil spills only a limited number of countries are expected to suffer disproportionately from the growing risk of oil spills. Some 25 countries show globally significant vulnerabilities to oil spills, each either major oil producing or consuming countries, global supply chain nodes like Singapore or neighbouring states.

Middle East countries such as Kuwait and Saudi Arabia top the list of those countries most vulnerable to oil spills. The greatest share of effects is estimated to impact Kuwait, Russia, Saudi Arabia and the US, each suffering more than one billion dollars in average annual losses in 2010. These cost estimations are averages, so that one billion dollars of losses in one year might represent a 20 billion dollar loss once every 20 years.

BIGGER PICTURE



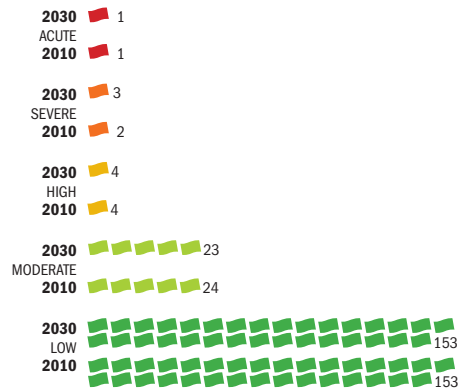
SURGE



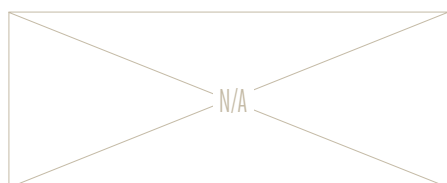
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Muehlenbachs et al., 2011; Schmidt, 2004; Westwood, 2010

BASE DATA: CEDRE, 2010; Tryse, 2010

Number of major oil spills per decade (over 10,000 tonnes of oil spilled)

= 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low



THE INDICATOR

The indicator measures the costs of oil spills in terms of environmental damage and is based on a pooled database of information on global oil spill incidents (Etkin, 2004; Tryse, 2010; CEDRE, 2012; Center for Tankship Excellence, 2012). Costs are assumed to affect countries listed as sites for oil spills in the past, which biases the predicted distribution of oil spill disasters. These might otherwise only be estimated in a semi-random manner, since each oil spill event is unique and random. It also does not take account of shifts in production that could occur over the next 20 years as new countries discover and expand exploitation, in particular of large scale offshore oil reserves: Brazil, for instance, is expected to become the world's fourth largest non-Organisation of Petroleum Exporting Countries (OPEC) supplier of conventional oil by 2035 (US EIA, 2011). Cost estimates of spills have been based on incidents in the US, with costs for other countries determined in relation to GDP.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		□	
	2010	2030	2010	2030
ACUTE				
Kuwait	3,250	15,000	8,250	9,000
SEVERE				
Ecuador	350	1,500	2,750	3,000
Saudi Arabia	2,000	8,000	8,250	9,000
Uzbekistan	250	850	4,250	4,750
HIGH				
Angola	250	850	4,250	4,500
Lebanon	65	250	400	450
Mozambique	20	65	1,250	1,250
Singapore	300	1,250	500	500
MODERATE				
Australia	100	200	550	600
Brazil	5	20	50	55
Canada	20	35	80	85
China	60	350	600	650
France	85	150	400	400
India	1	5	15	15
Ireland	5	5	15	15
Italy	450	750	2,250	2,500
Japan	60	90	300	300
Mexico	5	25	40	45
Nigeria	40	150	1,000	1,250
Norway	20	30	75	85
Pakistan	25	100	450	500
Philippines	1	5	20	20
Russia	300	1,000	1,500	1,750
South Africa	5	10	30	35
South Korea	55	250	150	150
Spain	500	800	2,250	2,500
Ukraine	1	5	10	10
United Arab Emirates	50	200	250	250

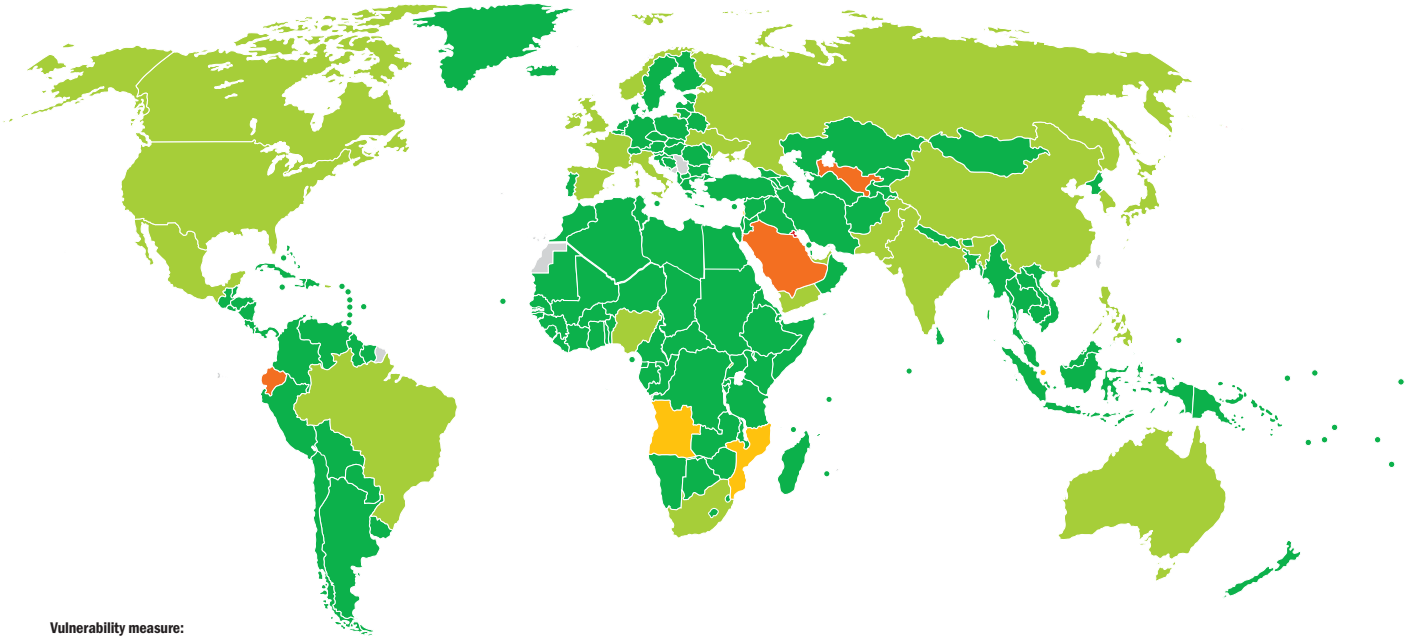
COUNTRY	\$		□	
	2010	2030	2010	2030
United Kingdom	650	1,000	2,500	2,750
United States	3,500	6,250	15,000	15,000
Yemen	10	30	200	200
LOW				
Afghanistan				
Albania				
Algeria				
Antigua and Barbuda				
Argentina				
Armenia				
Austria				
Azerbaijan				
Bahamas				
Bahrain				
Bangladesh				
Barbados				
Belarus				
Belgium				
Belize				
Benin				
Bhutan				
Bolivia				
Bosnia and Herzegovina				
Botswana				
Brunei				
Bulgaria				
Burkina Faso				
Burundi				
Cambodia				
Cameroon				
Cape Verde				
Central African Republic				

COUNTRY	\$		□	
	2010	2030	2010	2030
Chad				
Chile				
Colombia				
Comoros				
Congo				
Costa Rica				
Cote d'Ivoire				
Croatia				
Cuba				
Cyprus				
Czech Republic				
Denmark				
Djibouti				
Dominica				
Dominican Republic				
DR Congo				
Egypt				
El Salvador				
Equatorial Guinea				
Eritrea				
Estonia				
Ethiopia				
Fiji				
Finland				
Gabon				
Gambia				
Georgia				
Germany				
Ghana				
Greece				
Grenada				
Guatemala				



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		□		COUNTRY	\$		□		COUNTRY	\$		□	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
Guinea					Mauritania					Slovakia				
Guinea-Bissau					Mauritius					Slovenia				
Guyana					Micronesia					Solomon Islands				
Haiti					Moldova					Somalia				
Honduras					Mongolia					Sri Lanka				
Hungary					Morocco					Sudan/South Sudan				
Iceland					Myanmar					Suriname				
Indonesia					Namibia					Swaziland				
Iran					Nepal					Sweden				
Iraq					Netherlands					Switzerland				
Israel					New Zealand					Syria				
Jamaica					Nicaragua					Tajikistan				
Jordan					Niger					Tanzania				
Kazakhstan					North Korea					Thailand				
Kenya					Oman					Timor-Leste				
Kiribati					Palau					Togo				
Kyrgyzstan					Panama					Tonga				
Laos					Papua New Guinea					Trinidad and Tobago				
Latvia					Paraguay					Tunisia				
Lesotho					Peru					Turkey				
Liberia					Poland					Turkmenistan				
Libya					Portugal					Tuvalu				
Lithuania					Qatar					Uganda				
Luxembourg					Romania					Uruguay				
Macedonia					Rwanda					Vanuatu				
Madagascar					Saint Lucia					Venezuela				
Malawi					Saint Vincent					Vietnam				
Malaysia					Samoa					Zambia				
Maldives					Sao Tome and Principe					Zimbabwe				
Mali					Senegal									
Malta					Seychelles									
Marshall Islands					Sierra Leone									



BIODIVERSITY



CORROSION



WATER

↓ **\$** 300 BILLION LOSS 2010
1,750 BILLION LOSS 2030



↓ **\$** 1 BILLION LOSS 2010
5 BILLION LOSS 2030



↓ **\$** 5 BILLION LOSS 2010
10 BILLION LOSS 2030



BIODIVERSITY



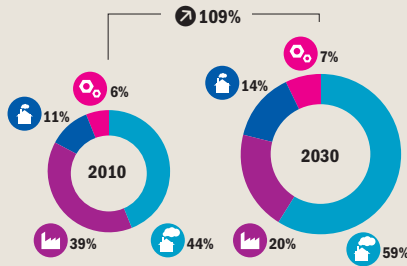
ESTIMATES GLOBAL CARBON IMPACT



2010 EFFECT TODAY
 USD LOSS PER YEAR **300** BILLION

2030 EFFECT TOMORROW
 USD LOSS PER YEAR **1,750** BILLION

ECONOMIC IMPACT



CONFIDENCE INDICATIVE

SEVERITY

AFFECTED

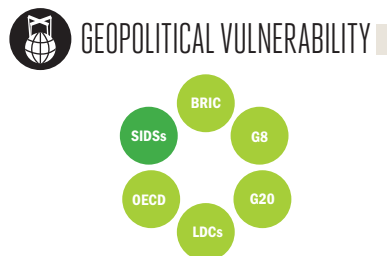
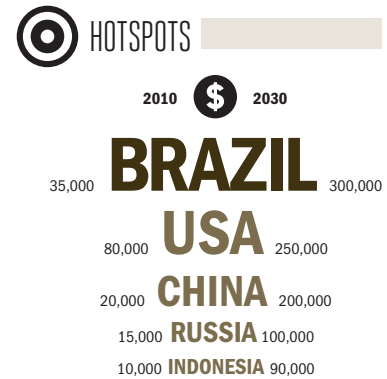
MDG EFFECT

RELATIVE IMPACT

2010: 97 (represented by 97 red dollar signs) vs 3 (represented by 3 green dollar signs)

2030: 94 (represented by 94 red dollar signs) vs 3 (represented by 3 green dollar signs)

- Natural resources support businesses, communities and economies but are rarely accounted for in company balance sheets or GDP calculations
- Emissions of greenhouse gases, especially toxic ground-level ozone and acid rain, are causing significant losses to biodiversity, much of which will add invisible costs to businesses and economies around the world
- Countries with the richest ecosystems will suffer these effects the most
- Reducing emissions of sulphur and sources of ozone as a priority in the energy, transport and agricultural sectors forms the basis of any plan for stemming these losses



Economic Cost (2010 PPP non-discounted)
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Losses per 1,000 USD of GDP
 = Millions of USD (2010 PPP non-discounted)
 Change in relation to overall global population and/or GDP

= Millions of USD (2010 PPP non-discounted)

Global biodiversity is undergoing a period of phenomenal decline across all major land-based and aquatic ecosystems (WWF, 2012). Measured in economic terms the costs of decline in global biodiversity have been estimated at close to seven trillion dollars today, or around 10% of global GDP (UNEP, 2010). This represents the impact of the sum of human activities and changes made to the environment. Carbon economy and GHG emissions that could be eliminated through targeted mitigation efforts are estimated to contribute a modest share of these costs. The effects of climate change further affect biodiversity independently from the direct effects of pollution. Solving climate change will not resolve the biodiversity crisis facing the planet but it will significantly help.

purification, heat regulation, drought stabilization or numerous other values (Mace et al. in Hassan et al. (eds.), 2005). Businesses and communities operating in eco-service abundant areas ultimately reap the benefits through lower operating costs or higher productivity (Costanza et al., 1997; Bayon and Jenkins, 2010). Industrial or transport-related emissions, such as high-sulphur-content acid rain and ground-level ozone, are toxic for plants and have a negative effect on primary productivity, affecting plant growth and health. That negative effect is transferred to the whole ecosystem and damages the abundance and quality of ecosystem services generated. Communities, businesses and economies ultimately suffer these losses through reduced prosperity and returns to investors (UNEP, 2010).

Around 20 countries are acutely vulnerable to these effects, all tropical developing countries with highly abundant ecosystems in Africa, Latin America and Southeast Asia. The impacts will undermine development, especially since lowest income groups are more dependent on ecosystem services, such as water treatment, pollination and pest control. The greatest overall effects, however, are suffered by the world's most powerful economies: the US, China, Russia and Brazil, each with losses numbering in the tens of billions of dollars. The US is estimated to already suffer 80 billion dollars' worth of lost biodiversity potential in the year 2010.

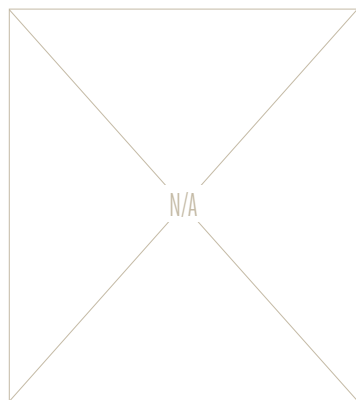
HAZARD MECHANISM

Biodiversity comprises the totality of all genes, species, and ecosystems. When healthy, ecosystems provide so-called ecosystem services to economic systems in abundance: including water catchment, pest control, pollination, air

IMPACTS

The global impact of GHG emissions on biodiversity is causing large-scale and widespread losses, estimated at over 290 billion dollars for 2010. As the carbon economy is expected to expand over the next 20 years, these losses will climb to 1.7 trillion dollars by 2030, doubling in scale in proportion to GDP.

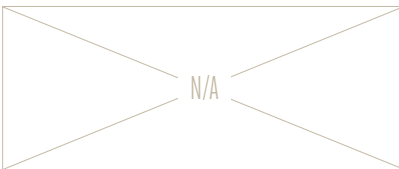
BIGGER PICTURE



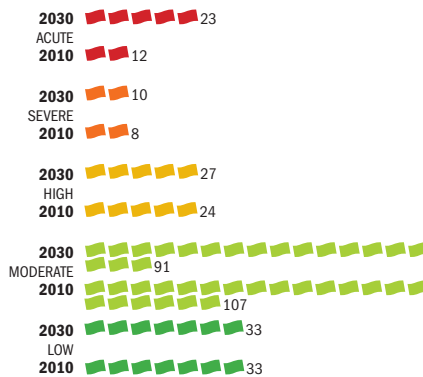
SURGE



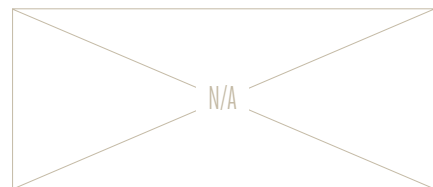
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Costanza, 2006; Hooper, 2012; Reilly, 2008
 BASE DATA: OECD, 2012; Reilly, 2008

= 5 countries (rounded)



THE INDICATOR

The indicator measures losses in biodiversity richness resulting from ground-level ozone toxicity and acid rain and their effect on net primary productivity (Reilly, 2007; Hooper et al., 2012). The change is mapped on the basis of vegetation distribution and translated into losses in ecosystem services value per hectare per year (Costanza et al., 2007). While emissions intensities and projections are fairly reliable, the indicator is very sensitive to changes in the relationship between acid rain and ozone and their effects on primary productivity. Vegetation changes introduce further uncertainty (Ruesch and Gibbs, 2008). Overall however, the large difference between countries currently rich in biodiversity – those countries with the most at stake – and those with comparatively little, is a principal factor in determining vulnerability.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$	
	2010	2030
ACUTE		
Angola	4,500	30,000
Belize	150	1,000
Bolivia	4,000	30,000
Botswana	600	4,000
Brunei	700	5,500
Cameroon	1,250	7,750
Central African Republic	400	2,500
Congo	1,250	7,250
DR Congo	1,000	6,500
Equatorial Guinea	1,250	7,250
Gabon	5,250	35,000
Guinea	300	2,000
Guinea-Bissau	55	350
Guyana	2,250	15,000
Laos	350	3,750
Liberia	55	350
Nicaragua	400	3,000
Papua New Guinea	1,500	15,000
Paraguay	1,500	10,000
Peru	7,250	55,000
Suriname	1,250	9,000
Timor-Leste	150	1,500
Zambia	600	3,750
SEVERE		
Argentina	9,000	70,000
Bhutan	55	450
Brazil	35,000	300,000
Cote d'Ivoire	700	4,500
Madagascar	250	1,750
Malaysia	7,750	60,000
Mongolia	150	1,750

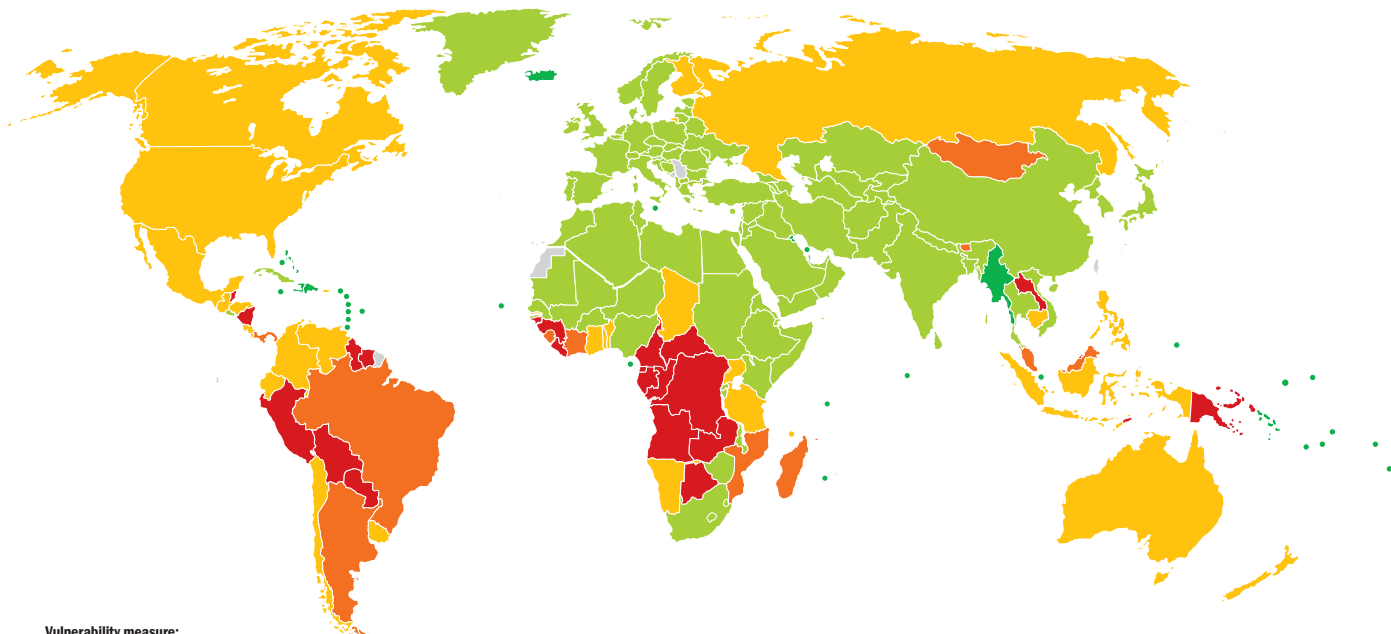
COUNTRY	\$	
	2010	2030
Mozambique	450	2,750
Panama	700	5,250
Sierra Leone	85	550
HIGH		
Australia	8,500	25,000
Benin	150	950
Cambodia	300	3,500
Canada	10,000	30,000
Chad	100	650
Chile	1,750	15,000
Colombia	5,500	40,000
Comoros	5	25
Costa Rica	250	2,000
Ecuador	1,000	8,000
Finland	850	2,500
Gambia	20	100
Ghana	600	4,000
Guatemala	350	2,750
Honduras	400	3,250
Indonesia	10,000	90,000
Mexico	8,000	60,000
Namibia	150	1,000
New Zealand	1,000	3,000
Philippines	1,750	15,000
Russia	15,000	100,000
Tanzania	500	3,000
Togo	45	300
Uganda	200	1,500
United States	80,000	250,000
Uruguay	200	1,500
Venezuela	4,000	30,000

COUNTRY	\$	
	2010	2030
MODERATE		
Afghanistan	10	65
Albania	30	200
Algeria	60	450
Armenia	15	85
Austria	250	800
Azerbaijan	45	300
Bangladesh	55	400
Belarus	250	1,750
Belgium	55	150
Bosnia and Herzegovina	50	350
Bulgaria	150	1,000
Burkina Faso	15	90
Burundi	1	10
China	20,000	200,000
Croatia	70	500
Cuba	250	1,750
Cyprus	5	15
Czech Republic	100	800
Denmark	55	150
Djibouti		1
Egypt	10	80
El Salvador	200	1,250
Eritrea	1	5
Estonia	35	250
Ethiopia	95	650
France	950	3,000
Georgia	65	450
Germany	750	2,250
Greece	350	1,000
Hungary	95	650
India	2,750	20,000



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Iran	550	4,250	Romania	200	1,500	Barbados		
Iraq	10	85	Rwanda	1	15	Cape Verde		
Ireland	100	350	Saudi Arabia	35	250	Dominica		
Israel	10	70	Senegal	60	400	Dominican Republic		
Italy	550	1,750	Slovakia	100	750	Fiji		
Japan	5,250	15,000	Slovenia	50	350	Grenada		
Jordan	1	5	Somalia	10	50	Haiti		
Kazakhstan	350	2,250	South Africa	1,500	9,000	Iceland		
Kenya	100	650	South Korea	350	2,750	Jamaica		
Kyrgyzstan	25	150	Spain	1,250	3,500	Kiribati		
Latvia	40	300	Sri Lanka	300	2,250	Kuwait		
Lebanon	10	70	Sudan/South Sudan	40	300	Maldives		
Lesotho	5	25	Swaziland	5	45	Malta		
Libya	15	150	Sweden	1,000	3,250	Marshall Islands		
Lithuania	65	450	Switzerland	85	250	Mauritius		
Luxembourg	5	15	Syria	5	50	Micronesia		
Macedonia	35	250	Tajikistan	10	70	Myanmar		
Malawi	35	250	Thailand	1,750	15,000	Palau		
Mali	30	200	Tunisia	20	150	Qatar		
Mauritania	10	55	Turkey	650	2,000	Saint Lucia		
Moldova	10	50	Turkmenistan	40	250	Saint Vincent		
Morocco	35	250	Ukraine	350	2,250	Samoa		
Nepal	150	1,000	United Arab Emirates	5	30	Sao Tome and Principe		
Netherlands	45	150	United Kingdom	350	1,000	Seychelles		
Niger	5	40	Uzbekistan	20	150	Singapore		
Nigeria	900	6,000	Vietnam	800	8,750	Solomon Islands		
North Korea	15	150	Yemen	15	100	Tonga		
Norway	450	1,250	Zimbabwe	30	200	Trinidad and Tobago		
Oman	10	70	LOW			Tuvalu		
Pakistan	100	800	Antigua and Barbuda			Vanuatu		
Poland	400	2,750	Bahamas					
Portugal	250	750	Bahrain					

CORROSION



ESTIMATES GLOBAL CARBON IMPACT

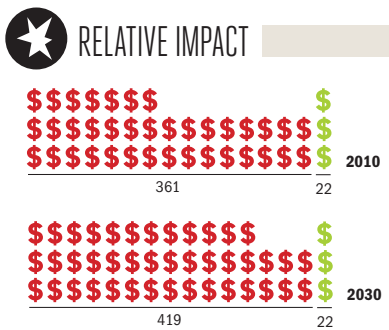
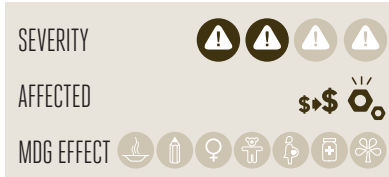
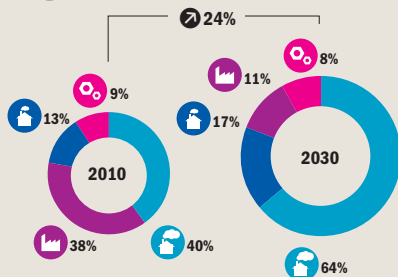
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **1 BILLION**

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **5 BILLION**

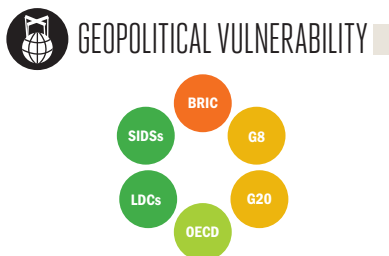
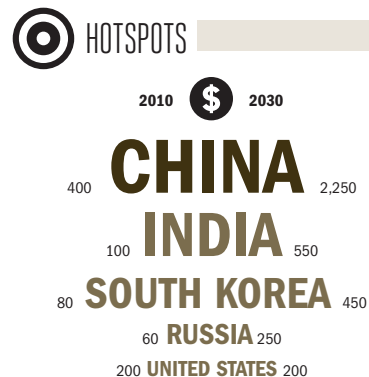
ECONOMIC IMPACT



➔ Air pollution from industrial, residential and transport emissions causes costly damage to infrastructure, vehicles and other materials

➔ The corrosion effect is most severe where industrialized or newly-industrializing countries lack controls on harmful emissions such as sulphur dioxide and that rely intensively on coal power generation, an important contributor to acid rain

➔ Affected countries can take inspiration from regulations put into effect in developed countries since the 1990s that have met with considerable success in reducing the amount of acid rain and damages to infrastructure as well as health and the environment



\$ Economic Cost (2010 PPP non-discounted)
🇧🇩 Developing Country Low Emitters **🏭** Developed
🇧🇩 Developing Country High Emitters **🏭** Other Industrialized

★ **\$** = Losses per 10 million USD of GDP
🎯 **\$** = Millions of USD (2010 PPP non-discounted)
↔ Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

Air pollution and the acid rain and smog associated with it accelerate the corrosion of materials and infrastructure, in particular metals. The impact of acid rain is visible on the green streaking of bronze monuments in major metropolitan areas of industrialized countries where it has leached at their protective patina (Bernardi et al., 2009). The US EPA estimated costs to Americans from acid-proofing the paint of automobiles at 60 million dollars a year (US EPA, 2010). In the 1970s, not one government had regulations on air pollution aimed at reducing acid rain. Since the 1990s, however, many governments have implemented regulations that have drastically reduced the environmental impact of the worst forms of acid rain and smog in North America and Europe. Those regulations have cost effectively contributed to clean air in a testament to the economic and social viability of such actions to reduce the impact of pollution (Munton et al. in Young (ed.), 1999; Burns et al., 2011). It has long been recognized that where newly industrializing and transition economies lack those same regulations, especially where coal combustion

is unrestrained, acid rain and smog present a serious challenge (Hart, 1996). These effects of pollution also create major economic concerns for many countries. The World Bank estimated that in 2003 alone corrosion of material and infrastructure due to acid rain cost southern China hundreds of millions of dollars (World Bank, 2005). Places like Nigeria are yet to show any significant impacts, although continued and unregulated industrialization in fast emerging economies can only lead to damages similar to those seen elsewhere (Okafor et al., 2009).

HAZARD MECHANISM

Air pollutants such as sulphur dioxide, nitrogen dioxide and other gases such as ozone derived from industrial, residential and transport emissions, especially coal burning, become corrosive when they dissolve in rain or otherwise come into contact with buildings, cars and other infrastructure. Ordinary water has a pH value of 7, but ordinary rain is more acidic at a pH of 5.6 because of ambient CO₂. Even in the US today, rain rendered more acidic through air pollution can lower pH values to 4.3 (US EPA, 2007). Elevated

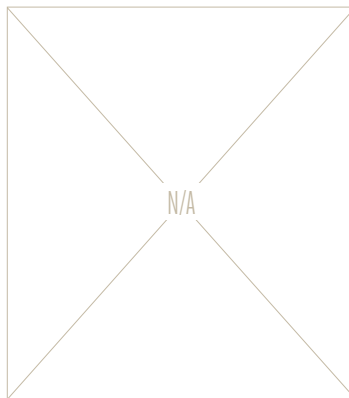
levels of sulphur dioxide and other harmful pollutants accelerate corrosion of a wide range of metals, which can cause cosmetic and structural damage (Mellanby (ed.), 1988). Corrosion rates in metals such as steel accelerate as exposure time grows and resistance falls (Lin et al., 2011b). Concrete is also vulnerable to degradation, which raises concerns for the vast new quantities of infrastructure being erected in areas with highly concentrated acid rains such as China (Shah et al., 2000; Jiangang, 2011; Hui-fang Guo et al., 2012). Historic buildings are often especially vulnerable, in particular when stones with low acidity resistance, such as limestone, have been used in construction (Camuffo, 1992). Infrastructure under ground, such as pipes, can also be damaged if acid rain affects soil pH (Ismail and El Shamy, 2009).

IMPACTS

Globally, the annual cost of damages to materials and infrastructure from acid rain corrosion is estimated to have been 1.5 billion dollars for the year 2010, with that figure expected to grow slightly as a share of GDP to 5 billion dollars a year by 2030. Elevated

The countries most severely affected include parts of East and South Asia, Eastern Europe and the Middle East, including China, India, Russia and Bangladesh. China has the largest overall losses, estimated to reach over 2 billion dollars a year by 2030. Other large-scale losses occur in India, South Korea, Russia, the US and Japan. In general, newly-industrializing and fast-emerging economies as well as transition economies, such as Bulgaria, are particularly vulnerable, while developed countries with emission regulations and lower-income countries with little industry are less affected or unaffected.

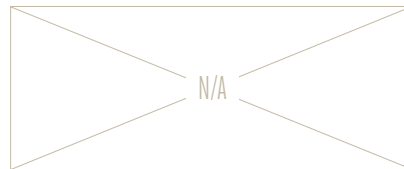
BIGGER PICTURE



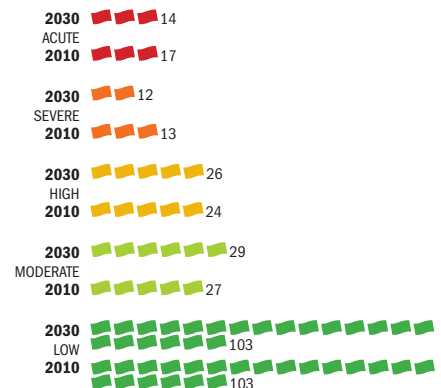
SURGE



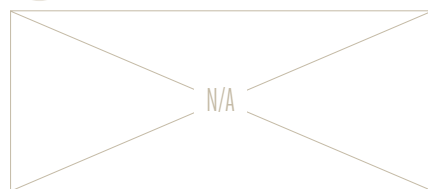
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: OECD, 2012
 BASE DATA: World Bank, 2005b

= 5 countries (rounded)



THE INDICATOR

The indicator measures the cost of the corrosive effect of acid rain on materials and infrastructure. Emissions of sulphur dioxide (SO₂) are used to determine the level of acid rain, and that level is translated into damages according to intensity on the basis of a World Bank study in China and the assumed relation of infrastructure density to population density (EDGAR, 2012; World Bank, 2005; Hoekstra et al., 2010). Emissions were projected to 2030 on the basis of regional changes estimated by the Organization for Economic Co-operation and Development (OECD, 2012). The main weaknesses of the indicator relate to the extrapolation of the damage from a study in just one country and the simplified assumptions relating to infrastructure.

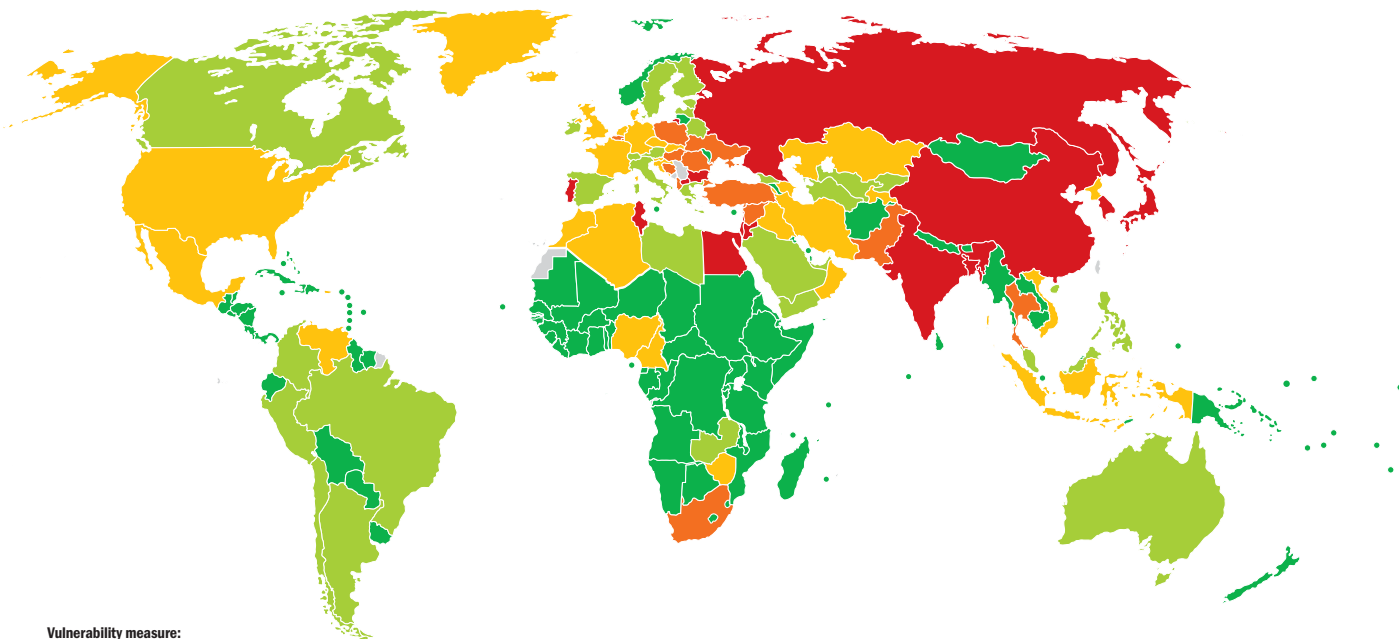
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE								
Bangladesh	5	25	Croatia	1	1	Estonia		
Bulgaria	5	10	Czech Republic	5	10	Finland		
China	400	2,250	Denmark	1	1	Georgia		
Egypt	15	80	France	20	20	Greece	1	1
India	100	550	Germany	40	40	Ireland		
Israel	15	35	Indonesia	5	30	Italy	10	10
Japan	150	150	Iran	10	40	Kyrgyzstan		
Jordan	1	10	Iraq	1	5	Latvia		
Lebanon	10	40	Kazakhstan	1	5	Libya		1
Macedonia	1	1	Mexico	15	35	Malaysia	1	5
Portugal	15	15	Morocco	1	5	Peru		
Russia	60	250	Netherlands	5	5	Philippines	1	5
South Korea	80	450	Nigeria	1	5	Saudi Arabia	1	10
Tunisia	1	10	North Korea		1	Spain	5	5
			Oman		1	Sweden	1	1
SEVERE			Slovakia	1	5	Switzerland		
Albania	1	1	Slovenia	1	1	Turkmenistan		
Belgium	15	15	Tajikistan			United Arab Emirates		1
Bosnia and Herzegovina	1	1	United Kingdom	40	45	Uzbekistan	1	1
Hungary	5	15	United States	200	200	Yemen		1
Pakistan	10	40	Venezuela	1	10	Zambia		
Poland	20	50	Vietnam	1	20			
Romania	5	15	Zimbabwe			LOW		
South Africa	10	35				Afghanistan		
Syria	1	10	MODERATE			Angola		
Thailand	10	45	Argentina		1	Antigua and Barbuda		
Turkey	10	20	Australia	1	1	Armenia		
Ukraine	5	20	Austria	1	1	Bahamas		
HIGH			Belarus	1	1	Bahrain		
Algeria	1	5	Brazil	5	15	Barbados		
Azerbaijan	1	1	Canada	5	5	Belize		
Cameroon	1	1	Chile	1	1	Benin		
			Colombia	1	1	Bhutan		



CARBON VULNERABILITY

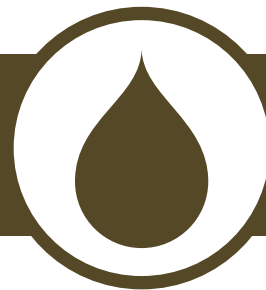
● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

\$		\$		\$				
COUNTRY	2010	2030	COUNTRY	2010	2030			
Bolivia			Guyana			Palau		
Botswana			Haiti			Panama		
Brunei			Honduras			Papua New Guinea		
Burkina Faso			Iceland			Paraguay		
Burundi			Jamaica			Qatar		
Cambodia			Kenya			Rwanda		
Cape Verde			Kiribati			Saint Lucia		
Central African Republic			Kuwait			Saint Vincent		
Chad			Laos			Samoa		
Comoros			Lesotho			Sao Tome and Principe		
Congo			Liberia			Senegal		
Costa Rica			Lithuania			Seychelles		
Cote d'Ivoire			Luxembourg			Sierra Leone		
Cuba			Madagascar			Singapore		
Cyprus			Malawi			Solomon Islands		
Djibouti			Maldives			Somalia		
Dominica			Mali			Sri Lanka		
Dominican Republic			Malta			Sudan/South Sudan		
DR Congo			Marshall Islands			Suriname		
Ecuador			Mauritania			Swaziland		
El Salvador			Mauritius			Tanzania		
Equatorial Guinea			Micronesia			Timor-Leste		
Eritrea			Moldova			Togo		
Ethiopia			Mongolia			Tonga		
Fiji			Mozambique			Trinidad and Tobago		
Gabon			Myanmar			Tuvalu		
Gambia			Namibia			Uganda		
Ghana			Nepal			Uruguay		
Grenada			New Zealand			Vanuatu		
Guatemala			Nicaragua					
Guinea			Niger					
Guinea-Bissau			Norway					

WATER



ESTIMATES GLOBAL CARBON IMPACT

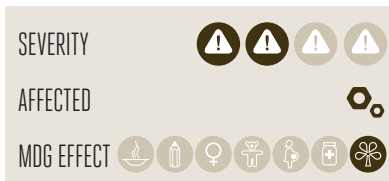
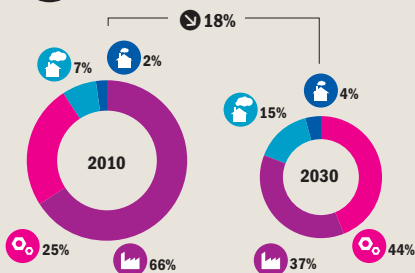
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **5** BILLION

2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **10** BILLION

ECONOMIC IMPACT



- Bodies of fresh water become acidic when continuously subjected to highly acidic rainfall as a result of air pollution from local or regional heavy industries
- Local vulnerabilities are higher where soils are more acidic and fail to reduce the acidity level of polluted rains
- Acidic water is toxic for fish, if used for irrigation it is toxic for crops, if drunk it is toxic for human health, and if used for industrial purposes, it can corrode and damage technical infrastructure
- If acidic water is not treated, the costs incurred further down the supply chain are likely to be greater and more harmful to populations and the economy

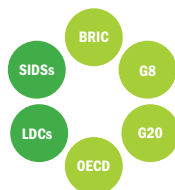
RELATIVE IMPACT



HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
 Developing Country Low Emitters (blue icon) Developed (pink icon)
 Developing Country High Emitters (light blue icon) Other Industrialized (purple icon)

★ \$ = Losses per million USD of GDP
 Change in relation to overall global population and/or GDP (arrow icon)

◎ \$ = Millions of USD (2010 PPP non-discounted)

Acid rain is a by-product of heavy industrial emissions, in particular nitrogen oxide (NOX) and sulphur dioxide (SO2). Acid rain has a variety of effects including the acidification of inland bodies of water, such as lakes and rivers. Problems resulting from acidic water include reductions in agricultural productivity, water biodiversity, human health and recreational options. (Driscoll et al., 2001; Vörösmarty et al., 2010). Water can, of course, be treated to reduce acidity, but at a cost. The level of heavy industrial emissions does not directly correspond to the highest levels of vulnerability because of the complex role that soil chemistry plays in attenuating or exacerbating the impact of acid rain. Soils that have been subjected to heavy emissions for long periods of time have their capacity to buffer acid rain depleted and allow more acidity to accumulate in bodies of water (Jeziorski et al., 2008). This explains why industrialized nations from Russia through western Europe to North America are particularly vulnerable to acid rain, while for the time being China, whose concentrations of acid rain are the world's highest, is still

relatively resilient to its impact (OECD, 2012). China's buffering capacity has also been enhanced in the north of the country by natural alkaline dust blown in from the deserts (Larsen et al., 2006). Other recently industrialized countries like Thailand have been less fortunate and suffer more severe effects. The impact of air-borne pollution on water resources is widespread and understood to inflict significant damage for a wide-ranging group of economies across Africa, Asia and Europe in particular.

HAZARD MECHANISM

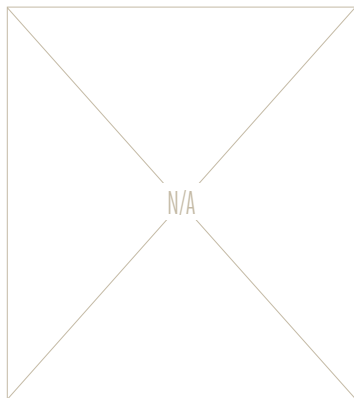
Practically everywhere where dense heavy industry is found today there are significant local sources of highly acidic aerosols, such as sulphur and nitrogen dioxide. A share of these aerosols finds its way to ground level within a certain proximity to the source of emissions (Mehta, 2010). Acidic emission debris is distributed either through acid rain or as dry deposits, where, if the supply is continuous, it accumulates and can render entire bodies of water highly acidic: in some northern and eastern areas of the US, the EPA gauged through a survey in the 1980s that 4.2% of all lakes and 2.7% of streams

were acidic (Stoddard et al., 2003). Acidic water has measurable impacts on organisms, and at a certain level becomes lethal to most fish species (Ikuta et al., 2008). Acidic water is also toxic for human consumption in many cases, because it increases the rate at which heavy metals dissolve, among other concerns (Kumar, 2012). Plants, and hence agricultural production, also suffer losses as a result of sustained exposure to high levels of acidity (World Bank, 2005). Therefore, acidic water must be treated, or else risk incurring higher costs than that of treatment. Vulnerability to acid contamination of water varies considerably worldwide in accordance with the natural ability of land to neutralize acidity. The chemical composition and absorptive potential of the soil in particular determines the rate at which acidity shocks can be diffused (Stoddard et al., 2003). Industrialized countries are seriously exposed since buffering capacity has been depleted by more than a century of harmful emissions: China, India and South Africa generally have a high soil neutralizing capacity, whereas the eastern US, western Europe and Russia all have high vulnerability to acid contamination (Vörösmarty et al., 2010).

IMPACTS

The global impact of acid rain due to industrial processes on water resources is estimated at a modest five billion dollars in 2010. It is assumed these effects will double by 2030 but remain stable as a share of GDP with losses of ten billion dollars a year. Around 20 countries are considered acutely vulnerable to the impact of acid rain on water resources, in particular in Africa, Eastern Europe and South-East Asia. The largest share of the impact is estimated to concern Eastern European countries like Belarus and Poland, each of which experienced upwards of 200 million dollars of losses in 2010. The greatest total losses concern the US, with over 1.5 billion dollars of losses per year in 2010. Given the lower levels of emissions among lower-income and least developed countries, many of these are not affected to the same degree as industrialized and major emerging economies, so the effect is not considered a major impediment to poverty reduction efforts.

BIGGER PICTURE



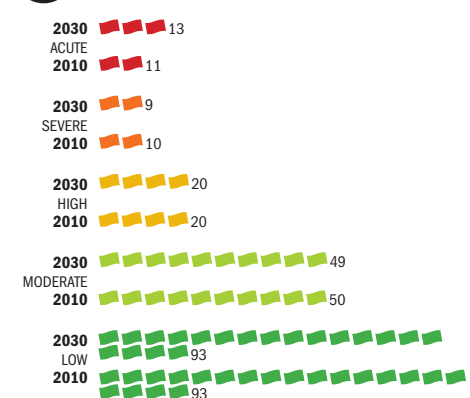
SURGE



OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: OECD, 2012
 BASE DATA: Vörösmarty et al., 2010

➡ = 5 countries (rounded)



THE INDICATOR

The indicator measures the impact of acid rain on water. It assesses the extent to which emissions linked to acid rain would be likely to affect ground-level acidity of water bodies, and then calculates the cost of treating the acidified water for the anticipated demand of communities affected (OECD, 2012; Vörösmarty et al., 2010). The indicator assumes a minimal cost basis since untreated water in populated and/or agriculturally productive areas mapped for the purpose would be likely to have greater negative effects than the cost of water treatment (Hoekstra et al., 2010; Portmann et al., 2010). A weakness of the indicator is not factoring in possible changes in soil acid buffering capacity of such rapidly emerging economies like China, which may result in underestimation of 2030 impacts.

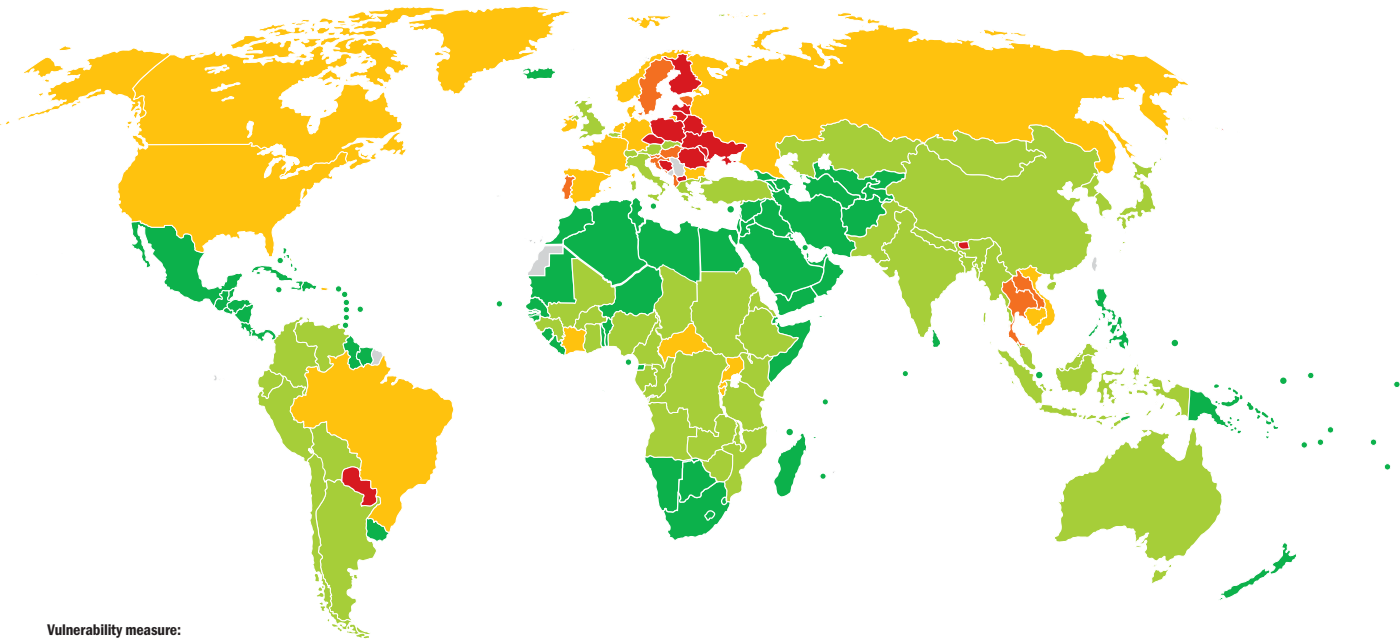
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		🌐		COUNTRY	\$		🌐		COUNTRY	\$		🌐	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
ACUTE					ACUTE					ACUTE				
Belarus	300	1,250	7,500	10,000	Denmark	30	35	1,000	900	Gabon				1
Bhutan	1	5	45	60	France	150	200	4,750	4,250	Ghana	1	5	250	350
Bosnia and Herzegovina	5	25	300	400	Germany	350	450	10,000	8,750	Greece	10	15	350	300
Czech Republic	90	250	2,250	2,000	Ireland	15	20	400	350	Guinea			25	35
Finland	50	65	1,750	1,500	Luxembourg	5	5	65	55	India	30	150	3,250	3,750
Latvia	25	100	1,000	1,500	Netherlands	40	50	950	850	Indonesia	1	5	250	250
Lithuania	65	300	2,250	3,000	Norway	15	20	450	400	Italy	1	1	80	70
Macedonia	10	45	350	500	Russia	100	500	4,500	5,250	Japan	10	10	300	250
Moldova	10	40	1,250	1,750	Rwanda	1	1	200	250	Kazakhstan	1	5	55	75
Paraguay	5	30	500	700	Spain	90	100	2,750	2,500	Kenya			5	5
Poland	200	650	6,500	5,750	Uganda	1	10	750	1,000	Malawi		1	80	100
Romania	75	350	3,500	5,000	United States	1,500	2,250	30,000	25,000	Malaysia	1	15	95	150
Ukraine	100	600	7,250	10,000	Vietnam	20	150	2,000	3,000	Mali			5	5
SEVERE					MODERATE					Mongolia				
Albania	1	15	150	250	Angola	1	5	150	200	Mozambique			15	20
Croatia	10	60	450	650	Argentina				1	Myanmar	1	5	200	300
Estonia	5	15	200	200	Australia	10	10	250	200	Nepal			10	15
Hungary	35	100	1,250	1,000	Austria	15	15	300	250	Nigeria	1	1	90	100
Laos	1	15	250	350	Bangladesh	1	10	400	550	North Korea			1	20
Portugal	50	65	1,750	1,500	Belgium	10	10	250	200	Pakistan	1	15	350	500
Slovenia	10	25	250	200	Bolivia	1	5	55	75	Peru	1	10	80	100
Sweden	60	80	1,750	1,500	Burkina Faso				5	Slovakia	5	15	150	100
Thailand	85	450	4,750	6,750	Cameroon	1	5	200	300	South Korea	30	150	650	850
HIGH					Chad			1	30	Sudan/South Sudan	1	1	100	150
Brazil	90	400	6,750	7,750	Chile					Switzerland	1	1	30	25
Bulgaria	5	20	150	200	China	45	300	3,250	3,750	Tanzania	1	5	350	450
Burundi		1	200	250	Colombia	1	5	70	100	Turkey	5	5	150	250
Cambodia	1	10	250	350	Congo	1	1	80	100	United Kingdom	95	100	2,500	2,000
Canada	150	200	4,250	3,500	DR Congo	1	5	1,000	1,500	Venezuela	5	35	400	550
Central African Republic		1	150	200	Ecuador			1	10	Zambia			20	30
Cote d'Ivoire	1	10	600	800	Eritrea				10	Zimbabwe			10	10
					Ethiopia			1	30					



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		⊕		COUNTRY	\$		⊕		COUNTRY	\$		⊕	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030	2010	2030
LOW														
Afghanistan					Honduras					Qatar				
Algeria					Iceland					Saint Lucia				
Antigua and Barbuda					Iran					Saint Vincent				
Armenia					Iraq					Samoa				
Azerbaijan					Israel					Sao Tome and Principe				
Bahamas					Jamaica					Saudi Arabia				
Bahrain					Jordan					Senegal				
Barbados					Kiribati					Seychelles				
Belize					Kuwait					Sierra Leone				
Benin					Kyrgyzstan					Sierra Leone				
Botswana					Lebanon					Singapore				
Brunei					Lesotho					Solomon Islands				
Cape Verde					Liberia					Somalia				
Comoros					Libya					South Africa				
Costa Rica					Madagascar					Sri Lanka				
Cuba					Maldives					Suriname				
Cyprus					Malta					Swaziland				
Djibouti					Marshall Islands					Syria				
Dominica					Mauritania					Tajikistan				
Dominican Republic					Mauritius					Timor-Leste				
Egypt					Mexico					Togo				
El Salvador					Micronesia					Tonga				
Equatorial Guinea					Morocco					Trinidad and Tobago				
Fiji					Namibia					Tunisia				
Gambia					New Zealand					Turkmenistan				
Georgia					Nicaragua					Tuvalu				
Grenada					Niger					United Arab Emirates				
Guatemala					Oman					Uruguay				
Guinea-Bissau					Palau					Uzbekistan				
Guyana					Panama					Vanuatu				
Haiti					Papua New Guinea					Yemen				
					Philippines									

COSTS

2010
172 BILLION
2030
630 BILLION

HEALTH
IMPACT



AIR POLLUTION



INDOOR SMOKE



OCCUPATIONAL HAZARDS



SKIN CANCER

↓ 1.4 MILLION
2.1 MILLION

2010
2030 

  
▶▶

↓ 3.1 MILLION
3.1 MILLION

2010
2030 

      
◀

↓ 55,000
80,000

2010
2030 

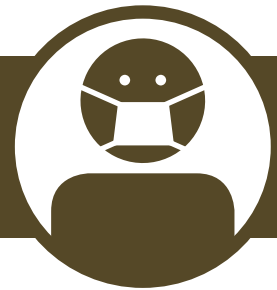

▶

↓ 20,000
45,000

2010
2030 


▶

AIR POLLUTION



ESTIMATES GLOBAL CARBON IMPACT



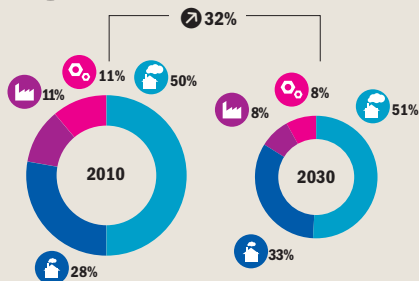
2010 EFFECT TODAY

DEATHS PER YEAR **1.4 MILLION**

2030 EFFECT TOMORROW

DEATHS PER YEAR **2.1 MILLION**

MORTALITY IMPACT

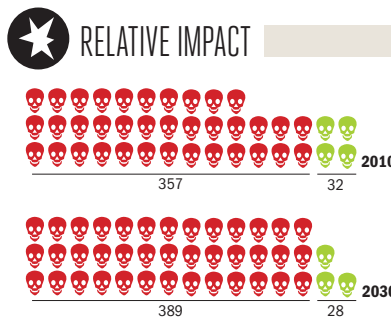


CONFIDENCE ROBUST

SEVERITY

AFFECTED

MDG EFFECT



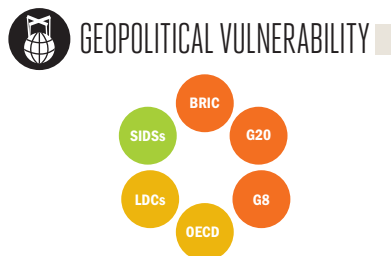
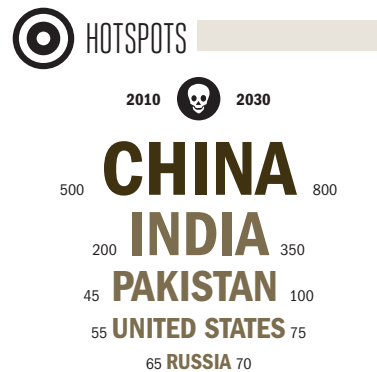
➤ Cities are home to over half the world's population and growing, all concentrated on only 2% of its surface area, producing 80% of all GHG emissions

➤ Where there are no strict emission controls, air contaminants from industry and transportation may become toxic and lethal

➤ Air pollution is a leading cause of death globally, triggering cancer, heart disease, acute respiratory illnesses, and common asthma

➤ Technology and government regulation play a major role in making the air safer

➤ However, access to technology and capacity to implement regulation are lowest in parts of the developing world where air pollution is highest



Deaths
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Deaths per million
 Change in relation to overall global population and/or GDP

Billion of USD (2010 PPP non-discounted)

Preventing or reducing air contamination relies on a community's or region's determination to ensure safety and health. Technology, such as particle filters for vehicles, high quality refined fuels, and regulations on clean air are the main tools for limiting toxic emissions. Air pollution and its negative effects for health can and have been brought under control through these means in major economies of the world (Khan and Swartz, 2007). Although many developing countries have struggled to implement emission standards, they remain locked out of technological solutions for access, capacity, and financial reasons. However, some evidence for alternative regulation policies through incentives rather than penalties has demonstrated a potentially separate route (Blackman et al., 2010). Furthermore, low-tech responses, such as increasing urban tree cover, have also been proven to yield dividends for clean air (Nowak et al., 2006).

HAZARD MECHANISM

Air pollution is caused when fossil or biomass fuels are burnt, often

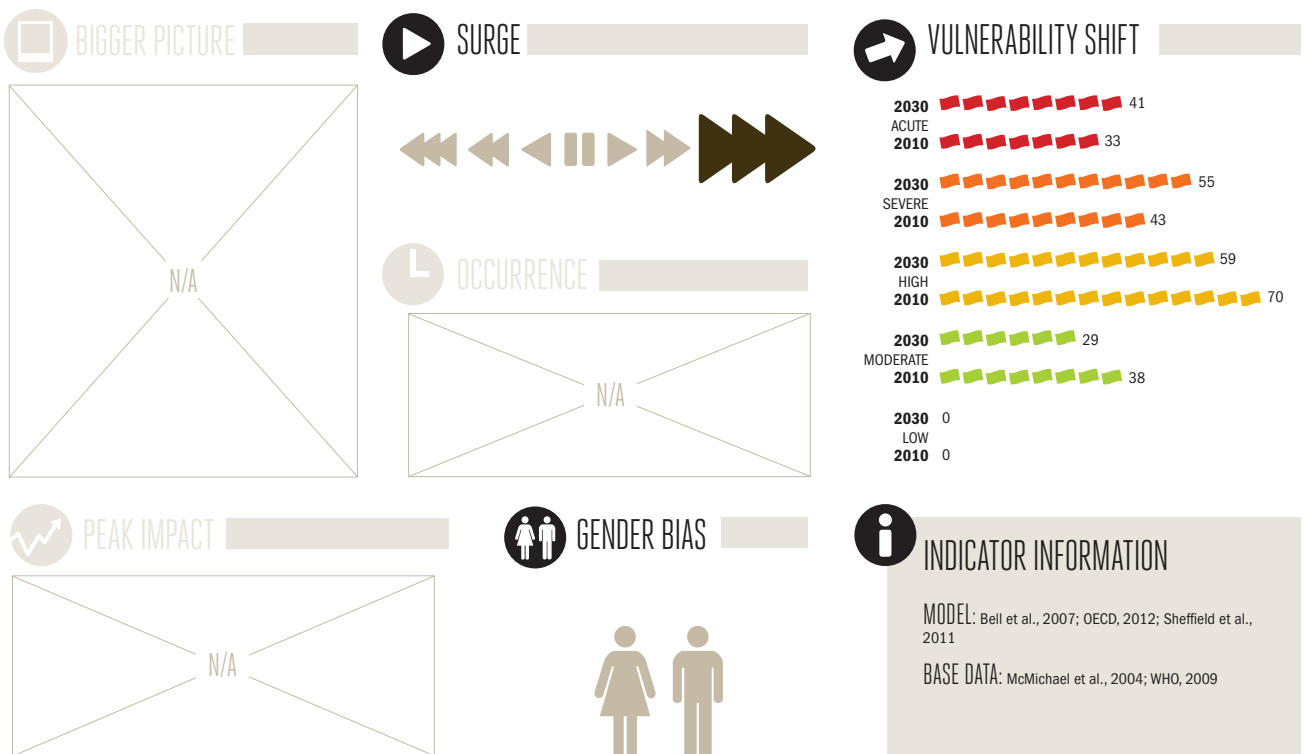
incompletely, by vehicles, in industrial settings, or through residential heating and cooking (Barman et al., 2010). These emissions contaminate the local environment at ground level, resulting in illness, which is dependent on the length of exposure to pollutants and the dose received (Hewitt and Jackson eds., 2009). Fine particles suspended in the air through these processes are small enough to be inhaled and represent a primary hazard. Research consistently shows a high rate of disease resulting from prolonged exposure to elevated levels of ambient air pollution, in particular due to heart disease, lung cancer, and respiratory illnesses, but also asthma and other illnesses such as allergies (World Health Organization (WHO), 2004; Cohen et al., 2005; Chen et al., 2008; Brook et al., 2010; Bell et al., 2007; Sheffield et al., 2011; D'Amato, 2011). Reducing particulate concentrations in areas of high pollution by around half can cut mortality by 15% (WHO, 2006). Experts have calculated that half a year of life is added for every 10 micrograms (μg) fewer fine particulates (PM_{2.5}) per cubic meter of ambient air, or a 1-2% increase in mortality rates for several major diseases per $10\mu\text{g}/\text{m}^3$ more particulates (Pope et al.,

2009; Zanobetti and Schwartz, 2009). Currently, the global average of fine particle pollution is $20\mu\text{g}/\text{m}^3$ (PM_{2.5}). China's major industrial zones have the world's highest concentrations, at over $100\mu\text{g}$ (PM_{2.5}). More than half the population of East Asia currently exceeds the World Health Organization's $35\mu\text{g}$ (PM_{2.5}) uppermost safety limit (WHO, 2006). By comparison, recommended levels are below $10\mu\text{g}$, a full order of magnitude under China's lethal concentrations (Donkelaar et al., 2010). Urban residents of industrial centres in developing economies face the highest and fastest growing risks (Campbell-Lendrum and Corvalán, 2007).

IMPACTS

Air pollution is estimated to kill 1.4 million people a year today in industrial and fast-emerging economies. That impact is expected to exceed 2.1 million deaths per year in 2030. Even as global population increases steadily over the next 20 years, deaths caused by air pollution are expected to grow as a share of population since the carbon intensive growth and urbanization, particularly of developing countries, exposes wider populations to toxic air environments (Hewitt and Jackson eds., 2009).

The most severe impacts are seen in former Soviet Union countries, such as Russia and the Ukraine, where heavy industrial emissions from the early 1990s, 1980s and earlier still contribute to high incidences of cancer, cardiopulmonary and respiratory illnesses. However, major emerging economies, especially China, Iran, and Pakistan have very similar and acute levels of vulnerability. Certain developed countries, such as Singapore and Greece, are highly vulnerable because they have important contemporary concentrations of small air particulates. Other advanced economies that have drastically cut pollutant levels, such as the UK or Latvia, also still experience an elevated disease burden from earlier periods of intense pollution. In terms of total impacts, China is estimated to account for nearly 800,000 deaths due to air pollution by 2030, with India half that level at around 350,000 deaths. Pakistan, the US and Russia would each suffer 70-100,000 deaths by 2030. Children are particularly vulnerable in particular to mortality resulting from acute respiratory illnesses worsened by high levels of particulate exposure, as well as other sicknesses (WHO, 2004; Nordling et al., 2008; Charpin et al., 2009).



→ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

Effects are widely felt, with over one hundred countries experiencing heightened impacts. But a large number of countries are also relatively unaffected, paradoxically as a result of either very low or very high development, which either rules out industrialization or facilitates tight constraints on emissions, respectively. Given the short time frame of the Monitor's analysis (to 2030) and the way in which the assessment is calculated, it is possible that impacts are underestimated for such newly industrializing countries as Bangladesh or Thailand, where mortality may not show up in national health data for five to ten years, or later, after the explosion of pollution effects.



THE INDICATOR

The impact of air pollution is measured for four different diseases: acute respiratory illnesses, cardiopulmonary disease, lung cancer, and asthma. Regionally differentiated attributable risk factors from the WHO are relied upon for the first three diseases and an independent study for the asthma-related impact (WHO, 2004 and 2009; Bell et al., 2007). The Organization for Economic Co-operation and Development was referred to for projections of emissions and evolving impact, with mortality data from the WHO adjusted for 2030 in relation to expected economic development (OECD, 2012; Mathers and Loncar, 2005). The indicator is considered robust, due to the high quality of global analysis provided by the World Health Organization covering much of the impact estimated. The scientific basis for the cause-and-effect relationships involved have been rigorously studied for decades and are particularly well understood (Chen et al., 2008).

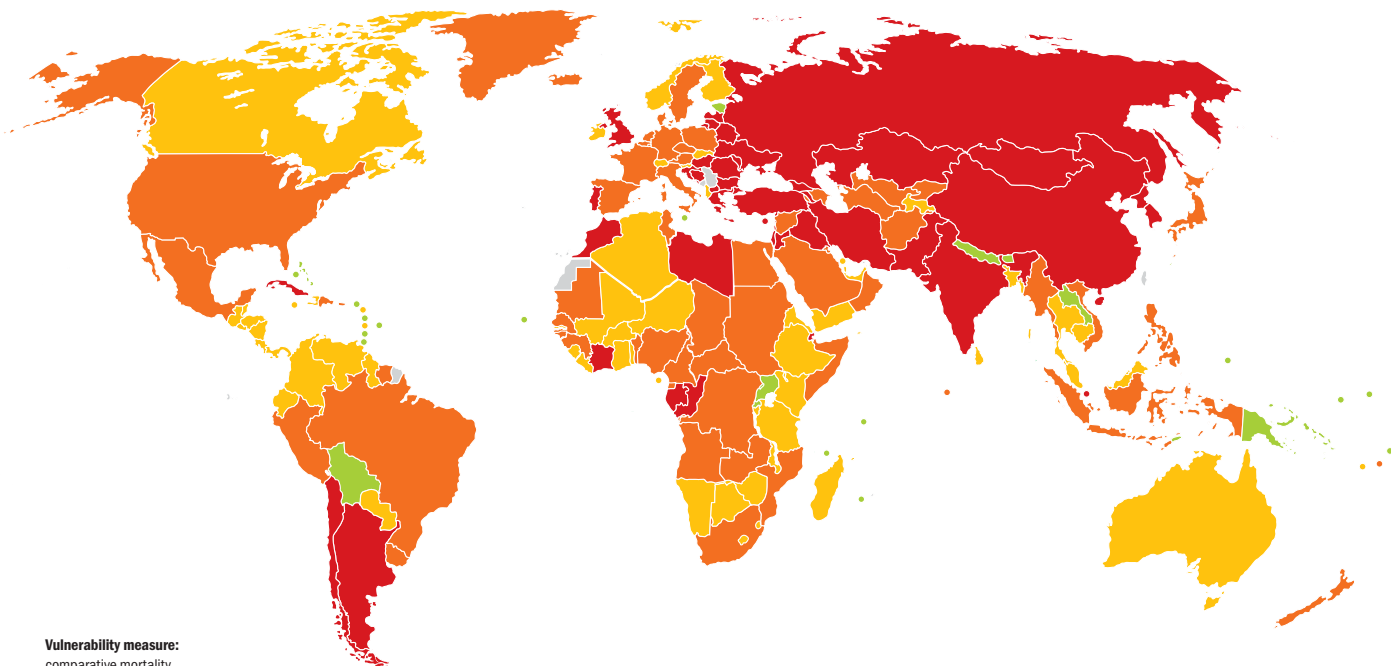
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	ACUTE		SEVERE		COUNTRY	ACUTE		SEVERE	
	2010	2030	2010	2030		2010	2030	2010	2030
ACUTE									
Argentina	9,500	10,000	100,000	150,000	North Korea	6,000	7,000	85,000	150,000
Armenia	2,000	2,000	20,000	30,000	Pakistan	45,000	100,000	400,000	1,000,000
Belarus	3,500	3,500	60,000	100,000	Portugal	3,000	3,000	40,000	50,000
Bosnia and Herzegovina	2,000	2,000	20,000	30,000	Romania	7,500	8,000	70,000	80,000
Bulgaria	4,000	4,000	35,000	35,000	Russia	65,000	70,000	900,000	1,000,000
Chile	3,500	4,500	35,000	55,000	Singapore	1,500	2,500	20,000	45,000
China	500,000	800,000	4,500,000	8,000,000	South Korea	10,000	15,000	300,000	600,000
Congo	1,000	2,000	15,000	40,000	Turkey	25,000	35,000	300,000	450,000
Cote d'Ivoire	3,500	5,500	60,000	150,000	Ukraine	30,000	30,000	300,000	350,000
Croatia	1,000	1,500	15,000	15,000	United Kingdom	15,000	15,000	200,000	350,000
Cuba	3,000	3,500	30,000	45,000	SEVERE				
Cyprus	300	350	5,000	8,500	Afghanistan				
Djibouti	300	400	3,000	5,500					
Gabon	350	600	6,500	15,000					
Georgia	2,000	2,000	25,000	35,000					
Greece	3,500	4,000	40,000	45,000					
Hungary	2,000	2,500	25,000	30,000					
India	200,000	350,000	2,000,000	6,000,000					
Iran	20,000	40,000	250,000	800,000					
Iraq	7,500	10,000	70,000	150,000					
Israel	2,000	3,000	25,000	45,000					
Jordan	1,500	2,000	15,000	30,000					
Kazakhstan	6,500	8,000	85,000	150,000					
Latvia	1,000	1,000	10,000	15,000					
Lebanon	1,000	1,500	15,000	20,000					
Libya	2,500	3,500	25,000	45,000					
Lithuania	700	750	8,000	10,000					
Macedonia	600	700	7,500	10,000					
Moldova	1,500	1,500	10,000	15,000					
Mongolia	600	750	4,500	6,000					
Morocco	6,500	9,000	65,000	100,000					



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative mortality
as a share of population
(national)

COUNTRY	2010		2030		COUNTRY	2010		2030		COUNTRY	2010		2030	
	2010	2030	2010	2030		2010	2030	2010	2030		2010	2030		
HIGH														
Albania	250	350	9,500	20,000	Lesotho	150	200	5,500	20,000					
Algeria	2,000	3,000	65,000	200,000	Liberia	350	750	8,000	25,000					
Australia	1,500	2,000	45,000	95,000	Madagascar	1,000	2,000	20,000	65,000					
Bahrain	75	100	1,500	3,000	Malawi	1,000	2,000	20,000	60,000					
Bangladesh	9,500	20,000	200,000	700,000	Malaysia	2,000	4,500	35,000	100,000					
Belize	15	15	200	400	Mali	800	1,500	15,000	45,000					
Botswana	150	250	5,000	15,000	Namibia	150	250	5,500	20,000					
Brunei	15	35	500	1,500	Nicaragua	300	450	4,000	10,000					
Burkina Faso	1,000	2,000	20,000	60,000	Niger	650	1,500	10,000	35,000					
Burundi	350	700	15,000	60,000	Norway	500	600	15,000	25,000					
Cambodia	650	1,500	25,000	100,000	Panama	200	250	3,000	5,000					
Canada	2,500	3,000	45,000	80,000	Paraguay	300	500	4,500	9,000					
Colombia	5,000	7,000	55,000	90,000	Qatar	100	150	1,500	2,000					
Costa Rica	250	300	3,000	5,000	Saint Vincent	10	10	100	200					
Dominica	5	10	150	350	Sao Tome and Principe	15	30	350	1,000					
Ecuador	850	1,000	9,500	15,000	Sierra Leone	550	950	8,500	25,000					
El Salvador	450	600	8,500	20,000	Slovakia	500	550	6,000	7,500					
Eritrea	250	500	7,000	25,000	Slovenia	200	250	3,000	4,000					
Ethiopia	3,500	6,500	100,000	400,000	Sri Lanka	900	2,000	65,000	250,000					
Finland	600	700	15,000	20,000	Swaziland	50	80	5,000	20,000					
Gambia	150	250	3,500	10,000	Switzerland	850	950	15,000	25,000					
Ghana	2,000	3,500	40,000	100,000	Tajikistan	300	450	4,000	10,000					
Guatemala	600	900	10,000	25,000	Tanzania	3,500	6,000	60,000	150,000					
Guyana	85	80	1,500	2,000	Thailand	4,500	8,000	75,000	250,000					
Haiti	900	1,000	10,000	25,000	Togo	450	800	15,000	45,000					
Honduras	600	900	15,000	30,000	United Arab Emirates	600	800	8,000	10,000					
Ireland	200	250	5,500	10,000	Vanuatu	10	15	250	700					
Jamaica	300	400	4,000	7,500	Venezuela	3,000	4,500	35,000	55,000					
Kenya	2,000	3,000	40,000	100,000	Yemen	1,500	4,000	20,000	50,000					
					Zimbabwe	1,500	2,000	15,000	45,000					
MODERATE														
					Antigua and Barbuda									

INDOOR SMOKE

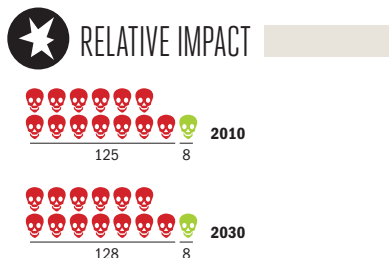
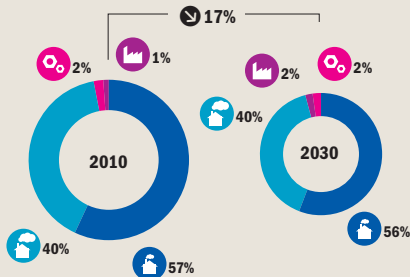


ESTIMATES GLOBAL CARBON IMPACT

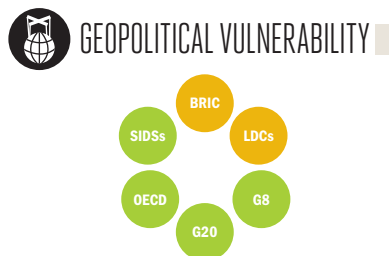
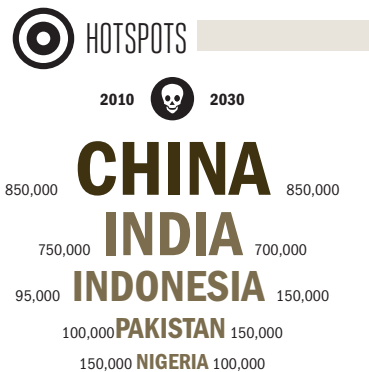
2010 EFFECT TODAY
 DEATHS PER YEAR **3.1 MILLION**

2030 EFFECT TOMORROW
 DEATHS PER YEAR **3.1 MILLION**

MORTALITY IMPACT



- The world is familiar with the fact that passive indoor tobacco smoke is a risk factor for lung cancer
- Indoor smoke from burning wood and coal for cooking and heating causes mortality on a much larger scale in developing countries
- Uneven sustainable development has locked out more than 1.3 billion people from access to electricity, so a large part of the world's population still cooks with indoor fires
- The practice means long-term exposure to toxic fumes, which can result in sickness ranging from chronic respiratory disease to lung cancer, tuberculosis and cardiovascular disease; it is a serious threat to human development



Deaths
 Developing Country Low Emitters Developed
 Developing Country High Emitters Other Industrialized

= Deaths per 100,000
 Change in relation to overall global population and/or GDP

Passive cigarette smoke indoors is well understood to be a risk factor for lung cancer among non-smokers, and governments around the world have taken significant regulatory action to combat indoor tobacco smoking for just this reason (Taylor et al., 2007; McNabola and Gill, 2009). Indoor smoke has long been identified as one of the most serious risk factors for mortality worldwide, especially among lower-income developing countries (WHO, 1997). But millions of people still die every year as a result of burning fuels like coal, wood and other biomass (crop waste, dung) in their homes for basic cooking and heating purposes (WHO, 2009). Lack of access to electricity or other forms of modern clean-burning fuels, such as kerosene or gas, force a reliance on locally available fuels like wood, which can also aggravate local deforestation (IEA, 2011; UNEP, 2005). Continued reliance on traditional burning stoves, however, is estimated to close the poverty trap tighter on more than 100 million of the world's poorest due to the comprehensive health effects. The impact is particularly severe on women, who are more likely to be

cooking on a regular basis, and for infants, who are more likely to be confined indoors when smoke exposure is highest (Amoli, 1997; Smith et al., 2000; Mishra et al., 2005).

HAZARD MECHANISM

When wood, coal or other forms of solid fuels are burned, almost all stoves commonly used in developing countries do not burn the fuel completely. This means fine particles are released into the enclosed air space and are inhaled, with damaging consequences for human lungs (Kleeman et al., 1999; Pope et al., 2002). Many houses lack ventilation or have poor ventilation, and the typical smoke released when stoves are used contains a potent and hazardous cocktail of toxins, including carbon monoxide, nitrogen and sulphur oxides, benzene, formaldehyde, butadiene and benzo(a)pyrene. Inhaling this smoke repeatedly over a number of years seriously predisposes those affected to illness and death tied to a wide range of health concerns, in particular chronic respiratory diseases (e.g. chronic obstructive pulmonary disease), lower respiratory illnesses, lung cancer and cardiovascular disease (WHO, 2004; Fullerton et al., 2008).

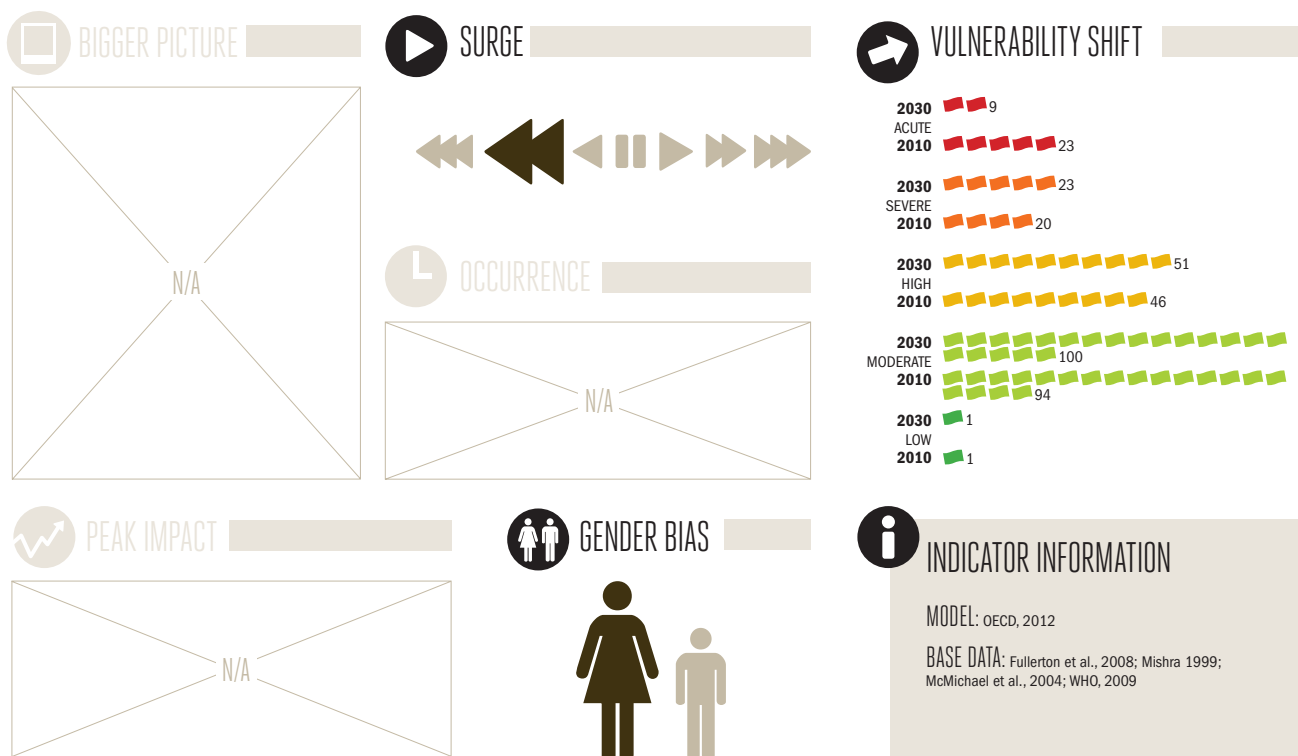
Smoke inhalation is thought to impede the body's ability to resist tuberculosis, since exposure to indoor smoke has additionally been shown to substantially increase the risk of contracting that disease (Mishra et al., 1999a). Indoor smoke exposure can also lead to partial or complete visual impairment (acquired blindness), while people suffering from complete visual impairment are more than seven times more likely to die as a result of an unintentional injury than those with non-impaired vision (Mishra et al., 1999b; Lee et al., 2003b). Other health concerns have been identified but are not covered here, such as the much higher risks of sudden antenatal death (stillbirth) shown to occur when mothers are exposed to indoor smoke (Mishra et al., 2005).

IMPACTS

The annual global impact of indoor smoke was estimated to be 3.1 million deaths for the year 2010. That figure of 3.1 million annual deaths is expected to remain stable but decline as a share of overall global population through 2030. Over 150 million people are estimated to be affected by illnesses stemming from indoor smoke every single year. The impact presents a comprehensive

challenge to human development, with low-income developing countries in particular from Africa and Asia severely affected. Most sub-Saharan African countries are assessed as acutely or severely affected. China and India have by far the largest share of mortality, with an estimated 800,000 deaths each for the year 2010 and more than 30 million people affected by illness as a result of indoor smoke in each country. Other countries with large-scale impacts include Nigeria, Ethiopia, Pakistan, Indonesia, Bangladesh, Afghanistan and DR Congo.

While the majority of developing countries are experiencing serious effects, not a single developed country has vulnerability above Moderate, with only fractional numbers of annual deaths attributed to indoor smoke.



OCCUPATIONAL HAZARDS



ESTIMATES GLOBAL CARBON IMPACT



2010 EFFECT TODAY



DEATHS PER YEAR

55,000

2030 EFFECT TOMORROW

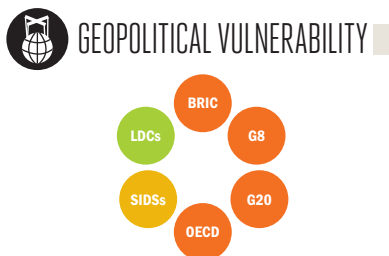
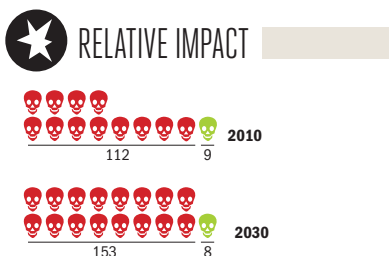
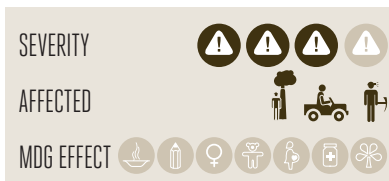
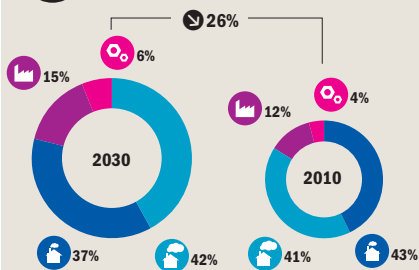


DEATHS PER YEAR

80,000



MORTALITY IMPACT



➤ A world economy relying on carbon-intensive forms of energy for 90% of its needs puts the health of millions of exposed workers at risk

➤ Hazardous professions range from coal miners facing elevated risks of stomach cancer to thermal power plant workers or truck drivers disproportionately exposed to chronic lung diseases

➤ Population level vulnerabilities are as high for developed countries as for the lowest-income developing countries

➤ Renewable and low-carbon forms of energy, such as windmills or solar panels, are significantly safer for the health and safety of industry workers and consumers alike



HOTSPOTS



Deaths
 Developing Country Low Emitters
 Developed
 Developing Country High Emitters
 Other Industrialized

= Deaths per 10 million
 Change in relation to overall global population and/or GDP

Mining accidents that kill hundreds of workers, such as the 2005 Sunjiawan mine disaster in Fuxin, China, are vivid reminders of the risks faced as the world strives to feed a growing carbon economy. Coal is set to nearly double its contribution to global energy needs over the next 20 years (US EIA, 2011). Most occupational health risks linked to the carbon economy are less attention grabbing than mining explosions but cause a much more significant human toll. While miners face the highest dangers, elevated occupational risks also apply to power generation workers in thermal plants burning coal and gas, for example, and to commercially active drivers, especially in urban settings (Burke et al., 2011). In situations where workers do not have access to adequate social protection, the risk to livelihoods and families is significant (Marriot, 2008). Carbon-intensive forms of energy exploitation are much more hazardous for human health than low-carbon or renewable alternatives (IPCC, 2012b). A carbon-neutral world economy would see virtually all of these health risks eliminated. In a transition phase, numerous measures and policy

solutions exist to reduce the hazards workers face (Driscoll et al., 2004). Companies are, however, largely not implementing the necessary measures or covering the health costs resulting from a lack of safety measures. The soundest measures would considerably increase the costs of exploiting fossil fuels, so regulations to protect workers often result in an increase in outsourcing to companies not subjected to the same requirements as firms seek to regain profitability (Giuffrida et al., 2002; Johnstone et al., 2005).

HAZARD MECHANISM

Exposure to toxic fumes, carcinogenic airborne compounds and fine particles from exhaust emissions, silica and mining dust in addition to other carbon-intensive industrial hazards causes asthma, chronic respiratory diseases and, in the case of coal miners, coal worker's pneumoconiosis (Driscoll et al., 2004; Aydin, 2010). Coal miners additionally face greatly elevated risks of lung cancer as well as stomach cancer, since toxic particles inhaled are also understood to reach the stomach (Swaen et al., 1995). Men are disproportionately affected by the sweeping health implications of these



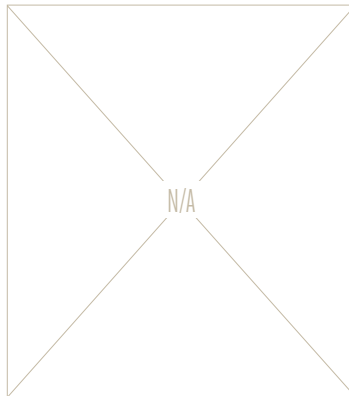
hazards since they make up the largest share of the workforce in these risk sectors (ILO, 2005).

IMPACTS

The annual global impact of carbon-intensive industries on the occupational health and safety of workers was estimated at 50,000 deaths for the year 2010, with the health of 5 million people affected. By 2030, the death toll is expected to increase to 80,000 deaths per year, with the health of 7 million people affected. Effects are widespread globally in

line with the comprehensive breadth of a carbon-intensive economy in all but the lowest-income low-emissions developing countries. Industrialized countries figure among those worst affected. China and India are estimated to have the largest total impact, each with occupational mortality in excess of 10,000 deaths per year. The health of an estimated half million people in China and nearly one million in India is negatively affected. Other countries experiencing large-scale losses include the US, Indonesia, Russia and Bangladesh.

BIGGER PICTURE



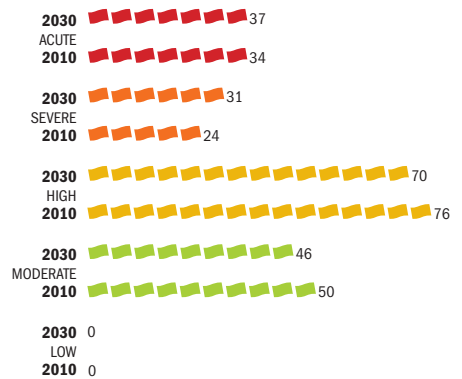
SURGE



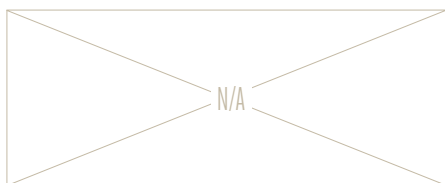
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: BP, 2012; Mathers and Loncar, 2006
 BASE DATA: Aydin, 2010; CDCP, 2012; Driscoll et al., 2004; Swaen et al., 1995; World Energy Council, 2010; WHO, 2009



THE INDICATOR

The indicator measures the impact of the carbon economy on the health and well-being of people in professions that expose them to heightened safety risks, such as in GHG emissions-intensive industries and/or sectors comprising a core link in the supply chain that fuels the carbon economy. The indicator has two main components. The first concerns occupational risks related to asthma and chronic obstructive pulmonary disease among workers in the electricity generation, transportation and mining sectors based on ILO data, with corrections to achieve broad sector accuracy (Driscoll et al., 2004; ILO LABORSTA, 2012). The second concerns occupational risks specific only to coal-mining industry workers, including coal worker's pneumoconiosis (CWP), stomach cancer and unintentional accidents (Aydin, 2010; Swaen et al., 1995; IMFR, 2012). The indicator's main limitations relate to corrections for occupational employment data from the ILO that was not designed to identify GHG-intensive industries.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	☠		👤	
	2010	2030	2010	2030
ACUTE				
Armenia	30	30	4,750	4,750
Australia	350	550	45,000	65,000
Austria	60	65	9,750	10,000
Bangladesh	1,000	2,000	150,000	200,000
Belarus	65	70	30,000	30,000
Belgium	150	150	20,000	20,000
Bulgaria	90	85	3,250	3,000
Canada	300	400	35,000	40,000
China	15,000	25,000	500,000	650,000
Colombia	300	450	20,000	20,000
Croatia	40	40	2,500	2,750
Cuba	85	100	7,750	8,750
Czech Republic	100	100	6,250	6,250
Denmark	75	75	7,750	8,000
Germany	700	750	100,000	100,000
Greece	90	90	5,750	5,750
Hungary	80	85	6,000	6,250
India	15,000	25,000	900,000	1,500,000
Indonesia	1,750	3,250	300,000	400,000
Italy	500	550	55,000	55,000
Kazakhstan	300	350	45,000	45,000
Macedonia	25	25	3,000	3,000
Malta	5	5	650	650
Mongolia	20	25	600	750
Netherlands	150	150	15,000	15,000
New Zealand	40	55	4,750	6,750
North Korea	200	300	30,000	40,000
Norway	55	55	8,500	8,500
Romania	150	150	8,250	8,250
Russia	1,500	1,500	350,000	350,000
South Africa	800	1,250	150,000	200,000

COUNTRY	☠		👤	
	2010	2030	2010	2030
SEVERE				
Spain	350	350	55,000	55,000
Sri Lanka	150	250	45,000	55,000
Sweden	65	70	10,000	10,000
Ukraine	350	350	45,000	45,000
United Kingdom	850	900	100,000	100,000
United States	3,250	4,000	300,000	400,000
BHUTAN				
Bhutan				

COUNTRY	☠		👤	
	2010	2030	2010	2030
HIGH				
Afghanistan				

SKIN CANCER



ESTIMATES GLOBAL CARBON IMPACT



2010 EFFECT TODAY

DEATHS PER YEAR

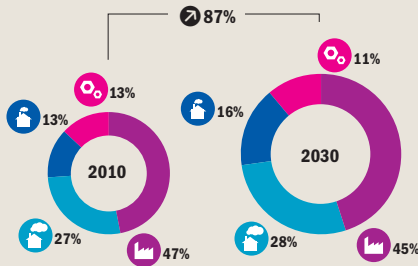
20,000

2030 EFFECT TOMORROW

DEATHS PER YEAR

45,000

MORTALITY IMPACT

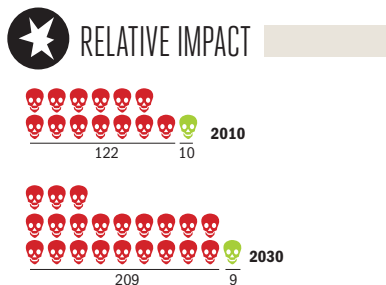


CONFIDENCE
ROBUST

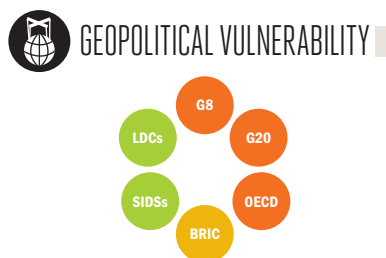
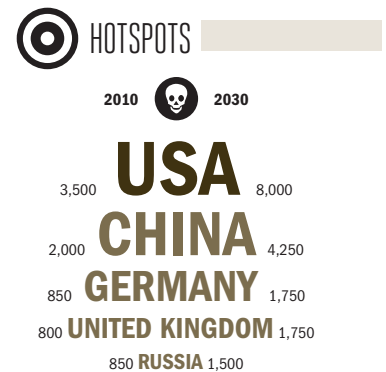
SEVERITY

AFFECTED

MDG EFFECT



- Exposure to UV rays from the sun is the principal cause of skin cancers such as melanoma
- Greenhouse gases that warm the planet are also largely responsible for depleting the Earth's upper atmosphere, allowing more UV radiation to reach ground levels
- The highly successful Montreal Protocol has phased out most ozone-depleting substances, however, so the root cause of the problem is already being addressed, with ozone depletion now set to recover
- Skin cancer rates have and will continue to increase, though, because of the lapse of time between accumulated UV exposure and the development of skin cancer



Deaths

Developing Country Low Emitters Developed

Developing Country High Emitters Other Industrialized

= Deaths per 10 million

Change in relation to overall global population and/or GDP

Tackling the hole in the ozone layer has been one of the most successful examples of international cooperation and environmental protection to date. The Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer has been effectively phasing out highly potent GHGs and ozone-depleting substances like chlorofluorocarbons (CFCs) and halocarbons (HCFCs). As a result, experts have suggested amending the Protocol, first signed in 1987, to tackle additional GHGs in order to support other global efforts on climate change (Molina et al., 2009). The ozone layer was at its maximum level of depletion during the late 1990s and through the last decade but is expected to recover rapidly in the years ahead (Dameris, 2010). Much of the damage to human health, however, has already been done. The slow recognition of the risks involved and delayed action will ultimately result in hundreds of thousands of deaths due to skin cancer, mainly in developed countries, that would not have occurred had the ozone layer remained stable (Martens, 1998; UNEP, 2002b).

HAZARD MECHANISM

Excessive ultraviolet (UV) radiation from accumulated sun exposure is now well recognized as the main cause of skin cancer (Armstrong and Kricker, 2001; Saraiya et al., 2004; Ramos et al., 2004). Depletion of the ozone layer exposes populations to more UV radiation, increasing skin cancer rates (UNEP, 2002b; Lucas et al., 2006). Aside from the ozone layer itself, radiation levels vary due to a number of other factors, including: 1) sun elevation – when the sun is higher in the sky, more UV radiation reaches ground level, 2) latitude – radiation being higher closer to the equator, 3) altitude – with every 1,000 metres gained in altitude, UV radiation increases 10% and 4) ground reflection, in that snow will reflect up to 80% of all UV rays and sand only 15% (WHO, 2002a). People’s behavioural patterns, such as an increasing trend in “sun-worshipping” or carelessness about sunscreen and other protection measures, also play an important role in incidence of skin cancer at the population level (Martens, 1998; Coups et al., 2008). Skin cancer is also a major occupational hazard for outdoor workers (Vecchia et al. (eds.), 2007). Fair-skinned people are more susceptible to cancer, and

childhood exposure to UV increases risks, although the onset of melanoma and other skin cancers generally occurs later in life (Armstrong and Kricker, 2001).

IMPACTS

The annual global impact of the carbon economy on skin cancer is estimated to have been 20,000 deaths for the year 2010, with that figure rising to 45,000 deaths per year in 2030 in a doubling of impact as a share of global population. It is estimated that 65,000 people were affected by skin cancer in 2010 as aggravated by the carbon economy, a figure that is expected to increase to almost 150,000 people by 2030. Developed and industrialized or transition economies in Australasia, Europe and North America are most severely affected due to significant proportions of populations with high-risk skin types in these countries. Australia and New Zealand have the highest rates of carbon-economy-aggravated skin cancer mortality as a share of population. The largest total impacts are felt in the US, China, Germany, Russia, the UK, France and Italy. Estimated annual mortality for the US and China is at 3,500 and 2,000 respectively, rising to 8,000 and 4,500 by 2030.

THE INDICATOR

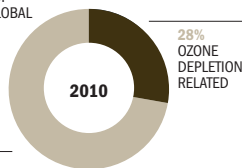
The indicator measures the impact on skin cancer rates due to UV radiation amplified by ozone depletion in the upper atmosphere (Martens, 1998). It relies on World Health Organization (WHO) data for skin cancer incidence (WHO BDD, 2012). The indicator is also adjusted to account for a number of closely related but independent factors, including the role of climate change in slowing or speeding the recovery of ozone in the upper atmosphere for different regions, the aging population, and the aggravating effect of increased artificial UV exposure (Bharath and Turner, 2009; Waugh et al., 2009). A key limitation is that the UV radiation impact was only available for Australia, which has had to serve as a global proxy, although the WHO base data already controls for prevalence of the disease internationally.



BIGGER PICTURE



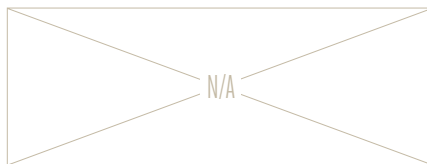
SHARE OF TOTAL GLOBAL DEATHS



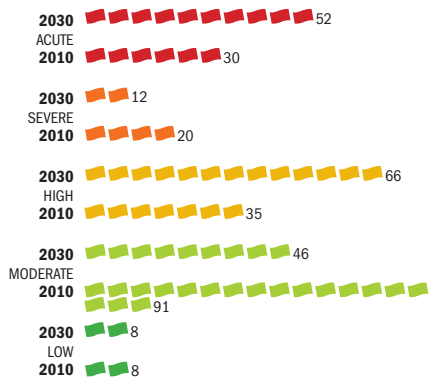
SURGE



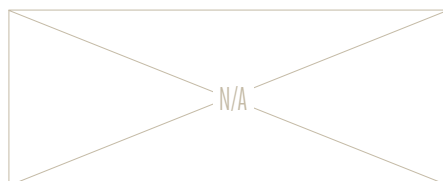
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Martens, 1998; WHO IARC, 2005

BASE DATA: WHO, 2009



AGRICULTURE



FISHERIES



FORESTRY

  **15 BILLION LOSS** 2010
150 BILLION GAIN 2030 



  **10 BILLION LOSS** 2010
75 BILLION LOSS 2030 



  **30 BILLION LOSS** 2010
85 BILLION LOSS 2030 



AGRICULTURE

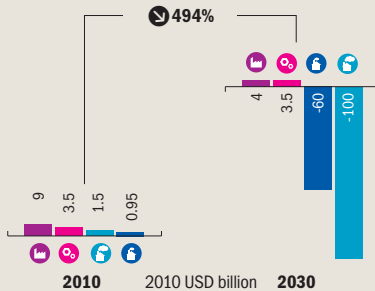


ESTIMATES GLOBAL CARBON IMPACT

2010 EFFECT TODAY
 USD **LOSS** PER YEAR
15 BILLION

2030 EFFECT TOMORROW
 USD **GAIN** PER YEAR
150 BILLION

ECONOMIC IMPACT

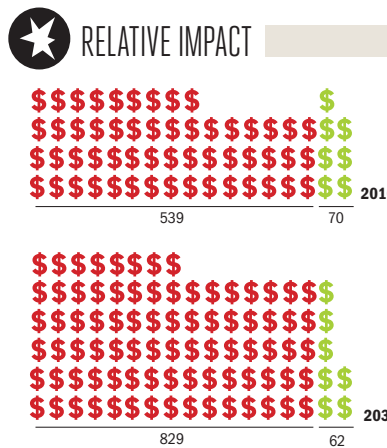


CONFIDENCE INDICATIVE

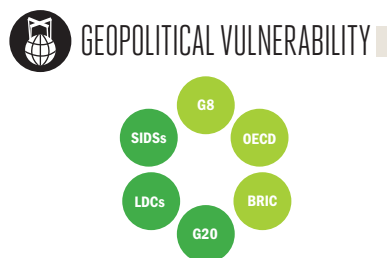
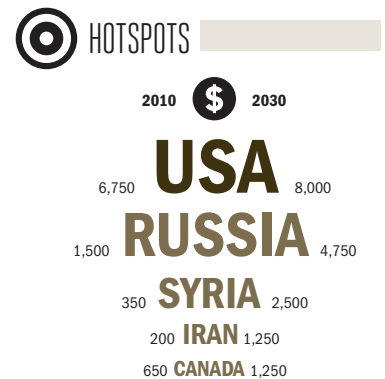
SEVERITY

AFFECTED

MDG EFFECT



- Air pollution harms people and has damaging and toxic effects for plants, impairing agricultural productivity
- Not all emissions are toxic: CO2 is a natural ingredient in photosynthesis, and enhances plant growth in optimal conditions
- The positive effects of “carbon fertilization” are often cancelled out by negative effects of localized/regional air pollution
- Net losses are substantial; but as CO2 levels climb, so do positive effects on plant growth, and by 2030 will far outweigh harmful concerns linked to localized pollution, making the effect for agriculture the largest positive contribution of the carbon economy



Economic Cost (2010 PPP non-discounted)
 \$ = Losses per million USD of GDP
 \$ = Millions of USD (2010 PPP non-discounted)

Developing Country Low Emitters
 Developed

Developing Country High Emitters
 Other Industrialized

Change in relation to overall global population and/or GDP

It has long been recognized that crop growth can be positively stimulated when the air contains more CO₂ (Idso, 1989). It has also been assumed that this positive effect—thought to entail a 30% boost to agriculture in the medium term—offsets completely or partially all other negative effects of climate change, at least initially (Mendelsohn in Griffin (ed.), 2003). However, GHG emissions and their by-products or co-pollutants also have a wide range of negative effects on crops and their yields; these concerns have increased significantly, with the evidence of gigantic transcontinental atmospheric brown clouds, which shut out sunlight and choke plant life (Auffhammer et al., 2006; Ramanathan and Fen, 2009). Bangladesh has actually seen its sunlight hours shrink by one-quarter over the past approximately 30 years, as a result of the growing dimming effect of pollution, and its negative implications for agricultural productivity (Ashan et al., 2011; Ramanathan et al., 2008). Toxic pollutants, such as acid rain and ozone that are trapped at ground-levels further inhibit plant growth (World Bank, 2005; Leisner and Ainsworth, 2011). By 2030, ground ozone alone in the South Asian region

is expected to surpass the level at which crop losses would attain 25% (Ramanathan et al., 2008). Extensive field-testing of crop responses to ambient CO₂ has also slashed earlier estimates of potential benefits by half or more (Ainsworth et al., 2008; Leaky et al., 2009). Regional studies that attempt to “disentangle” all the different contributing factors have shown that the negative effects of the carbon economy and climate change outweigh any positive benefits, and worsen with further warming (Welch et al., 2010). From the perspective of the carbon economy alone, initial negative impacts should progressively be cancelled out as CO₂ increases its concentration in the Earth’s atmosphere. Today’s losses are not significant or geographically pertinent enough to directly affect food security. The large-scale gains expected in 2030 are still only half the scale of the losses simultaneously estimated to be incurred as a result of climate change.

HAZARD MECHANISM

Common air pollutants from industrial and transportation sources affect agriculture in four key ways. First, ozone is a by-product of many carbon-intensive

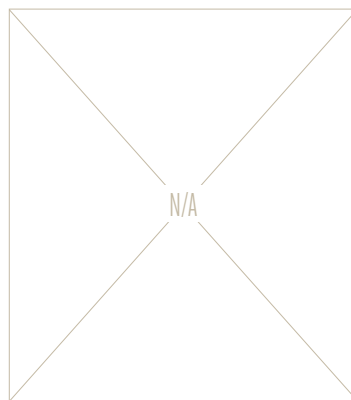
activities, and, while acting beneficially in the upper atmosphere, it is toxic for humans and plant life at ground level and limits agricultural productivity and growth potential in a variety of ways (OECD, 2012). Affected zones are shown to experience reductions in the productivity of a range of staple crops from 5 to 20% (Feng and Kobayashi, 2009; Leisner and Ainsworth, 2011; Wilkinson et al., 2012). Second, in some areas a lowering of the plant photosynthesis potential for many crops is an impact of so-termed “global dimming,” or a persistent reduction in solar energy due to widespread atmospheric pollution clouds which absorb and alter the transmission qualities of solar radiation (Stanhill and Cohen, 2000; Kumari et al., 2007; Wang et al., 2009; Ramanathan et al., 2008). However, some experts have argued that certain staple crops, such as shade-casting canopy-type plants, may benefit from more diffuse light refracted through immense atmospheric brown clouds

(Zheng et al 2011; Roesch et al., 2012). All these effects are geographically restricted and mainly confined to regions peripheral or adjacent to the world’s major industrial centres. The fourth effect, referred to as “carbon fertilization,” is the only one considered to be positive and differs from the other concerns in that it can be felt globally, since CO₂ is evenly dispersed in the earth’s atmosphere. As a result, its benefits are more widespread and significant than the counteracting effects of ozone, acid rain, and dimming, but may only be gained up to a certain point (not surpassed by 2030); plants only receive the full benefits under optimal conditions, since accelerated growth requires more moisture and nutrients to sustain (Van Veen et al., 1991; Long et al., 2005 and 2006; IPCC, 2007).

IMPACTS

The global impact of carbon-related emissions on agriculture is today estimated at around 15 billion dollars a year in losses. By 2030 however, an incremental increase in losses tied to anticipated emissions growth is estimated to be largely offset through CO₂-derived stimulus of the world’s

BIGGER PICTURE



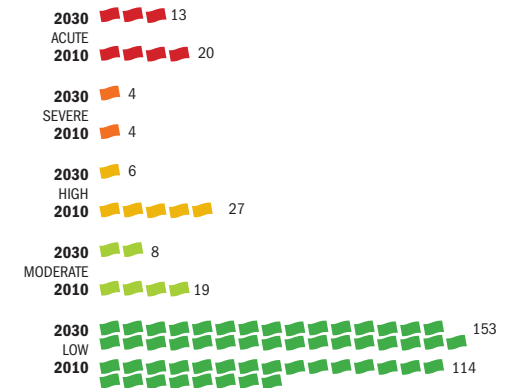
SURGE



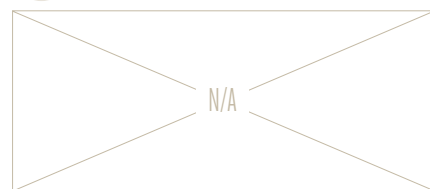
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Avnery, 2011; Hansen et al., 2007; Ramanathan et al., 2008; World Bank, 2005
 EMISSION SCENARIO: OECD, 2012
 BASE DATA: FAOSTAT, 2012; Portmann et al., 2010; Ramankutty and Foley, 1999

➡ = 5 countries (rounded)

staple crops. Potential net gains could reach a substantial 170 billion dollars a year.

The most negative effects are quite restricted and concern a heterogeneous group, dominated by industrialized or newly industrialized economies, including numerous former Soviet Union countries. The US, China, Russia, and India experience the largest total losses, with the US incurring 7 billion dollars a year in costs in 2010 and the others between 1 and 2 billion dollars in losses.

Initially the positive end of the spectrum is dominated by low-income, low-emitting African and Pacific island nations, who, far from the toxic emissions of the fastest-growing emerging economies, enjoy less contaminated air but are predisposed to the benefits of carbon fertilization, as it is uniformly diffuse in the atmosphere. By 2030, the picture of countries benefitting is considerably altered through the possibility of widespread gains resulting from carbon fertilization. With its 80 billion dollars in benefits, China far exceeds the more modest gains experienced by a handful of large developing countries still expected to have agricultural sectors of significant size.



THE INDICATOR

The indicator combines the separate information of acid rain effects (sulfur dioxide and nitrogen dioxide) with ground-level ozone toxicity, and crop responses to solar radiation variation resulting from atmospheric pollutant clouds (World Bank, 2005; Avnery et al., 2011; OECD, 2012; Ramanathan et al., 2008; Hansen et al., 2007). Global crop and irrigation maps and agricultural production are based on independent models and UN Food and Agriculture Organization (FAO) data (Portmann et al., 2010; Ramankutty and Foley, 1999; FAOSTAT, 2012). Carbon fertilization effects have been attributed according to the mid-point of estimates aggregated by the IPCC (IPCC, 2007). Countries are deemed to benefit completely, partially, or not at all from the stimulation, depending on the severity of combined climate change and carbon effects as assessed in the Monitor at country level. Recent research is less optimistic regarding the potential benefits of CO₂ fertilization than presented here (Ainsworth et al., 2008; Leaky et al., 2009).

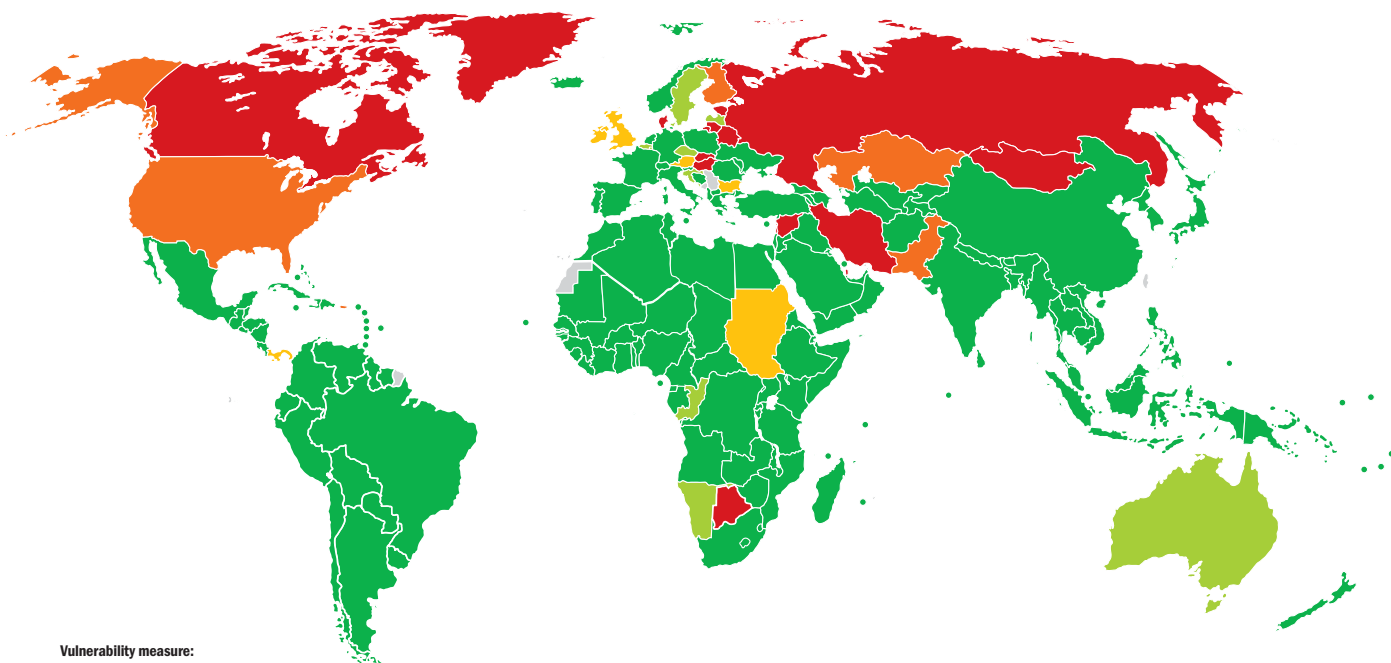
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			Latvia	10	5	Colombia	-1	-700
Belarus	200	750	Namibia	1		Comoros		-1
Botswana	15	90	Sweden	35	30	Costa Rica	-10	-400
Canada	650	1,000	LOW			Cote d'Ivoire	-35	-800
Denmark	150	250	Afghanistan	-10	-350	Cuba	-10	-650
Estonia	40	250	Albania	15	-100	Cyprus		
Hungary	300	1,000	Algeria	-1	-750	Djibouti	-1	-55
Iran	200	1,500	Angola	-25	-750	Dominica		-10
Lithuania	15	100	Antigua and Barbuda	-1	-20	Dominican Republic	-5	-250
Mongolia	5	60	Argentina	-25	-4,500	DR Congo	-20	-450
Qatar	40	300	Armenia	-1	-90	Ecuador	-10	-550
Russia	1,500	5,000	Azerbaijan	20	-90	Egypt	150	-2,000
Slovakia	95	400	Bahamas	-1	-85	El Salvador	-5	-200
Syria	350	2,500	Bahrain	-1	-75	Equatorial Guinea		-5
SEVERE			Bangladesh	-85	-3,500	Eritrea	-1	-20
Finland	45	80	Barbados			Ethiopia	-40	-1,500
Kazakhstan	150	300	Belize		-15	Fiji		-1
Pakistan	250	700	Benin	-10	-250	France	250	-950
United States	6,500	8,000	Bhutan	-1	-55	Gabon	-5	-250
HIGH			Bolivia	1	-150	Gambia	-1	-40
Austria	75	100	Bosnia and Herzegovina	10	-95	Georgia	1	-75
Bulgaria	150	90	Brazil	250	-3,000	Germany	250	-100
Ireland	25	30	Brunei	-5	-250	Ghana	-65	-1,500
Panama	10	20	Burkina Faso	-10	-250	Greece	-55	-400
Sudan/South Sudan	5	40	Burundi	-5	-100	Grenada	-1	-10
United Kingdom	450	850	Cambodia	-10	-700	Guatemala	-10	-350
MODERATE			Cameroon	-40	-1,000	Guinea	-10	-250
Australia	80	85	Cape Verde	-1	-15	Guinea-Bissau	-1	-50
Belgium	100	40	Central African Republic	-1	-35	Guyana	1	-10
Congo	1	1	Chad	-5	-200	Haiti	-1	-80
Croatia	40	1	Chile	10	-400	Honduras	-5	-300
Czech Republic	100	65	China	1,500	-80,000	Iceland		-1



CARBON VULNERABILITY

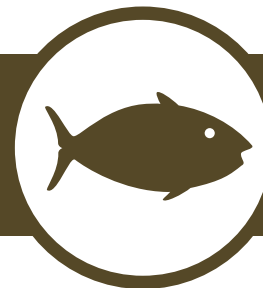
● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
India	1,500	-20,000	Mozambique	-15	-450	South Africa	40	-300
Indonesia	-200	-7,000	Myanmar	-10	-550	South Korea	-95	-5,000
Iraq		-150	Nepal	-30	-900	Spain	250	-1,000
Israel	40	-150	Netherlands	65	-60	Sri Lanka	-15	-550
Italy	150	-900	New Zealand	-5	-85	Suriname		-15
Jamaica	-10	-200	Nicaragua	-1	-100	Swaziland		-20
Japan	-200	-3,000	Niger	-5	-150	Switzerland	10	-50
Jordan		-55	Nigeria	-400	-10,000	Tajikistan	-1	-250
Kenya	-45	-1,000	North Korea	5	-55	Tanzania	-40	-1,500
Kiribati		-10	Norway	1	-20	Thailand	-15	-4,500
Kuwait	-10	-300	Oman	-5	-200	Timor-Leste		-35
Kyrgyzstan	-5	-250	Palau		-5	Togo		-150
Laos	-10	-550	Papua New Guinea	-5	-200	Tonga	-1	-10
Lebanon	10	-40	Paraguay	5	-200	Trinidad and Tobago	-5	-200
Lesotho		-15	Peru		-500	Tunisia	25	-250
Liberia	-1	-40	Philippines	-30	-2,000	Turkey	550	-1,000
Libya	-5	-500	Poland	400	-150	Turkmenistan	-45	-1,000
Luxembourg		-1	Portugal	55	-50	Tuvalu		-1
Macedonia	30	-55	Romania	50	-1,000	Uganda	-25	-850
Madagascar	-15	-400	Rwanda	-10	-250	Ukraine	250	-1,500
Malawi	-20	-450	Saint Lucia	-1	-15	United Arab Emirates	-15	-600
Malaysia	-35	-2,000	Saint Vincent		-10	Uruguay	10	-20
Maldives	-1	-10	Samoa	-1	-15	Uzbekistan	-45	-1,500
Mali	-15	-400	Sao Tome and Principe		-5	Vanuatu	-1	-25
Malta	-1	-5	Saudi Arabia	-10	-450	Venezuela	-10	-600
Marshall Islands		-5	Senegal	-10	-400	Vietnam	-100	-5,000
Mauritania	-5	-100	Seychelles	-1	-5	Yemen	-10	-350
Mauritius	-5	-50	Sierra Leone	-5	-80	Zambia	-5	-200
Mexico	75	-2,000	Singapore	-20	-550	Zimbabwe	1	-25
Micronesia	-15		Slovenia	5	-15			
Moldova	-5	-150	Solomon Islands	-1	-30			
Morocco	-15	-900	Somalia	-5	-200			

FISHERIES



ESTIMATES GLOBAL CARBON IMPACT



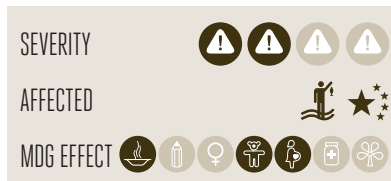
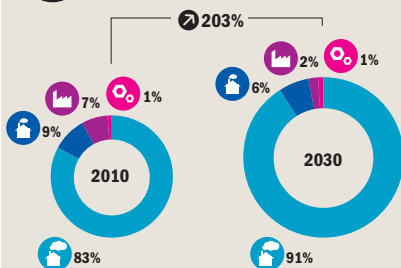
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **10** BILLION

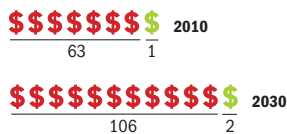
2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **75** BILLION

ECONOMIC IMPACT



RELATIVE IMPACT



- One third of all the carbon dioxide burned by the world's economies is being absorbed by the oceans
- This uptake of CO2 is fundamentally changing the acidity of the planet's oceans, making them less hospitable to aquatic life, especially coral, shellfish and krill
- Acid rain from heavy industrial sources also changes the pH of inland bodies of water, making them more acidic with a wide range of lethal and harmful effects for aquatic life
- These effects all have significant impacts on world fisheries
- They also risk destroying coral reefs, one of the world's most remarkable natural wonders, in a short-term timeframe

HOTSPOTS



GEOPOLITICAL VULNERABILITY



\$ Economic Cost (2010 PPP non-discounted)
🇧🇩 Developing Country Low Emitters **🇩🇪** Developed
🇧🇩 Developing Country High Emitters **🇨🇦** Other Industrialized

★ **\$** = Losses per 100,000 USD of GDP
↗ Change in relation to overall global population and/or GDP

🎯 **\$** = Millions of USD (2010 PPP non-discounted)

The increase in the acidity of the seas is unprecedented in the Earth's history: a single year's increase in ocean acidity today would have previously taken 100-200 years (Veron, 2008; Hoegh-Guldberg, 2011). When the oceans absorb CO₂, corals, shellfish and other marine organisms are stressed and go into decline since acidic seas inhibit the availability of minerals they depend on (Burke et al., 2011). Signs of decline are already visible: when CO₂ levels reached a level far below what they are today coral bleaching events became more common; the collapse of Galapagos Islands reefs in 1983 is an example (Baker et al., 2008; Hoegh-Guldberg, 2011). Bleaching is now evident in major reef systems, like the Great Barrier in Australia, that already show signs of serious degradation: a 15% decline in coral growth over several hundreds of monitored reef colonies since 1990 (De'ath et al., 2009). Most of the world's reefs are now in irreversible decline (Veron et al., 2009). Reefs are remarkably productive and act as anchors of the tropical sea ecosystem. Their disappearance would have catastrophic implications for the delicate balance of marine fisheries throughout the world. These negative

effects are already beginning to be felt (Crossland et al., 1991; Silverman et al., 2009; Narita et al., 2011). Air pollution generated by the carbon economy has more acute effects still in inland waterways, where CO₂ uptake is facilitated by acid rain in areas of heavy industrialization, which has further negative impacts for inland fisheries of all kinds (Ikuta et al., 2008). Research undertaken in Vietnam as a part of the Monitor's country study confirmed the direct relationship between water acidity (pH) and, for instance, disease control and the success of shrimp farming operations.

HAZARD MECHANISM

Two mechanisms are at work: 1) oceans are becoming more acidic as they absorb growing amounts - roughly a third - of the atmosphere's CO₂ and other fossil fuel emissions produced through human activities (IPCC, 2007; Sabine and Feely, 2007); 2) acid rain derived from the mainly sulphur and nitrogen emissions released when fossil fuels are burned are increasing the acidity of fresh and brackish bodies of inland water near the source of pollution (Ikuta et al., 2008). Small but consistent increases in ocean acidity

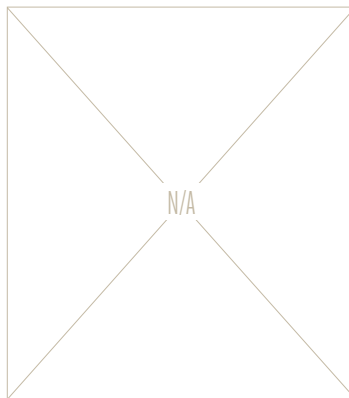
negatively affect the production of shellfish and coral since more acidic aquatic environments inhibit formation of mollusc shells, which are made of calcium carbonate (Narita et al., 2011). In krill, higher levels of acidity trigger or extinguish fertility (Kawaguchi et al., 2011). Closed bodies of inland water suffer more severe acidity surges. There is a clear progression of negative impacts from non-lethal to lethal depending on the pH level of the water (Ikuta et al., 2008). The fishing industry is negatively affected as a result.

IMPACTS

The global impact of GHG emissions on fishery production due to acidification processes is currently estimated at a relatively negligible ten billion dollars a year. However the impact triples as a share of GDP to 2030, by which time losses are estimated at around 45 billion dollars a year, an indicator of the devastating effects that could occur beyond this date if strong action on climate change is not forthcoming. Emissions will compound the potentially devastating effects of climate change and other unsustainable stresses on the world's waters and aquatic life. Harmfully, ocean acidification stress is

most severe outside and at the frontiers of the tropics, perfectly complementing the damaging effects of climate change that are most significant inside the tropics (Burke et al., 2011). Effects are widespread: approximately 40 countries are acutely vulnerable to the impact of GHG emissions on fisheries. Particularly affected are developing countries with proportionally large fisheries sectors. Remarkably, nearly 90% of all losses are estimated to occur in China, mainly as a result of acid rain losses for inland fisheries and aquaculture, over and above ocean acidification effects. Other countries already suffering significant total losses (over 200 million dollars a year) include Vietnam, South Korea and the US.

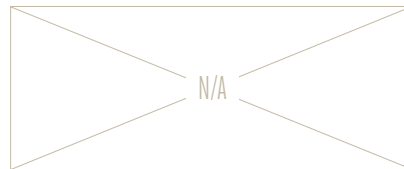
BIGGER PICTURE



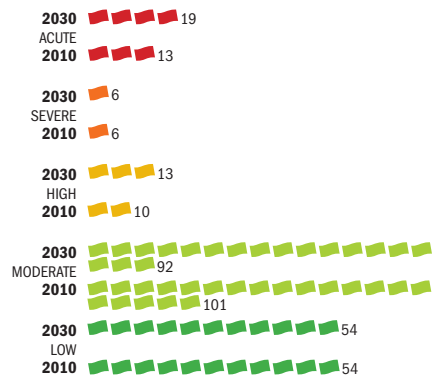
SURGE



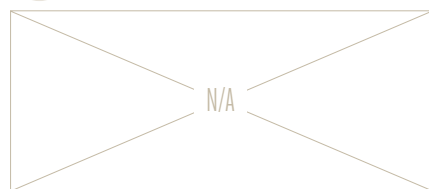
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: IGBP-DIS SoilData(V.0), 2008; OECD,2012
 BASE DATA: FAO FISHSTAT (2012); FAOSTAT (2012); Rubini et al., 1992

= 5 countries (rounded)



THE INDICATOR

The indicator relies on two separate studies assessing the effects for aquatic life of both acid rain on inland fisheries and ocean acidification (Ikuta et al., 2008; Narita et al., 2011). The indicator draws on the FAO's fisheries database (FAO FISHSTAT, 2012). The main limitations are that the detailed analysis of inland fisheries was only undertaken in one country and applied to other countries on the basis of emissions and fishery production. Clearly, further research is urgently required. The ocean acidification study enabled regional estimates of losses that were attributed to different countries on the basis of their fishery production. Regional aggregation compromised, to some degree, the accuracy of the results as not all countries in a region will react identically.

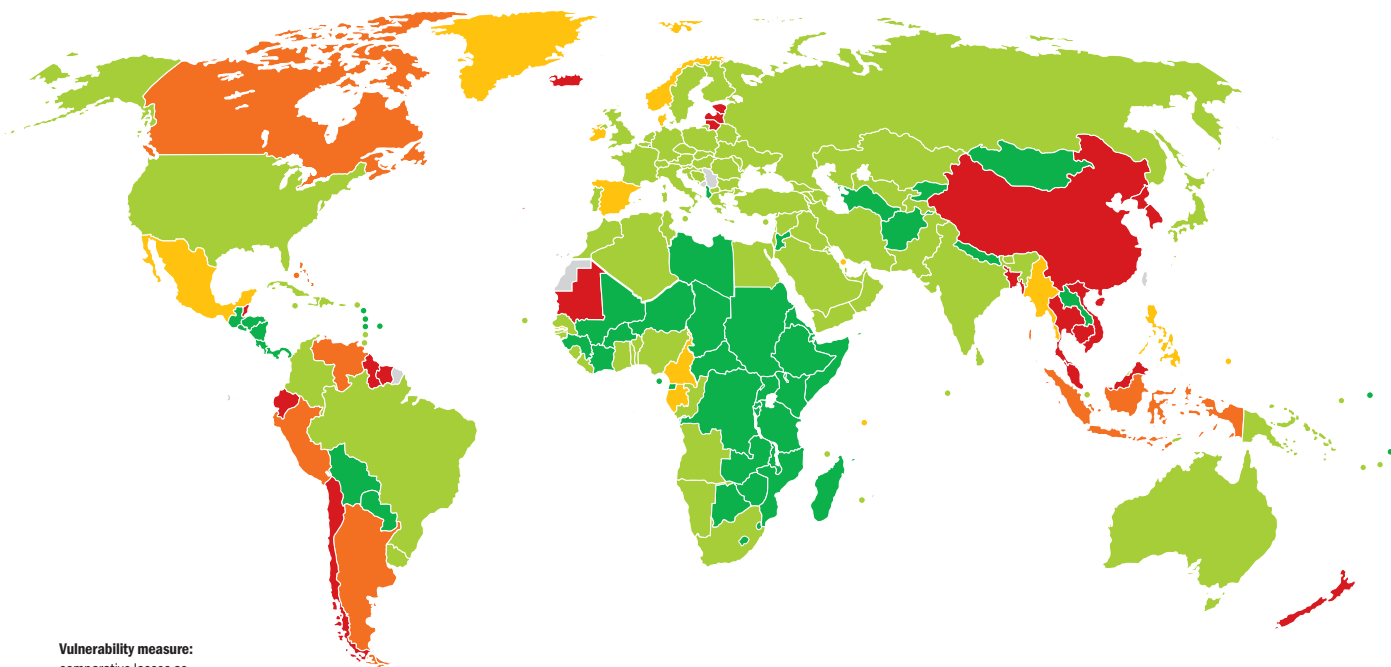
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE								
Bangladesh	65	300	Gambia		1	Czech Republic		
Belize		1	Ireland	10	30	Dominican Republic		1
Cambodia	10	50	Mexico	45	350	Egypt	1	5
Chile	80	600	Myanmar	1	15	Fiji		
China	6,500	65,000	Norway	15	40	Finland		
Ecuador	45	350	Palau			France	35	100
Estonia	35	250	Philippines	40	150	Georgia		
Guyana	5	45	Seychelles		1	Germany	5	15
Iceland	1	10	Spain	35	100	Ghana		1
Latvia	5	35	MODERATE			Greece	5	15
Lithuania	10	75	Algeria		1	Grenada		
Malaysia	80	500	Angola	1	1	Guinea-Bissau		
Mauritania	1	15	Antigua and Barbuda			Haiti		
New Zealand	20	60	Armenia			Hungary	1	1
North Korea	10	100	Australia	10	30	India	150	550
South Korea	250	2,000	Austria			Iran	5	15
Suriname	1	15	Azerbaijan			Iraq		
Thailand	200	1,000	Belarus			Israel		1
Vietnam	500	3,250	Belgium		1	Italy	20	60
SEVERE			Benin		1	Jamaica		
Argentina	60	450	Bhutan			Japan	65	200
Bahamas	1	5	Bosnia and Herzegovina			Kazakhstan		
Canada	150	400	Brazil	5	30	Kuwait	1	5
Indonesia	200	800	Brunei		1	Lebanon		
Peru	20	150	Bulgaria	1	10	Liberia		
Venezuela	25	200	Cape Verde			Macedonia		
HIGH			Colombia		1	Maldives		
Bahrain	1	10	Comoros			Malta		
Cameroon	1	10	Congo		1	Mauritius		
Denmark	10	25	Croatia	1	5	Micronesia		
Gabon	1	5	Cuba	1	5	Moldova		
			Cyprus			Morocco	1	5



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Namibia		1	United Kingdom	25	75	Laos		
Netherlands	10	35	United States	250	700	Lesotho		
Nigeria	5	20	Uruguay	1	10	Libya		
Oman		1	Uzbekistan			Luxembourg		
Pakistan	1	1	Vanuatu			Madagascar		
Papua New Guinea			Yemen			Malawi		
Poland	1	10	LOW			Mali		
Portugal	1	5	Afghanistan			Marshall Islands		
Qatar		1	Albania			Mongolia		
Romania			Barbados			Mozambique		
Russia			Bolivia			Nepal		
Saudi Arabia	5	45	Botswana			Nicaragua		
Senegal		1	Burkina Faso			Niger		
Sierra Leone		1	Burundi			Panama		
Singapore	1	10	Central African Republic			Paraguay		
Slovakia			Chad			Rwanda		
Slovenia		1	Costa Rica			Saint Lucia		
Solomon Islands			Cote d'Ivoire			Saint Vincent		
South Africa		1	Djibouti			Samoa		
Sri Lanka	1	10	Dominica			Sao Tome and Principe		
Sweden	1	1	DR Congo			Somalia		
Switzerland			El Salvador			Sudan/South Sudan		
Syria	1	5	Equatorial Guinea			Swaziland		
Tajikistan			Eritrea			Tanzania		
Timor-Leste			Ethiopia			Turkmenistan		
Togo			Guatemala			Tuvalu		
Tonga			Guinea			Uganda		
Trinidad and Tobago		1	Honduras			Zambia		
Tunisia	1	5	Jordan			Zimbabwe		
Turkey	5	15	Kenya					
Ukraine	1	10	Kiribati					
United Arab Emirates		1	Kyrgyzstan					

FORESTRY



ESTIMATES GLOBAL CARBON IMPACT

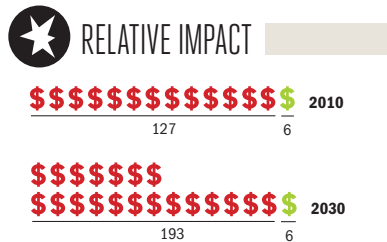
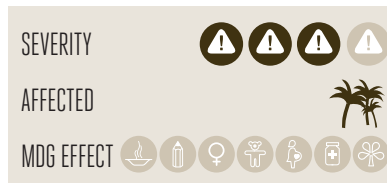
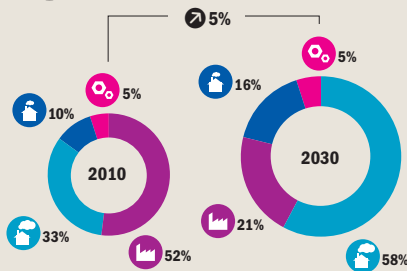
2010 EFFECT TODAY

\$ USD LOSS PER YEAR **30** BILLION

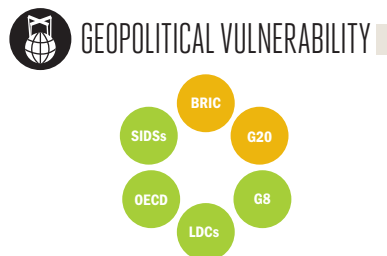
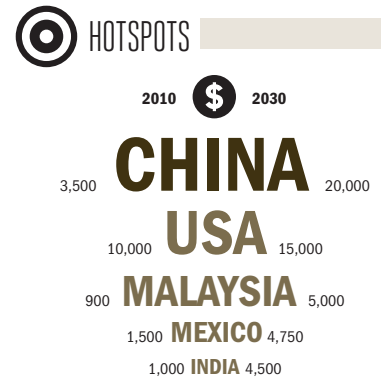
2030 EFFECT TOMORROW

\$ USD LOSS PER YEAR **85** BILLION

ECONOMIC IMPACT



- Commercial forestry in countries and regions with high levels of toxic emissions is experiencing productivity losses
- Ozone and acid rain impacts primary productivity and the growth rates of commercial forestry, generating losses in output
- Heavily forested nations especially in Africa and Southeast Asia suffer these effects disproportionately because of the relative significance of their forestry industries



\$ Economic Cost (2010 PPP non-discounted)
f Developing Country Low Emitters **m** Developed
F Developing Country High Emitters **o** Other Industrialized

★ **\$** = Losses per 100,000 USD of GDP
↻ Change in relation to overall global population and/or GDP

◎ **\$** = Millions of USD (2010 PPP non-discounted)

The earth's plant life is susceptible to environmental pollutants released into the air as a by-product of economic activities. Trees are by no means spared these effects, with losses already observable due to problems such as toxic ozone emissions at ground levels (Reilly et al., 2007). Studies have shown how ambient levels of ozone (O₃) in the atmosphere have already reduced tree productivity and will continue to do so rapidly as O₃ continues to rise. Critically, this would reduce a major global carbon sink (Wittig et al., 2009). Likewise, acid rain also affects tree productivity, especially where soil acid buffering is low (Likens et al., 1996). In order to significantly reduce the losses these effects produce, particularly for the forestry sector, major economies would need to make synchronized efforts to curtail the heaviest forms of industrial pollution, such as sulphur and nitrogen dioxide emissions generated by coal power and other substances that lead to the production of O₃. Trees are more resilient to heightened levels of ground-level O₃ and other pollutants than most staple crops, if anticipated losses in other segments

of the agricultural sector are taken as reference (Holm Olsen and Fenhann (eds.), 2008).

HAZARD MECHANISM

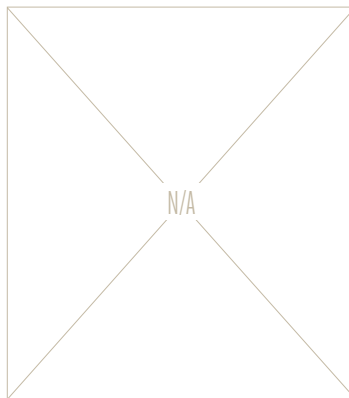
Emissions like sulphur and nitrogen dioxide and other ozone precursors lead to acid rain and high concentrations of O₃ at ground-level, which have long been shown to be toxic for the growth of plants, including trees (Wentzel, 1982; Mustafa, 1990). These effects directly impact plant and tree productivity, harming the growth of trees and forestry sector outputs (Reilly et al., 2007; Likens et al., 1996). In optimal conditions, higher levels of CO₂ in the atmosphere might also favour growth and expanded output (IPCC, 2007).

IMPACTS

The global impact of the carbon economy on forestry, independent of climate change, is estimated to currently cost 30 billion dollars a year. The level of impact is expected to grow modestly as a share of global GDP over the next 20 years, with losses of 80 billion dollars a year in 2030. Some 25 mainly forest countries in the tropics are acutely vulnerable to these effects

and will see the most significant impact. Africa and Southeast Asia are generally worst off, with important concerns for poverty reduction efforts that might be compromised through declining agro-forestry productivity. The US, China, Mexico, India and Japan are estimated to incur the largest total losses all at or in excess of one billion dollars per year in 2010, and growing rapidly by 2030.

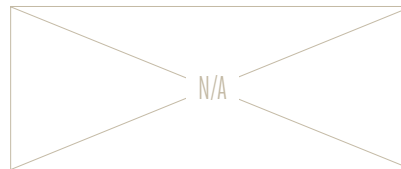
BIGGER PICTURE



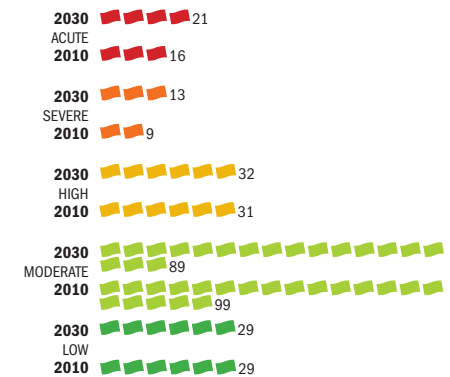
SURGE



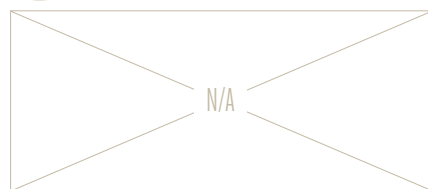
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Costanza et al., 1997; OECD, 2012; Reilly, 2008; Wentzel, 1982
 BASE DATA: FAOSTAT (2012); Reilly, 2008

= 5 countries (rounded)



THE INDICATOR

The indicator measures the impact of air pollution on the forestry sector focusing in particular on the extent to which ground-level ozone (O₃) and acid rain affect forest productivity. It relies on an ecosystem valuation approach to translate losses into GDP (Reilly et al., 2007; Wentzel, 1982; Costanza et al., 1997). Limitations relate to uncertainties over emissions leading to O₃ and acid rain and the regional aggregation of O₃ concentrations used (OECD, 2012). Also, research on the effects of acid rain on forests is very out of date. Further investigation is needed since coal energy, heavy in sulphur and nitrogen emissions, is poised to continue to be the world's leading global fuel for power generation well into the 2030s (US EIA, 2011).

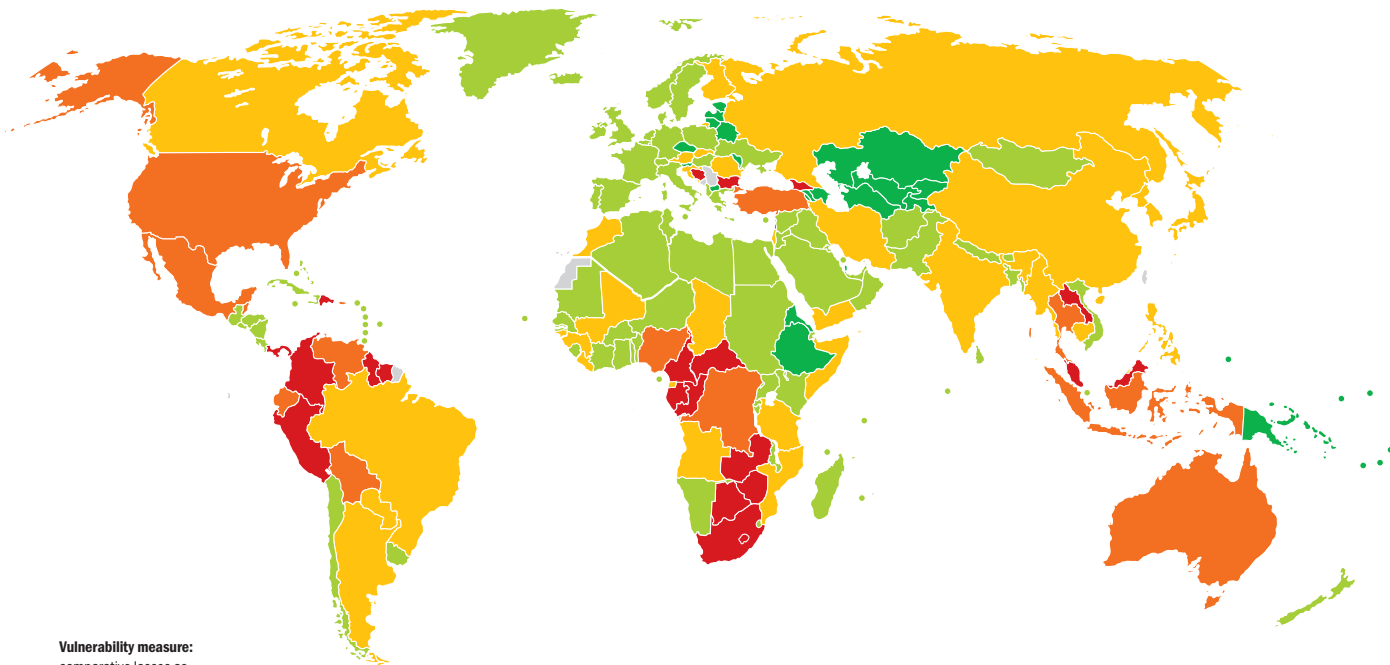
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
ACUTE			Timor-Leste	1	10	Slovakia	45	100
Bosnia and Herzegovina	45	100	Turkey	500	1,000	Somalia	1	5
Botswana	90	400	United States	10,000	15,000	South Korea	200	1,000
Bulgaria	150	450	Venezuela	200	1,000	Tanzania	10	50
Cameroon	50	250	HIGH			Yemen	10	50
Central African Republic	1	10	Angola	25	150	MODERATE		
Colombia	450	2,500	Argentina	250	1,250	Afghanistan		
Congo	70	300	Austria	150	200	Albania		1
Dominican Republic	150	750	Brazil	650	3,250	Algeria	20	100
Gabon	30	200	Brunei	5	25	Antigua and Barbuda		
Georgia	45	100	Cambodia	5	70	Bahamas	1	5
Guyana	5	35	Canada	350	500	Bahrain		
Laos	10	100	Chad	1	15	Bangladesh	10	55
Lebanon	70	350	China	3,500	20,000	Barbados		
Lesotho	5	20	Croatia	35	95	Belgium		1
Malaysia	900	5,000	Equatorial Guinea	5	35	Benin	1	5
Panama	200	1,000	Finland	35	70	Bhutan		1
Peru	250	1,250	Guinea	1	5	Burkina Faso	1	5
South Africa	500	2,000	Guinea-Bissau		1	Burundi		
Suriname	5	25	India	1,000	4,500	Cape Verde		
Zambia	50	250	Iran	200	1,000	Chile	5	40
Zimbabwe	10	45	Israel	70	200	Comoros		
SEVERE			Japan	950	1,000	Costa Rica	1	10
Australia	750	800	Liberia		1	Cote d'Ivoire	1	10
Belize	1	5	Mali	1	10	Cuba	1	10
Bolivia	15	100	Morocco	30	150	Cyprus		
DR Congo	5	40	Mozambique	5	35	Denmark		1
Ecuador	55	300	Myanmar	10	75	Djibouti		
Indonesia	550	2,750	Paraguay	5	25	Dominica		1
Mexico	1,500	4,750	Philippines	65	350	Egypt		
Nigeria	150	750	Romania	60	150	El Salvador		1
Thailand	350	2,000	Russia	450	1,750	France	250	300



CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative losses as
a share of GDP in USD
(national)

COUNTRY	\$		COUNTRY	\$		COUNTRY	\$	
	2010	2030		2010	2030		2010	2030
Gambia		1	North Korea		1	LOW		
Germany	550	650	Norway	10	25	Armenia		
Ghana	1	15	Oman			Azerbaijan		
Greece	35	40	Pakistan	10	65	Belarus		
Grenada			Poland	150	350	Czech Republic		
Guatemala	1	10	Portugal	1	5	Eritrea		
Haiti			Rwanda			Estonia		
Honduras	1	20	Saint Lucia			Ethiopia		
Hungary	1	5	Saint Vincent			Fiji		
Iceland			Sao Tome and Principe			Kazakhstan		
Iraq	10	40	Saudi Arabia		1	Kiribati		
Ireland		1	Senegal	1	10	Kyrgyzstan		
Italy	200	250	Seychelles		1	Latvia		
Jamaica		1	Sierra Leone		1	Lithuania		
Jordan			Singapore			Macedonia		
Kenya	1	5	Spain	250	300	Marshall Islands		
Kuwait			Sri Lanka		1	Micronesia		
Libya			Sudan/South Sudan	1	10	Moldova		
Luxembourg		1	Swaziland			Palau		
Madagascar	1	10	Sweden	40	90	Papua New Guinea		
Malawi	1	1	Switzerland	40	50	Qatar		
Maldives			Syria			Samoa		
Malta			Togo		1	Slovenia		
Mauritania		1	Trinidad and Tobago		1	Solomon Islands		
Mauritius			Tunisia		1	Tajikistan		
Mongolia	1	5	Uganda	1	5	Tonga		
Namibia		1	Ukraine	45	100	Turkmenistan		
Nepal		1	United Arab Emirates			Tuvalu		
Netherlands	60	70	United Kingdom	1	5	Uzbekistan		
New Zealand	1	5	Uruguay		1	Vanuatu		
Nicaragua	1	10	Vietnam	25	200			
Niger		1						

METHODOLOGY

ARCHITECTURE

FOUNDATIONS

In all, the Monitor comprises 34 indicators of the economic, human and ecological effects of climate change and the carbon economy. Indexes form the backbone of each indicator and are responsible for generating the relative level of vulnerability registered for each country.

Each index is determined exclusively on the basis of mortality and/or GDP per capita data, capturing only the climate change or carbon economy effect in isolation from other factors. In order to support fair socio-economic comparisons between countries, all estimates are made either in monetary terms (GDP losses) or in terms of mortality. Indicators in the Climate Environmental Disasters impact area are the only ones to combine both mortality and GDP per capita in order to determine the Monitor vulnerability level, where both variables are given full weighting. Combining the variables in this instance ensures a holistic interpretation of the full socio-economic spectrum of disaster vulnerability and does not seek to imply any value judgement on human life versus inanimate assets. Mortality, in many cases, might be fewer than 10 deaths per 10 million, so the smallest countries may not register vulnerability to extreme weather if economic losses are not accounted for. Additional variables of interest are provided for different indicators as appropriate in order to provide a fuller understanding of the impacts estimated to be taking place, such as populations at risk from desertification or illness rates for health indicators.

BREADTH AND AGGREGATION

The Monitor uses an enumerative methodology to estimate a wide range of distinct effects resulting from climate change and the carbon economy that can be summed to gauge overall country and global impacts in socio-economic terms. Each indicator represents a separate grouped set of effects that rely on independent research and data sets. All effects are unified by means of a common mathematical

framework and assimilated into indexes that facilitate comparison and analysis between the 184 countries.

IMPACT ESTIMATIONS

Each of the Monitor's 34 indicators provides cost or gain estimates for 2010 and 2030 that relate solely to climate change or the carbon economy. They are the results of this project's particular methodology and the underlying research and data sets chosen. Other choices, other methodologies and other projects will almost certainly yield different results. Ideally, comparable efforts by other research groups would help identify more readily the main areas of confluence and incongruence between the different findings and approaches that now exist.

VULNERABILITY LEVELS

The Monitor's vulnerability assessment system enables a comparison of impacts on a per capita basis across countries. The level of impact indicates the level of climate-related vulnerability. The five vulnerability levels used throughout the Monitor are statistically determined via (mean absolute) standard deviation, with the level "Low" representing near-zero or positive effects and the level "Acute" denoting impacts several degrees or intervals removed from (or above) Low. The upper three levels of vulnerability (Acute, Severe, High) also have two further sub-categories that are sometimes shown to illustrate where (at the top or low end) in these higher vulnerability categories the assessment places countries or groups. Vulnerability levels are determined for each indicator in relation to how all countries are collectively experiencing that particular effect. This is done at the effect level – Sea-Level Rise, for instance. So in some cases, effects for which a country has Acute vulnerability may be smaller in scale than concerns assessed at High vulnerability. Vulnerability levels indicate a country's deviation from the norm of impacts experienced for a given effect and do not necessarily indicate which effects present the highest risk to a country.

Aggregated indexes for the Climate and Carbon sections are determined by averaging or adding up the results of the lower tier assessments. Multi-dimensional vulnerability to Climate or Carbon is an average across all indexes and is only representative

of the degree to which countries are vulnerable to a wide range of effects, without considering the relative importance of different effects. The overall human (or mortality) impact or the overall economic impact data (indexes) on the other hand, represent the sum of all effects measured in the lower tiers and illustrate how these totals compare with other countries. The vulnerability levels are static so that progression of effects over time highlights the degree to which countries are estimated to be gaining or shedding vulnerability between 2010 and 2030. The whole statistical framework is an attempt to conserve the implications of the underlying scientific/research estimations, which are cited, together with key data, in the chapters for each indicator.

CALCULATING CLIMATE AND CARBON EFFECTS

To calculate the impact of individual effects, the Monitor combines estimations from expert and scientific literature or models with bodies of ecological, economic or societal data. It is assumed that the impacts of climate change and the carbon economy are already at play in the world's economic, environmental and social systems. Therefore, to estimate the impact of either process, "climate" or "carbon", on current levels of welfare, it is necessary to keep a counterfactual in mind. The counterfactual is the situation that would have prevailed in the absence of climate change and/or carbon intensive practices. Incremental economic, environmental or social outcomes assessed here are therefore estimated deviations from a level of welfare that would otherwise have been higher or lower. Any opportunity costs only make sense if an alternative to the carbon economy is available. Therefore, costs and benefits must be contextualized against the costs of transitioning towards a low-carbon economy – for which analysis is provided at the front of this report.

CONTEXTUAL BASES

The Monitor's system of analysis relies on reference projections in order to generate the most plausible understanding of how the world is likely to evolve between now and 2030. GHG emissions and temperature increases vary across indicators depending on the base research, with the most

common scenario being the medium-high A1B marker scenario of the IPCC (IPCC, 2000). Climate change is understood as the change in weather versus, in most cases, a base year of 1975 (as the mid-point of the 1961 to 1990 climate). Projections for population and economic growth are drawn from Columbia University's Centre for International Earth Science Information Network based on the IPCC A1B scenario (CIESIN, 2002). Reference GDP and population data is drawn respectively from the International Monetary Fund and the UN population division (IMF WEO, 2012; UN pop div., 2012). For certain indicators other dynamic adjustments are made to key parameters, such as an anticipated income-driven decline in the prevalence of some communicable diseases, or structural evolutions to developing economies (Mathers and Loncar, 2005; OECD, 2012). Current responses to climate change, such as adaptation or mitigation, are assumed to be held at today's relative levels so that estimates for 2030 represent business as usual. The Monitor doesn't adjust for any future policy initiatives that could increase or stimulate adaptation to or mitigation of climate change.

THE APPROACH

DEALING WITH CLIMATE UNCERTAINTIES

The Monitor is a pragmatic study. Exercises like the Monitor are by definition imperfect (Smith et al. in IPCC, 2001), above all because a variety of uncertainties exist in almost every tier of the analysis. There are six main sets of uncertainties involved in the Monitor's assessment:

- *Climate-related*: uncertainty about the levels of GHG emissions (present and future), temperature changes for different emission levels, effects for other weather variables such as wind and rainfall as a result of temperature changes, limitations of global or regional research (i.e. climate models) accurately describing effects at country or sub-national levels
- *Social and environmental*: uncertainty related to the varying quality or comprehensiveness of the base data, such as the accuracy of databases on current rates of illness, of reported disaster damage

MISSING THE FULL METHODOLOGICAL DOCUMENTATION?

The complete in-depth methodological documentation for the Monitor with technical descriptions for each of its indicators is available online at: www.dararint.org/cvm2/method

or of biodiversity concentrations and projections of population growth

- *Economic/technological*: uncertainty related to future economic growth and advances in technology
- *Scientific/empirical*: uncertainty in estimating the effects of climate change in social, economic or ecological terms
- *Extrapolation*: in many cases, effects are estimated in just a few representative countries and are then extrapolated to provide a global picture, introducing possibilities for error
- *Aggregation/assimilation*: when compiling diverse data sets, models and pieces of information, judgements of different kinds sometimes must be made, which could introduce further margins of error.

Many of the above factors are closely interrelated, such as population, economic growth and emissions of GHGs.

Uncertainty is, therefore, very real to the study of climate change and must be taken seriously. However, the world cannot simply wait, inactive, until all uncertainties have been mathematically weighed even as climate changes are clearly observable as recorded in successive IPCC reports (IPCC, 1990, 1995, 2001 and 2007). The uncertainty of this study is also relatively contained for the field of climate change, given the short timeframe of much of the analysis compared to the near centennial or longer focus of most climate research. Neither is uncertainty restricted to the field of climate change. Major macroeconomic and corporate decisions are made every day, shaping global and local economies around the world that involve the highest degrees of uncertainty (Oxelheim and Wihlborg, 2008).

Studies like this one make best attempts to soundly balance all of the competing considerations. Deliberate steps are also taken to minimize uncertainties. For instance, the database of economic damage caused by extreme storms and floods that the Monitor uses is a hybrid of the main international provider in the public sector and one of the main global reinsurers (CRED/EM-DAT, 2012; Munich Re NatCat, 2012). Relying on just one of these reduces considerably the losses for several countries, decreasing the robustness of any conclusions.

On the other hand, the homogeneity of more than 15 models in predicting large increases in heavy rainfall as the planet warms is quite striking, considering many of them were developed separately by experts living in different countries over varying periods of time (Kharin et al., 2007; IPCC, 2012a).

That so much research in this field reaches similar conclusions is remarkable precisely because of the implausibly large uncertainties that apply. The “unequivocal” language of the IPCC regarding the existence and primary causes of recent global warming is a good example (IPCC, 2007). It results from an overwhelming burden of proof with no alternative explanations (Royal Society, 2005). And it explains why the leading scientific bodies of more than 50 countries, including those of major economies like the US and China, regularly communicate concern on climate change issues (IAP, 2009).

While there's now clear consensus on the basics of climate change, the similar findings that result from similar assumptions from study to study do leave the door open to systemic risk. This could prevent anticipation of catastrophic outcomes. The economics field met with such a crisis following the collapse of the global financial system in 2008 (Krugman, 2009). Unlike business-cycle decisions, decisions on the climate do not leave as much scope for error and recuperation if full heed is paid to the conclusions of mainstream science and GHG emission modelling (IPCC, 2007; UNEP, 2011).

Experts say that, when making decisions in highly dynamic and uncertain conditions, those decisions should be robust to a wide range of possible outcomes, should involve learning for improved reactions to emerging risks and opportunities, and should be grounded in a wide range of analytical inputs so as not to exclude potentially important options or concerns (Lempert and Schlesinger, 2000; Vecchiato, 2012; Baddeley, 2010). This study offers just one further input to that process.

PRECAUTIONARY MEASURES

The 1992 UN climate change convention (UNFCCC), the key international treaty on climate change, does stipulate precaution and binds its 195 parties to take cost-effective measures to prevent or minimize harm

COMMENTS AND SUGGESTIONS

Readers, specialists and users of the report are highly encouraged to forward any suggestions for improvements to the structure, focus and/or methodology of the Monitor to DARA. The research team is most grateful for every input received. Please contact DARA via: cvm@daraint.org

when threats of serious or irreversible damage are evident – even in the absence of full scientific certainty (UNFCCC, 1992).

The conclusions offered by this report point to serious harm. The findings are, however, based on estimates that could, in reality, be either substantially lower or substantially higher – as uncertainty is symmetrical. Caution, though, is particularly flagged because the Monitor's approach is less precautionary than it is conservative in several respects.

LIMITATIONS OF ANALYSIS

To begin with, the emission scenario chosen for most indicators is not the highest available. While the second edition of the Monitor is significantly more comprehensive than the first, numerous impacts are simply beyond the analysis here for lack of adequate reference studies or due to methodological difficulties. This particularly applies to so-called “socially contingent” impacts, such as the effects on social and political stability, conflict, crime, or cultural assets, such as World Heritage sites – for which plausible relationships have been mapped or argued (Stern, 2006; Ahmed et al., 2009; Burke et al., 2009 and 2010; CNA, 2007; Scheffran et al., 2012; Agnew, 2012; UNESCO, 2010). Neither does the mainly near-term Monitor factor in the potential costs of future large-scale abrupt impacts, although a number of prominent economists whose timeframes of analysis are more extended advise otherwise (Nordaus and Boyer, 2000; Hope, 2006). Still, it is equally possible that some of the impacts not considered here include positive outcomes for society (Tol, 2010). Other more straightforward costs that are known lacunas for the field are also not adequately covered here. Agriculture is just one example. Costs associated with additional irrigation by farmers in a much warmer world are essentially unaccounted for in most agricultural models, even when high temperatures are expected to more than offset any additional rainfall (Cline, 2007). Furthermore, a broad range of staple crops are now understood to react more rapidly and negatively after exceeding a particular high temperature threshold than was previously understood to be the case (Schlenker and Roberts, 2009; Ackerman and Stanton, 2011).

Finally, this study uses the equivalent of a direct-cost approach for estimations, exploring impacts as losses or gains to independent sectors or as discrete gains/losses for those directly affected. This does not take into consideration the passing on of gains or losses elsewhere. It is, however, generally understood that markets can and do spread these effects further. Businesses for instance, pass on their prosperity or difficulties to their clients, competitors and suppliers, as well as to investors and financial markets (Kuik et al., 2008). That fact has led some experts to conclude that direct costs are, by definition, an underestimation (Bosello et al., 2005). One expert has estimated that direct damage costs could be multiplied by a factor of 20 in certain instances (Hallegatte, 2005).

Balancing Comprehensiveness and Accuracy

The Monitor attempts to contribute breadth and descriptiveness to the understanding of global climate-related issues without venturing too far into conjecture and methodological unknowns. Although the spectrum of over 30 indicators reviewed does range from the clearly speculative through to the more robust. The larger-scale impacts assessed in the Monitor are nevertheless evaluated as being more robust in general than the impacts of lesser macroeconomic significance also included here. Even when knowledge barriers allow for little more than speculation on the full nature of an effect, it was judged that not including these effects, such as tropical storms or impacts on the tourism industry – indicators endowed respectively with high uncertainty and low scientific foundations – would penalize the assessment more through a lack of comprehensiveness than might be gained through any enhanced certitude.

Uncertainties, once more, are fundamental to any understanding and response to climate change. As global warming accelerates, everyone from policy makers through to the general public will likely be required to engage and act more on the basis of uncertain and speculative information. Given the stage of development of climate policy, deliberately highlighting limitations within studies like this through inclusion of potentially vital information (while clearly signalling its shortcomings) can serve to shed light on how and where limitations lie, aid in

pinpointing research priorities and provide greater clarity in separating out the less robust information from the more robust. This report aims to advance understanding in all such respects.

ASSESSMENT CATEGORIZATION/DISTINCTIONS

OVERLAP AND SEPARATING EFFECTS

A very deliberate effort has been made to ensure that all indicators in the Monitor represent no – or at worst only marginal or statistically insignificant – overlap. The Climate Environmental Disasters indicator on drought is a case in point. Unlike the other disaster indicators, it does not account for any mortality impact. This is because the Hunger indicator under Health Impact is accounting for the ramifications of worsening food availability as a result of climate change, including drought. Another example relates to the Sea-Level Rise and Water indicators under Climate Habitat Change. The Water indicator measures the impact of a net change in water availability resulting from rainfall pattern alterations and heat. It does not, however, account for the saline contamination of water reservoirs in coastal areas caused by erosion due to rising sea levels, an effect captured under the Sea-Level Rise indicator.

Furthermore, two indicators, Heating and Cooling and Labour Productivity, both categorized under Climate Habitat Change, are near mirrors to one another and required adjustment to avoid overlap. Heating and Cooling estimates the rising or falling energy costs linked to the climate conditioning of indoor space to maintain unaltered levels of comfort as the planet warms. Labour Productivity measures the losses (or gains) to productivity incurred to the outdoor and indoor workforce exposed to increasing heat. The costs estimated in Heating and Cooling were removed from the Labour Productivity indicator to ensure no overlap. The Carbon section is generally more clear-cut than the Climate section, which assesses almost double the number of effects. The greatest propensity for overlap concerns the Climate indicators for Agriculture, Desertification, Drought and Water, although the extent of this is still considered limited. This is because the Agriculture indicator is mainly measuring

a departure from optimal growing conditions or how land value and production capacity evolve in relation to changing climate conditions, whereas Drought is estimating the implications – mainly for the agricultural sector – of the increasing occurrence of these major hydrological events, which are highly randomized and have severe repercussions that are not fully accounted for in climate productivity models of agricultural yield change. Desertification very specifically measures the highly accelerated degradation of arid lands due to heat and water stress and the associated depreciation of land investments and yield capacity. There is, however, some possibility of overlap due to the manner in which the land-value base estimates for agricultural losses are calculated as a component of the Monitor's Climate Agriculture indicator (see: Cline, 2007). As Desertification itself represents just 1% of estimated global losses due to climate change in 2010, any overlap would still be quite marginal to this study.

Rainfall and evaporation are other parameters built into the Agriculture indicator. Less favourable rainfall patterns or high levels of evaporation not compensated for by additional rain will invariably entail losses, especially for rain-fed only agriculture, some of which are certainly accounted for under the Agriculture indicator. The Drought indicator also measures farm losses due to extreme water scarcity. Independent from this, the Water indicator measures national variation in the water resource balance sheet and assumes that deficits due to climate change are made up at the lowest market price for water.

Where agriculture is rain-fed only, there is no overlap, since such farmers are not purchasing water on the market and are therefore not accounted for in water demand estimations. Where farmers rely on supplied irrigation, deviations from optimal conditions likely cause demand for water to increase as the farmer pays for the additional requirement (and incurs a cost). Alternatively, more water may not be purchased and yield losses could result (also incurring costs). But what the Water indicator measures is the overall change in supply to the market that the farmer purchases water from. It assumes that in order to maintain the same supply of water that existed prior to the onset of unfavourable conditions, costs will be incurred at the market rate for supplying more water.

That means it is accounting for the cost of retaining equilibrium market conditions to offset any scarcity at the time when the farmer is purchasing additional water. Of course, if the entire agricultural sector is purchasing more water, demand will also increase and so will the market price and the losses for the sector. Such intricacies can rarely be accounted for in agriculture models such as those the Monitor draws on for that indicator (Cline, 2007). Therefore, any overlap is largely contained.

CARBON: CONCEPTUAL FRAMEWORK

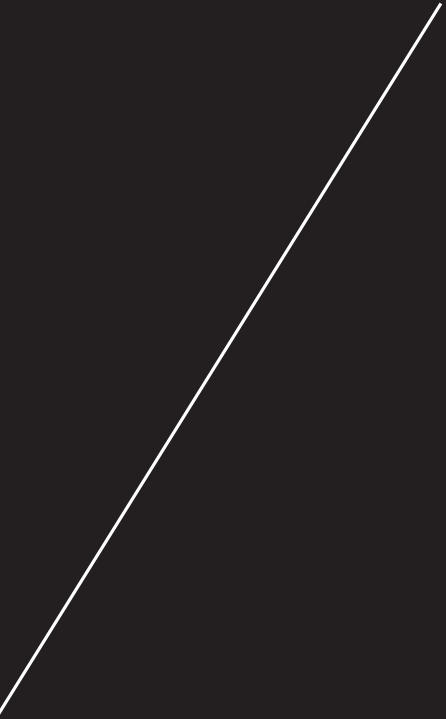
The new Monitor now supplements analysis with a detailed assessment of the economic, health and environmental impacts of the carbon economy. This assessment forms the second part of the Monitor, labelled "Carbon". Of special interest in the Carbon part of the Monitor is the acquisition and consumption of fuels and the release of various types of greenhouse pollutants via combustion. The Monitor examines the costs and benefits of all these processes – extraction, production, consumption – independently of the wide-ranging costs and benefits resulting from climate change, which, of course, is caused by these processes.

It is important to qualify three points related to the Carbon section. First, highly hazardous sulphur dioxide emissions are included in the analysis, although strictly speaking, sulphur is not a GHG and is even widely understood to have cooling, rather than warming, properties (Kaufmann et al., 2011; Smith et al., 2011). Other research, however, has asserted that sulphur is a principal initiator of global warming since it decreases the atmosphere's capacity to oxidize and deplete GHGs (Ward, 2009). Either way, sulphur dioxide is typically emitted together with other GHGs in transportation and energy production – coal power, in particular, which is also responsible for 40% of CO₂ emissions – and various mitigation policies targeting these gases would in most instances implicate sulphur dioxide as well (Olivier et al., 2012). Hence sulphur emissions go hand in hand with a carbon economy and are largely incompatible with a low-carbon economy.

Second, when the Monitor discusses urban air pollution and indoor smoke concerns for human

health, it includes the burning of biomass (e.g. wood, crop waste), especially in open or indoor fires, which may not necessarily contribute to global warming if the source of fuel is self-replenishing (such as crop waste). With nearly 3 billion people relying on traditional stoves for household needs worldwide, however, particulate-generating cooking stoves are still considered a major source of GHGs and, especially in arid countries with low biomass availability, can drive deforestation (Foell et al., 2011; Bensch and Peters, 2011). The burning of biomass, including in indoor settings, is in any case understood as a principal driver of current warming due to concentrated emissions of soot in highly populated tropical regions (Ramanathan and Carmichael, 2008). Measures to furnish clean burning stoves to households would also enhance GHG sinks. The Monitor did not, therefore, exclude this issue from the analysis.

The third issue relates to carbon fertilization, which is a phenomenon measured in the Carbon section (see: Carbon/Agriculture). However, the Hunger indicator in the Climate section (see: Climate/Hunger) nevertheless accounts for the positive role that carbon fertilization can play in reducing the degree of agricultural losses on the basis of a World Health Organization model (WHO, 2004).



DATA TABLES

	TOTAL		1,000s		% GDP PPP		% GDP PPP		% GDP PPP		
	2010	2030	2010	2030	2010	2030	2010	2030	2010		
Afghanistan					90,000	150,000	10,000	20,000	2.8%	4.9%	5.5%
Angola					45,000	45,000	10,000	15,000	4.1%	7.9%	9.2%
Armenia					3,000	3,000	95	95	0.6%	1.2%	0.5%
Bahamas					30	35	95	100	5.8%	15.8%	
Belize					45	55	30	40	7.7%	14.2%	5.3%
Benin					9,000	9,500	1,250	1,750	5.0%	10.2%	2.7%
Bolivia					3,000	3,500	1,000	1,500	3.3%	7.5%	8.8%
Bulgaria					7,000	6,000	85	80	0.7%	1.5%	0.7%
Burkina Faso					25,000	30,000	3,250	3,750	4.5%	8.6%	3.0%
Burundi					15,000	15,000	1,500	2,000	3.9%	8.7%	3.5%
Cambodia					15,000	20,000	1,750	2,000	4.9%	10.3%	2.7%
Cameroon					20,000	20,000	4,000	5,000	4.4%	9.0%	4.3%
Central African Republic					5,500	5,500	650	900	5.6%	11.9%	13.5%
Chad					20,000	20,000	2,500	3,000	5.0%	9.5%	3.1%
China					1,500,000	1,500,000	100,000	100,000	0.7%	1.3%	0.7%
Congo					3,500	4,500	450	650	3.4%	6.5%	8.0%
Cote d'Ivoire					25,000	25,000	2,250	3,250	4.6%	8.9%	3.7%
Dominica					15	15	60	80	5.9%	11.7%	0.1%
DR Congo					100,000	100,000	15,000	20,000	3.9%	8.5%	7.1%
Equatorial Guinea					250	350	250	350	3.1%	5.8%	5.0%
Fiji					300	300	95	95	6.2%	11.1%	0.2%
Gabon					700	950	250	350	5.8%	11.1%	23.1%
Gambia					1,500	1,000	250	300	9.0%	18.2%	1.7%
Guinea					10,000	10,000	1,250	1,500	8.0%	16.3%	4.3%
Guinea-Bissau					2,500	2,500	450	600	27.4%	47.2%	5.9%
Guyana					250	200	150	200	7.4%	12.6%	40.5%
Honduras					2,500	3,000	350	650	4.6%	9.0%	1.5%
India					1,000,000	1,500,000	250,000	450,000	2.2%	4.3%	1.0%
Kiribati					15	20	85	95	17.4%	28.1%	0.1%
Laos					4,000	4,500	650	800	3.5%	7.1%	3.0%
Liberia					6,000	7,000	600	700	9.9%	17.5%	6.1%
Madagascar					20,000	20,000	2,250	2,750	6.8%	11.8%	3.1%
Malaysia					5,500	8,000	2,750	3,250	3.6%	7.3%	2.2%
Maldives					70	150	250	350	9.2%	15.9%	0.2%
Mali					25,000	25,000	3,000	3,500	5.7%	11.9%	3.3%
Marshall Islands					30	35	55	60	31.3%	49.6%	0.4%
Mauritania					3,500	3,500	350	400	9.0%	16.6%	1.4%
Micronesia					30	35	20	25	10.3%	20.7%	0.3%
Mongolia					1,500	1,500	600	1,250	6.5%	8.4%	1.9%
Mozambique					25,000	25,000	6,000	8,500	7.7%	14.2%	3.6%
Myanmar					45,000	55,000	10,000	15,000	6.6%	12.9%	0.8%
Namibia					450	550	150	250	1.4%	13.5%	1.2%
Nicaragua					1,500	2,000	200	400	6.3%	11.8%	2.4%
Niger					35,000	40,000	4,000	4,500	5.3%	10.0%	4.9%
Pakistan					150,000	250,000	20,000	45,000	2.3%	4.4%	1.0%
Palau					5	5	5	5	8.6%	15.2%	0.1%

ACUTE

ACUTE

SEVERE

	👤+👤		👤+👤		👤		👤		👤	
	👤+👤		👤		👤		👤		👤	
	2010	2030	2010	2030	2010	2030	2010	2030	2010	
Panama	550	650	250	400	4.2%	8.4%	2.1%			
Papua New Guinea	3,500	5,000	850	1,500	6.6%	12.1%	11.6%			
Paraguay	1,000	1,500	150	250	1.3%	3.0%	4.7%			
Rwanda	20,000	15,000	1,500	2,000	2.4%	4.5%	3.6%			
Sao Tome and Principe	100	100	20	35	9.1%	15.8%	1.3%			
Senegal	15,000	15,000	1,500	2,000	6.2%	12.3%	1.9%			
Seychelles	10	10	20	30	8.1%	19.1%				
Sierra Leone	15,000	15,000	1,500	1,750	10.4%	20.5%	7.4%			
Solomon Islands	200	250	100	150	21.1%	34.1%	0.4%			
Somalia	20,000	20,000	3,000	4,000	16.7%	25.9%	3.4%			
Suriname	150	150	90	100	4.0%	7.2%	25.1%			
Timor-Leste	250	250	150	200	8.7%	16.0%	5.8%			
Togo	7,500	7,000	700	1,000	5.1%	10.2%	2.5%			
Tuvalu	5	5	10	10	11.0%	23.1%	0.4%			
Ukraine	45,000	40,000	3,250	4,000	0.8%	1.4%	0.4%			
Vanuatu	75	100	35	50	21.1%	44.8%	0.2%			
Vietnam	55,000	65,000	20,000	25,000	5.2%	10.7%	0.8%			
Zambia	15,000	15,000	1,750	2,250	3.1%	7.1%	5.2%			
Antigua and Barbuda	10	10	60	75	5.1%	10.6%	0.1%			
Bangladesh	100,000	150,000	55,000	70,000	2.8%	6.8%	0.9%			
Belarus	5,500	5,500	100	150	0.7%	1.2%	0.7%			
Bosnia and Herzegovina	3,000	3,000	150	300	0.5%	1.0%	0.5%			
Botswana	1,000	850	200	250	0.9%	1.5%	3.3%			
Brunei	35	55	100	150	0.5%	0.7%	3.5%			
Cape Verde	90	85	85	150	5.8%	10.6%	0.2%			
Colombia	10,000	15,000	1,250	2,000	2.6%	5.2%	1.5%			
Comoros	300	300	90	95	4.5%	7.5%	0.9%			
Costa Rica	700	850	100	200	3.1%	6.3%	0.6%			
Djibouti	550	600	200	300	3.6%	6.6%	0.4%			
El Salvador	1,500	1,500	300	500	3.6%	7.2%	0.5%			
Eritrea	3,000	3,000	300	450	5.2%	8.6%	1.3%			
Ethiopia	100,000	100,000	10,000	15,000	2.0%	3.7%	2.7%			
Georgia	3,500	3,500	150	150	1.5%	2.9%	0.7%			
Ghana	15,000	15,000	2,250	2,750	4.4%	8.9%	1.7%			
Grenada	10	10	25	30	5.2%	10.3%	0.1%			
Guatemala	3,500	5,000	1,750	2,500	2.9%	5.8%	0.8%			
Haiti	8,000	9,000	1,500	1,750	3.7%	7.1%	1.2%			
Indonesia	150,000	200,000	30,000	40,000	3.5%	7.0%	1.8%			
Jamaica	1,000	1,500	200	300	3.9%	8.1%	0.2%			
Kazakhstan	9,000	10,000	250	350	0.3%	0.4%	0.4%			
Kyrgyzstan	4,000	4,500	600	1,000	4.2%	6.0%	0.7%			
Latvia	1,500	1,500	75	75	0.1%		0.3%			
Macedonia	1,000	1,000	20	20	0.9%	1.8%	0.5%			
Malawi	20,000	20,000	2,000	2,500	3.2%	7.4%	2.6%			
Mexico	25,000	40,000	5,000	8,250	3.1%	6.1%	0.7%			
Moldova	2,500	2,500	40	40	0.2%	0.4%	0.3%			

👤 Additional mortality - yearly average

💰 Additional economic costs in 2010 USD (negative numbers show gains) - yearly average

👤 Additional persons affected - yearly average

SEVERE

HIGH

	TOTAL		1,000s		% GDP PPP		% GDP PPP		
	2010	2030	2010	2030	2010	2030	2010		
Nigeria		200,000	200,000	20,000	25,000	4.0%	7.6%	2.3%	
North Korea		9,500	10,000	3,500	4,500	7.0%	10.9%	0.2%	
Peru		7,000	9,000	1,750	2,500	1.3%	3.0%	2.8%	
Philippines		35,000	50,000	9,000	10,000	3.5%	7.1%	0.9%	
Romania		15,000	15,000	300	300	0.6%	1.1%	0.4%	
Russia		100,000	80,000	8,000	15,000	0.7%	0.8%	1.0%	
Samoa		65	70	25	35	5.2%	9.9%	0.3%	
Sri Lanka		8,500	9,000	1,500	2,250	3.6%	7.4%	0.6%	
Tajikistan		6,000	7,000	450	600	1.5%	2.6%	1.0%	
Thailand		25,000	30,000	7,500	9,000	3.6%	7.2%	0.6%	
Tonga		35	40	75	100	5.3%	9.6%	0.2%	
Turkey		35,000	50,000	2,500	4,000	0.6%	1.2%	0.5%	
Uganda		30,000	35,000	4,000	5,750	2.3%	5.4%	2.4%	
Venezuela		5,000	6,500	1,500	1,750	3.1%	6.2%	1.3%	
Albania		850	950	100	150	0.6%	1.2%	0.3%	
Argentina		15,000	15,000	1,500	2,000	1.0%	1.5%	1.6%	
Australia		4,000	6,500	2,500	2,750	0.5%	0.8%	1.1%	
Austria		1,500	2,000	45	65	0.6%	1.2%	0.2%	
Azerbaijan		4,500	4,500	250	200	0.4%	0.7%	0.4%	
Barbados		25	25	35	45	2.5%	5.2%	0.1%	
Belgium		2,000	2,500	2,250	2,500	0.1%		0.1%	
Bhutan		400	600	150	250	2.0%	3.0%	1.9%	
Brazil		55,000	70,000	10,000	15,000	0.7%	1.4%	1.9%	
Canada		4,500	6,500	1,250	2,000	0.2%	0.1%	1.4%	
Chile		4,500	6,000	650	900	1.0%	1.9%	0.8%	
Croatia		1,500	2,000	200	350	1.4%	2.8%	0.3%	
Cuba		4,500	5,000	500	600	2.7%	5.4%	0.4%	
Cyprus		350	450	40	55	0.3%	0.6%	0.1%	
Czech Republic		2,500	3,000	25	30	0.4%	0.8%	0.2%	
Denmark		1,000	1,500	1,250	1,250	-0.1%	-0.3%	0.2%	
Dominican Republic		3,000	3,500	550	950	2.4%	4.8%	0.3%	
Ecuador		2,000	2,500	850	1,250	0.5%	1.3%	1.3%	
Egypt		25,000	30,000	4,000	6,000	0.5%	1.0%	0.2%	
Estonia		250	300	15	20	0.8%	0.7%	0.6%	
Finland		900	1,000	300	300	-0.8%	-1.6%	0.6%	
France		10,000	15,000	3,500	4,500	0.5%	0.9%	0.1%	
Germany		15,000	20,000	3,250	3,750			0.1%	
Greece		4,500	5,000	500	650	0.6%	1.1%	0.2%	
Hungary		3,500	4,500	45	50	0.2%	0.4%	0.3%	
Iceland		60	80	35	35	-0.3%	-2.6%	0.1%	
Iran		25,000	50,000	2,000	3,000	0.7%	1.5%	0.3%	
Iraq		10,000	20,000	3,000	7,250	0.6%	1.3%	0.5%	
Israel		2,000	3,500	50	75	0.1%	0.1%	0.1%	
Italy		15,000	15,000	3,000	4,250	0.1%	0.3%	0.1%	
Japan		35,000	40,000	6,750	7,500	0.1%	0.1%	0.2%	
Jordan		2,000	3,000	150	200	0.1%	0.3%	0.1%	

Additional mortality - yearly average

Additional economic costs in 2010 USD (negative numbers show gains) - yearly average

Additional persons affected - yearly average

PARTNERS

ABOUT THE CLIMATE VULNERABLE FORUM

Founded in 2009, the Climate Vulnerable Forum is a semi-formal group of developing countries facing high degrees of insecurity due to climate change and actively seeking a concerted response to the climate crisis. Advocating ambitious directions for international climate change policy, the Forum proposed setting the temperature increase goal at 1.5° Celsius (2.7° Fahrenheit). This target was subsequently taken up by other groups of countries and played an important boundary definition role in the UN climate negotiations at Copenhagen in 2009 (COPP15). The Forum has insisted that decisions agreed at international talks on climate change and sustainable development be subject to accountability. Its members have committed themselves to low-carbon (Or even carbon neutral) national development pathways. The Forum currently has 20 members and meets periodically at head of government, ministerial and delegate levels. The Monitor is an analytical input and communication tool for Forum members. The two country studies included in this report (Ghana and Vietnam) were undertaken in member countries.

ABOUT DARA

Founded in 2003, DARA is an international organization headquartered in Madrid, Spain, committed to improving the effectiveness of aid for vulnerable populations suffering from conflict, disasters and climate change. It is an impartial, non-partisan and independent non-profit entity. DARA is actively engaged in field research and evaluation of aid programmes and operations in developing countries. Its specialized publications present data and analysis on aid accountability and effectiveness and emerging strategic concerns for the development, humanitarian and disaster reduction communities. DARA's Climate Vulnerability Initiative is mandated to develop the Monitor as an independent and politically impartial report. DARA convenes the external advisory bodies that provide third-party guidance and review inputs to this process. DARA alone is solely responsible for the final content of the report.

OTHER KEY PARTNERS AND SUPPORTERS

DARA is grateful to the number of partners with whom it has worked collaboratively in the development of this report.

Technical, quantitative and theoretical assistance has been provided by Commons Consultants, an advisory group based in Copenhagen, Denmark.

The Monitor's research contributes to Facilitating Enhanced Organizational Responsiveness West African Risk Reduction (FOREWARN), an initiative of the Humanitarian Futures Programme based at King's College, London. FOREWARN is supported by the Australian Agency for International Development (AusAID). FOREWARN is a collaborative project supporting the Economic Community of West African States (ECOWAS) to improve regional risk reduction capacity. It brings together DARA, the UN International Strategy for Disaster Reduction (UNISDR) and King's College programmes, including its African Leadership Centre. Research in Ghana which contributed to the Monitor was undertaken as a component of the FOREWARN initiative. Country research in Ghana was organized in close collaboration and with the support of the country's Environmental Protection Agency (EPA-Ghana) and its partners, the Ministry of Environment, Science and Technology and the National Disaster Management Organization (NADMO).

The Spanish International Development Cooperation Agency (AECID) funded the Monitor's country activities in Vietnam and supported the Monitor's development more generally. Research in Vietnam was organized by Live & Learn Vietnam with the participation of the Ministry of Natural Resources and Environment.

The Monitor's development additionally benefitted from the financial support of Fundación Biodiversidad, a public foundation of the Spanish government.

Additionally, UNDP country offices in Ghana and Vietnam facilitated and participated in country research activities.

ABBREVIATIONS

AECID: Agencia Española de Cooperación Internacional para el Desarrollo	EAC: Economics of Climate Adaptation Working Group	on Emissions Scenarios	PPP: Purchasing power parity adjusted/international dollar
AUSAID: Australian Agency for International Development	ECLAC: Economic Commission for Latin America and the Caribbean	ISO: International Organization for Standardization	RIO+20: United Nations Conference on Sustainable Development, "Earth Summit 2012", Rio de Janeiro, 13 th -22 nd June, 2012
BRIC: Brazil, Russia, India, and China	ECOWAS: Economic Community of West African States	IT: Information Technology	RSNZ: The Royal Society of New Zealand
°C: Celsius/Centigrade	EDGAR: Emission Database for Global Atmospheric Research	Kt CO ₂ : Kilotonne CO ₂	SIDSs: Small Island Developing States
CAPP: Canadian Association of Petroleum Production	EPA: Environmental Protection Agency	LDCs: Least Developed Countries	SO ₂ : Sulphur Dioxide
CAR: Central African Republic	ERC: Environmental Research Consulting	LLDCs: Landlocked Developing Countries	UNCCD: United Nations Convention to Combat Desertification
CCS: Carbon capture and storage	EU: European Union	MAD: Mean absolute deviation	UNDP: United Nations Development Programme
CDC: Centers for Disease Control and Prevention	F: Fahrenheit	MDGs: Millennium Development Goals	UNECE: United Nations Economic Commission for Europe
CDM: Clean Development Mechanism	FAO: United Nations Food and Agriculture Organization	Munich Re: Münchener Rückversicherungs-Gesellschaft (Munich Reinsurance Company)	UNEP: United Nations Environment Programme
CE: Climate Effect	FOREWARN: Facilitating Enhanced Organizational Responsiveness West African Risk Reduction	NADMO: National Disaster Management Organization	UNESCO: United Nations Educational, Scientific and Cultural Organization
CER: Certified Emission Reductions	G20: Group of Twenty Finance Ministers and Central Bank Governors	NAPA: National Adaptation Programme for Action	UNFCCC: United Nations Framework Convention on Climate Change
CFCS: Chlorofluorocarbons	GDP: Gross Domestic Product	NATO: North Atlantic Treaty Organization	UNHRC: United Nations High Commissioner for Refugees
CIESIN: Columbia University's Center for International Earth Science Information Network	GEF: Global Environment Facility	NASA: National Aeronautics and Space Administration	UNISDR: UN International Strategy for Disaster Reduction
CIF: Climate Impact Factor/Carbon Impact Factor	GHF: Global Humanitarian Forum	NASA GISS: NASA Goddard Institute for Space Studies	UNICEF: United Nations Children's Fund
CO ₂ : Carbon Dioxide	GHG: Greenhouse gases	NESDIS: National Environmental Satellite, Data, and Information Service	US EIA: United States Energy Information Administration
COP15: UN climate negotiations at Copenhagen in 2009	GIM: Generation Investment Management LLP	NOAA: National Oceanic and Atmospheric Administration	US EPA: United States Environmental Protection Agency
CRED: Centre for Research on the Epidemiology of Disasters	GNP: Gross National Product	O ₃ : Ozone	USDAAF: United States Department of the Army and Air Force
CRED/EM-DAT: CRED/Emergency Events Database	GTZ: Deutsche Gesellschaft für Technische Zusammenarbeit	ODA: Official Development Assistance	USEIA: U.S. Energy Information Administration
CRISIS: Center for Remote Sensing of Ice Sheets	GWh: Gigawatt hour	OECD: Organisation for Economic Co-Operation and Development	UNISDR: United Nations International Strategy for Disaster Reduction
CTI: The Carbon Tracker Initiative	HCFCs: Halocarbons	OPEC: Organization of the Petroleum Exporting Countries	UNSD: United Nations Statistics Division
CVI: Climate Vulnerability Initiative	IAP: Interacademy Panel on International Issues	OSDG: Oil Sands Developers Group	WBG: Wet Bulb Globe Temperature
CVF: Climate Vulnerable Forum	IEA: International Energy Agency	ORS: Oral rehydration solution	WHO: World Health Organization
CWP: Coal Worker's Pneumoconiosis	IFRC: The International Federation of Red Cross and Red Crescent Societies	ORT: Oral rehydration therapy	WRI: World Resources Institute
DALY: Disability-adjusted life year	ILO: International Labour Organization	pH: Water Acidity	
DCPP: Disease Control Priorities Project	IMF: International Monetary Fund	PPM: Parts Per Million	
DIVA: Dynamic Interactive Vulnerability Assessment	IPCC: Intergovernmental Panel on Climate Change		
DR Congo: Democratic Republic of the Congo	IPCC SRES: IPCC Special Report		

GLOSSARY

ADAPTATION

An action or response that helps communities or their ecosystems cope with a changing climate. In particular, steps that reduce any losses or harm inflicted - the possible levels of which the Climate section of the Monitor attempts to estimate.

ADAPTIVE CAPACITY

The ability of a system to adjust to climate change, variability and extreme to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

AFFECTED COMMUNITIES

Communities that have seen their livelihoods compromised temporarily or permanently by climate change.

ANTHROPOGENIC

Produced as a result of human activity.

BLACK CARBON

An aerosol rich in carbon that absorbs sunlight and gives soot its black color. It is produced both naturally and by human as a result of the incomplete combustion of fossil fuels, biofuels, and biomass.

BIODIVERSITY

The international definition of biodiversity is “variability among living organisms” (CBD, 1992).

CARBON

The term “Carbon” is used as the moniker for the second part of the Monitor’s assessment, which broadly speaking deals with socio-economic effects of the carbon economy. Carbon dioxide (CO₂) is a principal greenhouse gas along with numerous other “heat-trapping” pollutants, such as methane, black carbon or nitrous oxide. Like these other pollutants, CO₂ is typically generated as a by-product of combustion when fuels of many different kinds are burned.

CARBON DIOXIDE (CO₂)

A naturally occurring gas and a by-product of burning fossil fuels, land use changes, and other industrial processes and is the main greenhouse gas that causes atmospheric temperature changes.

CLIMATE

Climate is taken to mean the average weather. The classical time period used by the World Meteorological Organization to determine the climate is 30 years. So the climate is the average weather over a given period of 30 years. Parameters such as temperature, rainfall and wind can be examined to determine key characteristics of the state of the climate at different periods in time, and to identify variation across time periods.

CLIMATE CHANGE

Climate change is a change in average weather. For the purpose of this study, it is assumed that human activities are the principal and overwhelming – if not exclusive – cause of the contemporary warming of the climate, in accordance with the broad consensus and more recent evidence on this subject (IPCC, 2007; Rohde et al., 2012; Muller, 2012). According to the UN Framework Convention on Climate Change, climate change is also in addition to natural climate variability (UNFCCC, 1992).

CLIMATE DISPLACED PEOPLE

Persons displaced temporarily or permanently due to climate change and its impacts or shocks, notably land desertification, sea-level rise and weather-related disasters. It is almost never possible to identify an individual as exclusively a climate displaced person due to the range of factors that are likely involved in forced or voluntary movement of people.

CLIMATE EFFECT

Indicates the relative effects of climate change on social and economic variables at the country level. It is calculated based on observed values of social and economic variables and the effects of climate change.

Climate Impact Factor

The relative contribution of climate change to the development of a given variable.

CLIMATE MODEL

Numerical representations of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes. They account for all or some of its known properties.

CLIMATE SCENARIO

Probable representations of the future which are consistent with assumptions about future GHG emissions and other pollutants based on existing understanding of the effect of increased atmospheric concentrations GHGs on the global climate.

CLIMATE VULNERABILITY

The degree to which a community experiences harm (or not) as a result of a change in climate. Vulnerability encapsulates socio-economic concerns, such as income levels, access to information, education, social safety nets and other meaningful determinants of the resilience of a given community. It also encapsulates environmental or so-called "bio-physical" factors, such as geographic location, topography, natural resource supplies, vegetation and otherwise.

CLIMATE VULNERABILITY LEVEL

Aggregate vulnerability levels indicates the extent to which countries are affected in comparison with effects experienced by all other countries. Vulnerability levels are determined statistically, using mean absolute standard deviations.

CLIMATE VULNERABILITY MONITOR

The Climate Vulnerability Monitor provides a global overview of vulnerability to climate change and the carbon economy. It provides fair estimates of the types of impacts already faced by society. It also shows where the impacts are taking place and captures the evolving global vulnerability to climate change/carbon economy.

CONFIDENCE

Degree of accuracy and repeatability of a statistical test.

COST-EFFECTIVENESS

Refers to the relationship between the economic input/cost of a given adaptation measure and the degree of beneficial output.

DESERTIFICATION

Land degradation in arid, semi-arid and sub-humid areas resulting from various factors including climatic variations and human activities (UNCCD, 2010).

DEVELOPMENT AID

Aid to support the economic, social, and political development of developing countries. The aim is to alleviate poverty in the long run. It is often termed Official Development Assistance (ODA).

DISABILITY-ADJUSTED LIFE YEAR (DALY)

This time-based measure combines years of life lost due to premature death and years of life lost due to time lived in states of less than full health. The DALY metric was developed in the original Global Burden of Disease 1990 study to assess the burden of disease consistently across diseases, risk factors, and regions.

DISASTER RISK REDUCTION

A framework for assessing measures for minimizing vulnerabilities and disaster risks throughout a society, to prevent or limit the adverse impacts of hazards.

DROUGHT

In general terms, drought is a recurring extreme climate event that, over a period of months or years, has precipitation levels that are below-normal (Dai, 2010).

EMISSION SCENARIO

Emissions scenarios describe future releases into the atmosphere of greenhouse gases, aerosols, and other pollutants and, along with information on land use and land cover, provide inputs to climate models. They are based on assumptions about driving forces such as patterns of economic and population growth, technology development, and other factors. Levels of future emissions are highly uncertain, so scenarios provide alternative images of how the future might unfold (WMO, 2012).

ENVIRONMENTAL DISASTERS

Disasters that are generated in whole or in part through human activities. This report measures the role of climate change or the carbon economy in extreme weather events or geographically restricted pollution disasters. Extreme weather events affected by climate change are natural phenomena, but their aggravation through climate change constitutes a human-induced contribution and influence on the final scale of disaster – disasters are also widely understood as socially constructed regardless of the natural phenomenon involved.

EXPOSURE TO CLIMATE CHANGE

Exposure to physical manifestations of alterations in weather conditions and the environment as a result of climate change. See also “Vulnerability - Physical vulnerability to climate change”.

EXTREME WEATHER EVENT

Infrequent meteorological events having a significant impact on the society or ecosystem in a specific location.

FOOD SECURITY

Refers to the availability of food and people’s access to it. A household is food secure when its occupants do not live in hunger or fear of starvation.

FOSSIL FUEL EMISSIONS

Emissions of greenhouse gases resulting from the combustion of fuels from fossil carbon deposits such as oil, gas and coal.

GLOBAL DIMMING

Reductions in solar radiation that reaches the Earth’s surface during the last 50 years (Stanhill and Cohen, 2005).

GREENHOUSE EFFECT

Greenhouse gasses effectively absorb thermal infrared radiation, emitted by the Earth’s surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth’s surface. Thus, greenhouse gases trap heat within the surface-troposphere system (IPCC, 2007).

GREENHOUSE GASES (GHG)

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth’s surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect.

HABITAT CHANGE

Refers to shifts, changes or loss of human and ecological habitats due to climate change impacts.

HEALTH IMPACT

The impacts of climate change that have an effect (positive or negative) on human health.

HYDRO ENERGY

A “green energy” source in which running water is used to turn turbines, which in turn generates electrical energy (Eon Energy Lab, 2012).

HUMANITARIAN AID

Activities involving protection of civilians and those no longer taking part in hostilities, and provision of material or logistical assistance for people affected by humanitarian crises and to facilitate their return to normal lives and livelihoods.

INDUSTRY STRESS

The effect of climate change on specific industry sectors captured in this report is based on e.g. fisheries, forestry, and agricultural losses or gains.

LANDSLIDES

Landslides occur when masses of rock, earth or debris move down a slope and are caused by disturbances in the slope’s natural stability. They often accompany heavy rains, droughts, earthquakes, or volcanic eruptions. This report only considers weather-related landslides.

MITIGATION

Mitigation is broadly understood as human actions and interventions that stem global warming, i.e. that mitigate the warming effect.

OCEAN ACIDIFICATION

The ocean absorbs approximately one third of the carbon dioxide emitted to the atmosphere from the burning of fossil fuels. As carbon dioxide dissolves in seawater, the pH of the water decreases, which is called "acidification"(Ocean Acidification Network).

OIL SANDS

Oil sands are a major source of unconventional oil for fuel/energy. They comprise a mixture of sand, water, clay and bitumen. Bitumen is oil that needs to be diluted or heated in order to be pumped due to its heaviness or thickness (CAPP, 2012).

PERMAFROST

Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (IPA, 2012).

PROJECTION

A future value calculated according to predetermined changes in the assumptions of the environment (IPCC, 2007).

RESILIENCE

The ability of a community or ecosystem to recover from, return to equilibrium, or bounce back following a shock.

SCENARIO

Model-generated set of market projections based on assumptions other than those used in the baseline. They are used to provide quantitative information on the impact of changes in assumptions on the outlook.

SEA-LEVEL RISE

The rising of sea-levels due mostly to thermal expansion and the melting of land-based ice.

SINK

Any process, activity or mechanism that removes a greenhouse gas, an aerosol, or a precursor of either from the atmosphere.

SOCIO-ECONOMIC IMPACT

Refers to climate change impacts of both social and economic character, comprising for instance mortality, illness (social) or monetary losses (economic).

SRES SCENARIOS

Emission scenarios developed the IPCC.

VULNERABILITY

The conditions determined by physical, social, economic, and environmental factors or

processes, which increase the susceptibility of a community to the impact of hazards.

VULNERABILITY - PHYSICAL VULNERABILITY TO CLIMATE CHANGE

Refers to people who live in regions that are prone to more than one type of physical manifestation of climate change: floods, storms, droughts, sea-level rise, etc (similar to "exposure").

VULNERABILITY - SOCIO-ECONOMIC VULNERABILITY TO CLIMATE CHANGE

Refers to the capacity of individuals, communities, ecosystems, economies, and societies to adapt to climate change impacts and avoid suffering from long-term, potentially irreversible, losses in well-being and stability. Also referred to as "underlying vulnerabilities".

WEATHER-RELATED DISASTERS

Natural disasters that are related to weather patterns, such as floods, droughts, and heat waves. Geophysical disasters such as earthquakes are not considered by this report.

WET BULB GLOBE TEMPERATURE (WBGT)

Composite temperature for estimating temperature, humidity, wind chill and solar radiation effect on humans.

BIBLIOGRAPHY

Ackerman et al. (2009)

F. Ackerman, S.J. DeCanio, R. B. Howarth, K. Sheeran (2009)
Limitations of integrated assessment models of climate change
Climatic Change, vol. 95:3-4, pp. 297-315

Ackerman and Stanton (2011)

Frank Ackerman and Elizabeth A. Stanton (2011)
Climate Economics: The State of the Art
Stockholm Environment Institute-U.S. Center

Adamo et al. (2011)

S. Adamo, S. Trzaska, G. Yetman, J. del Corral, M. Thomson, and C. Perez (2011)
Integration of Demographic, Climate, and Epidemiological Factors in the Modeling of Meningococcal Meningitis Epidemic Occurrence in Niger.
Poster presented at the 2011 Annual Meeting of the Population Association of America in Washington, D.C., March 30-April 1.
Retrieved:
http://www.ciesin.org/documents/adamo-model-meningococcal_paa_mar2011.pdf

Adeel et al. (2005)

Zafar Adeel, Uriel Safriel, David Niemeijer, and Robin White (2005)
Ecosystems and Human Well-being .
Desertification Synthesis. A Report of the Millennium Ecosystem Assessment
Washington, DC, US: World Resources Institute,.

Adger et al. (2003)

W. N. Adger, S. Huq, K. Brown, D. Conway and M. Hulme (2003)
Adaptation to climate change in the developing world
Progress in Development Studies, vol. 3, no. 3, pp. 179-195

Aerts and Droogers (2009)

J. Aerts and P. Droogers (2009)
Climate Change in the Water Sector
In: P. Kabat, F. Ludwig, M. van der Valk and H. van van Schaik (eds): *Climate Change Adaptation in the Water Sector* (pp.87-107)
London, UK: Earthscan

Agnew (2012)

Robert Agnew (2012)
Dire forecast: A theoretical model of the impact of climate change on crime
Theoretical Criminology, vol. 16 no. 1, pp. 21-42

Agnew et al. (2009)

D. J. Agnew, J. Pearce, G. Pramod, T. Peatman, R. Watson, J. R. Beddington and T. J. Pitcher (2009)
Estimating the Worldwide Extent of Illegal Fishing
Plos one, vol.4, no.2

Agrawal et al. (2008)

M. Agrawal, M. Auffhammer, U.K. Chopra, L. Emberson, M. lyngararasan, N. Kalra, M.V. Ramana, V. Ramanathan, A.K. Singh and J. Vincent (2008)
Impacts of Atmospheric Brown Clouds on Agriculture
Part II of Atmospheric Brown Clouds: Regional Assessment Report with Focus on Asia
Nairobi, Kenya: United Nations Environment Programme

Ahmed (2008)

E. W. Ahmed (2008)
Process water treatment in Canada's oil sands industry: I. Target pollutants and treatment objectives
Environmental Engineering Science, vol. 7, pp. 123-138

Ahmed et al. (2009)

S. A. Ahmed, N. S. Diffenbaugh and T. Whertel (2009)
Climate volatility deepens poverty vulnerability in developing countries
Environmental Research Letters, vol. 4, no. 3 (8pp)

Ahrens and Rudolph (2006)

J. Ahrens and P.M. Rudolph (2006)
The Importance of Governance in Risk Reduction and Disaster Management
Journal of Contingencies and Crisis Management, vol. 14, Iss.4, pp. 207-220

Ahsan et al. (2011)

S. Ahsan, M. S. Aili, M. R. Hoque, M. S. Osman, M. Rahman, M. J. Babar, S. A. Begum, D. M. Rahman and K. R. Islam (2011)
Agricultural and Environmental Changes in Bangladesh in Response to Global Warming
In: R. Lal et al. (eds): *Climate Change And Food Security In South Asia* (Part 3, pp.119-134)
Springer Science and Business Media

Ainsworth et al. (2008)

E. Ainsworth, A.D.B. Leakey, D.R. Ort and S.P. Long (2008)
FACE-ing the facts: inconsistencies and interdependence among field, chamber and modeling studies of elevated [CO₂] impacts on crop yield and food supply
New Phytologist (2008), Letters

Akpinar-Ferrand and Singh (2010)

Ezgi Akpinar-Ferrand and Ashbindu Singh(2010)
Modeling increased demand of energy for air conditioners and consequent CO₂ emissions to minimize health risks due to climate change in India
Environmental Science and Policy, vol. 13, Iss. 8, pp. 702-712

Akyeampong (2001)

Emmanuel Kwaku Akyeampong (2001)
Between the Sea & the Lagoon: An Eco-social History of the Anlo of Southeastern Ghana c. 1850 to recent times
Athens, Ohio, Ohio University Press

Allen et al. (2009)

C.D. Allen, A. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, P. Gonzales, T. Hogg, A. Rigling, D.D. Breshears, R. Fensham, Z. Zhang, T. Kitzberger, J.-H. Lim, J. Castro, S. W. Running, G. Allard, A. Semerci, and N.Cobb (2009)
Climate-induced forest mortality: a global overview of emerging risks
Forest Ecology and Management, vol. 259, iss.4, pp. 660-684

Allen and Ingram (2002)

Myles R. Allen and William J. Ingram (2002)
Constraints on future changes in climate and the hydrologic cycle
Nature - insight review articles, vol. 419 , pp. 224-232

Allison et al. (2009)

E. H. Allison, A. L. Perry, M. Badjeck, W. N. Adger, K. Brown, D. Conway, A. S. Halls, G. M. Pilling, J. D. Reynolds, N. L. Andrew and N. K. Dulvy (2009)
Vulnerability of national economies to the impacts of climate change on fisheries
Fish and Fisheries, vol.10, iss.2, pp.173-196

Amelung et al. (2007)

Bas Amelung, Sarah Nicholls and David Viner (2007)
Implications of Global Climate Change for Tourism Flows and Seasonality
Journal of Travel Research, vol. 45, pp. 285-296

Amoli (1997)

K. Amoli (1997)
Bronchopulmonary disease in Iranian housewives chronically exposed to indoor smoke
European Respiratory Journal, vol.11, no:3, pp. 659-663

Anisimov (2009)

O. Anisimov (2009)
Probabilistic modeling of climate change impacts in permafrost regions
EGU General Assembly 2009, held 19-24 April, 2009 in Vienna, Austria, p.238
Retrieved: <http://meetings.copernicus.org/egu2009>

Appeaning Addo et al. (2011)

K. Appeaning Addo, P.N.Jayson-Quashigah and K. S. Kufogbe (2011)
Quantitative Analysis of Shoreline Change Using Medium Resolution Satellite Imagery in Keta, Ghana
Marine Science, vol.1, no.1, pp.1-9

Appeaning Addo and Larbi (2009)

K. Appeaning Addo and L. Larbi (2009)
Assessing the impact of sea level rise on vulnerable coastal communities in a remote sensing environment
Proceedings of AARSE Conference held in Addis Ababa
Retrieved: <http://ugspace.ug.edu.gh:8080/xmlui/handle/123456789/1174>

Archabald and Naughton-Treves (2001)

Karen Archabald and Lisa Naughton-Treves (2001)
Tourism revenue-sharing around national parks in Western Uganda: early efforts to identify and reward local communities
Environmental Conservation, vol. 28, iss. 02, pp 135-149

Ark et al. (2008)

Bart van Ark, Mary O'Mahony, and Marcel P. Timmer (2008)
The Productivity Gap between Europe and the United States: Trends and Causes
Journal of Economic Perspectives, vol. 22, no. 1, pp. 25-44

Armah (2005)

A.K. Armah (2005)
The Coastal Zone of Ghana: Vulnerability and Adaptation Assessment to Climate Change
Presentation from The Vulnerability and Adaptation Assessment Training Workshop, held in Maputo, Mozambique, from 18-22 April, 2005

Armstrong and Kricker (2001)

B. Armstrong and A. Kricker (2001)
The epidemiology of UV Induced Skin Cancer
Journal of Photochemistry and Photobiology B: Biology, vol. 63, Iss. 1-3, pp. 8-18

Arnell (2004)

Nigel W. Arnell (2004)
Climate change and global water resources: SRES emissions and socio-economic scenarios
Global Environmental Change, vol. 14, pp. 31-52

Arnell et al. (2011)

Nigel W. Arnell, Detlef P. van Vuuren, Morna Isaac (2011)
The implications of climate policy for the impacts of climate change on global water resources
Global Environmental Change, vol. 21, Iss. 2, pp. 592-603

Arora (2001)

S. Arora (2001)
Health, Human Productivity, and Long-Term Economic Growth
The Journal of Economic History, vol. 61, no. 3, pp. 699-749

Arrhenius (1896)

Svante Arrhenius (1896).
On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.
The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. Fifth Series. April 1896, vol XXI

Arrhenius (1908)

Svante Arrhenius (1908)
Worlds in the making. The evolution of the universe
New York, London, Harper and Brother Publishers
Retrieved: http://openlibrary.org/books/OL7149587M/Worlds_in_the_making

Asano (2002)

Takashi Asano (2002)
Water from (Waste)Water -- The Dependable Water Resource
Paper written for the 2001 Stockholm Water Prize Laureate Lecture

Asante et al. (2010)

Felix Ankamah Asante, Ama Essel and Patrick Addai Aidoo (2010)
National Environmental, Economic and Development Study (NEEDS) for Climate Change: Ghana Country Report
Retrieved: <http://unfccc.int/files/adaptation/application/pdf/ghananeeds.pdf>

Asenso-Okyere et al. (2011)

K. Asenso-Okyere, C. Chiang, P.Thangata and K. Andam (2011)
Interactions between health and farmlabor Productivity
Food policy reports 23
International Food Policy Research Institute (IFPRI).

Ashbolt (2004)

Nicholas John Ashbolt (2004)
Microbial contamination of drinking water and disease outcomes in developing regions
Toxicology, vol. 198, pp. 229-238

Ashdown et al. (2011)

Lord Paddy Ashdown (2011)
Humanitarian Emergency Response Review
Department of International Development, UK

Auffhammer et al. (2006)

M.Auffhammer, V. Ramanathan, and J. R. Vincent (2006)
Integrated model shows that atmospheric brown clouds and greenhouse gases have reduced rice harvests in India
PNAS, vol. 103, no. 52, pp. 19668-19672

Avnery et al. (2011)

Avnery S., D.L. Mauzerall, J. Liu, L.W. Horowitz (2011)
Global Crop Yield Reductions due to Surface Ozone Exposure: 1. Year 2000 Crop Production Losses and Economic Damage
Atmospheric Environment, vol. 45, pp. 2284-2296.

Ayers (2010)

J. Ayers (2010)
Understanding the Adaptation Paradox: Can Global Climate Change Adaptation Policy be Locally Inclusive?
PhD thesis, The London School of Economics and Political Science.

Aydin (2010)

H. Aydin (2010)
Evaluation of the risk of coal workers pneumoconiosis (CWP): A case study for the Turkish hardcoal mining
Scientific Research and Essays, vol. 5, no. 21, pp. 3289-3297.

Baddeley (2010)

M. Baddeley (2010)
Herding, social influence and economic decision-making: socio-psychological and neuroscientific analyses
Philosophical Transactions of the Royal Society Biological Sciences, vol. 365, pp.281-290.

Baker et al. (2008)

A.C. Baker, P.W. Glynn, B. Riegl (2008)
Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook
Estuarine, Coastal and Shelf Science, vol. 80, iss. 4, pp. 435-471

Baltodano et al (eds.) (2008)

Javier Baltodano, Luisa Paz and Janice Wormworth (eds.) (2008)
Community-based forest governance: from resistance to proposals for sustainable use
Amsterdam, The Netherlands, Friends of the Earth International

Baran (2010)

Eric Baran (2010)
Strategic Environmental Assessment Of Hydropower On The Mekong Mainstream Mekong Fisheries and Mainstream Dams
International Centre for Environmental Management

Barkin (2011)

J. Samuel Barkin (2011)
Degradation and Cooperation in the High Seas: The case of the International Fisheries Management
In: S. Dinar (ed.): *Beyond Resource Wars: Scarcity, Environmental Degradation, and International Cooperation (Global Environmental Accord: Strategies for Sustainability and Institutional Innovation)* (pp. 141-164)
Cambridge, MA: Massachusetts Institute of Technology

Barman et al (2010)

S.C. Barman, N. Kumar, R. Singh, G.C. Kisku, A.H. Khan, M.M. Kidwai, R.C. Murthy, M.P.S. Negi, P. Pandey, A.K. Verma, G. Jain and S.K. Bhargava (2010)
Assessment of urban air pollution and its probable health impact
Journal of Environmental Biology, vol. 2010, no. 31, iss.(6), pp. 913-920

Barret and Wallace (2011)

Greg Barrett and Margaret Wallace (2011)
An Institutional Economics Perspective: The Impact of Water Provider Privatisation on Water Conservation in England and Australia
Water Resources Management, vol. 25, no. 5, pp. 1325-1340

Bates et al. (2008)

B.C. Bates, Z.W. Kundzewicz, S. Wu and J.P. Palutikof (Eds) (2008)
Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change
Geneva, IPCC Secretariat

Baumert and Selman (2003)

Baumert K. and Selman M (2003)
Data Note: Heating and Cooling Degree Days
World Resources Institute

Bayon and Jenkins (2010)

R. Bayon, M. Jenkins (2010)
The business of biodiversity
Nature, vol. 466, pp. 184-185

Beach et al. (2009)

W. W. Beach, D. W. Kreutzer, K. A. Campbell, and B. Lieberman (2009)
The Economic Impact of Waxman-Markey
WebMemo22, No. 2438
The Heritage Foundation (THF)

Becker et al (2010)

Gary S. Becker, Kevin M. Murphy and Robert H. Topel (2010, September, rev)
On the Economics of Climate Policy
Paper prepared for a conference on "Energy Policy and the Economy" jointly sponsored by the University of Chicago, Resources for the Future, and the University of Illinois.
Retrieved: http://www.econ.ucsb.edu/about_us/events/seminar_papers/topel.pdf

Bell et al. (2007)

Michelle L. Bell, Richard Goldberg, Christian Hogrefe, Patrick L. Kinney, Kim Knowlton, Barry Lynn, Joyce Rosenthal, Cynthia Rosenzweig, Jonathan A. Patz (2007)
Climate change, ambient ozone, and health in 50 US cities
Climatic Change, vol. 82, no. 1, pp. 61-76.

Bellard et al. (2012)

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. (2012).
Impacts of climate change on the future of biodiversity
Ecology Letters, vol. 15, iss. 4, pp. 365-377.

Bentham (1997)

C.G. Bentham (1997)
Health
In: J.P. Palutikof, S. Subak, and M.D. Agnew. (eds.): *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995* (pp.87-95)
UK Department of the Environment

Bensch and Peters (2011)

G. Bensch and J. Peters (2011)
Combating Deforestation? Impacts of Improved Stove Dissemination on Charcoal Consumption in Urban Senegal
Ruhr Economic Papers ner. 306
Ruhr-Universität Bochum (RUB), Department of Economics.

Benton and Twitchett (2003)

Michael J. Benton and Richard J. Twitchett (2003)
How to kill (almost) all life: the end-Permian extinction event
TRENDS in Ecology and Evolution, vol.18, no.7

Bernardi et al. (2009)

E. Bernardi, C. Chiavari, B. Lenza, C. Martini, L. Morselli, F. Ospitali and L. Robbiola (2009)
The atmospheric corrosion of quaternary bronzes: The leaching action of acid rain
Corrosion Science, vol.51:1, pp. 159-170

Berritella et al. (2004)

M. Berritella, A. Bigano, R. Roson, R. S.J. Tol (2004)
A General Equilibrium Analysis of Climate Change Impacts on Tourism
EEE Working Papers Series - N. 17

Betts et al. (2009)

R. A. Betts, M. Collins, D. L. Hemming, Ch. D. Jones, J. A. Lowe and M. Sanderson (2009)
When could global warming reach 4°C?
Philosophical Transactions of the Royal Society, vol. 369, no.1934, pp. 67-84

Bharath and Turner (2009)

Bharath A.K. and Turner R.J. (2009)
Impact of climate change on skin cancer
Journal of the Royal Society of Medicine, vol. 102, no. 6, pp. 215-218.

Bilenko et al. (1999)

N. Bilenko, D. Fraser and L. Naggan (1999)
Maternal knowledge and environmental factors associated with risk of diarrhea in Israeli Bedouin children
European Journal of Epidemiology, vol. 15, no. 10, pp. 907-912

Bindi and Olesen (2011)

Marco Bindi and Jørgen E. Olesen (2011)
The responses of agriculture in Europe to climate change
Regional Environmental Change, vol. 11, Suppl. 1, pp.S151-S158

Black et al. (2008)

R. E Black, L. H Allen, Z. A Bhutta, L. E Caulfield, M. de Onis, M. Ezzati, C. Mathers, J. Rivera (2008)
Maternal and child undernutrition: global and regional exposures and health consequences
The Lancet, Series, Maternal and Child Undernutrition 1

Blackman et al. (2010)

A. Blackman, B. Lahiri, W. M. Rivera Planter and C. Muñoz Piña (2010)
Voluntary environmental regulation in developing countries: Mexico's clean industry program
RFF Discussion Paper 07-36-REV
Resources For the Future
Retrieved: <http://www.rff.org/RFF/Documents/RFF-DP-07-36-REV2.pdf>

Blöschl and Montanari (2010)

G. Blöschl and A. Montanari (2010)
Climate change impacts- throwing the dice?
Hydrological Processes, vol. 24, pp. 374-381

Boateng (2009)

I. Boateng (2009)
Development of integrated shoreline management planning: a case study of Keta, Ghana
Proceedings of the Federation of International Surveyors Working Week 2009- Surveyors Key Role in Accelerated Development, Israel, 3-8 May
Retrieved: <http://eprints.port.ac.uk>

Bole et al. (2009)

A. Bole, C. Ammer, M.s Löf, G.J. Nabuurs, P. Schall and P. Spathelf (2009)
Adaptive Forest Management: A Prerequisite for Sustainable Forestry in the Face of Climate Change
Managing Forest Ecosystems, vol. 19, pp. 115-139

Bosello et al. (2005)

F. Bosello, R. Roson and R. S.J. Tol (2005)
Economy-Wide Estimates of the Implications of Climate Change: Human Health
Paper was presented at the Workshop on Infectious Diseases: Ecological and Economic Approaches held in Trieste on 13-15 April 2005.

Bouwer (2011)

L.M. Bouwer (2011)
Have Disaster Losses Increased due to Anthropogenic Climate Change?
Bulletin of the American Meteorological Society, vol. 92, pp. 39-46

Bouwer et al. (2010)

Laurens M. Bouwer, Philip Bubeck and Jeroen C.J.H. Aerts.
Changes in future flood risk due to climate and development in a Dutch polder area.
Global Environmental Change, vol. 20, Issue 3, pp. 463-471

Boyd and Banzhaf (2007)

James Boyd, Spencer Banzhaf (2007)
What are ecosystem services? The need for standardized environmental accounting units
Ecological Economics, vol. 63, pp. 616-626

BP (2012)

BP (2012)
BP Energy Outlook 2030

Bradshaw et al. (2007)

Corey J. A. Bradshaw, Navjot S. Sodhi, Kelvin S.-H. Peh and Barry W. Brook
Global evidence that deforestation amplifies flood risk and severity in the developing world
Global Change Biology, vol. 13, pp. 2379-2395.

Brander (2007)

K. M. Brander (2007)
Global fish production and climate change
Proceedings of National Academy of Sciences, vol. 104, no.50, pp. 19709-19714

Breman (2001)

J.G. Breman (2001)
The Ears of the Hippopotamus: Manifestations, Determinants, and Estimates of the Malaria Burden
American Journal of Tropical Medical Hygiene, vol. 64, suppl. 1, 2, pp. 1-11

Bridge (2010)

J.R. Bridge (2010, August 31)
Mitigating Wildlife Disaster: Early Detection and Commitment
Disaster Recovery Journal
Retrieved: <http://www.drj.com/2010-articles/online-exclusive/mitigating-wildfire-disaster-early-detection-and-commitment.html>

Brinson and Malvárez (2002)

Mark M. Brinson and Ana Inés Malvárez (2002)
Temperate freshwater wetlands: types, status, and threats
Environmental Conservation, vol. 29, iss. 2, pp. 115-133

Brook et al. (2008)

Barry W. Brook, Navjot S. Sodhi and Corey J.A. Bradshaw (2008)
Synergies among extinction drivers under global change
Trends in Ecology and Evolution, Vol.23, No.8

Brook et al. (2010)

Robert D. Brook, Sanjay Rajagopalan, C. Arden Pope III, Jeffrey R. Brook, Aruni Bhatnagar, Ana V. Diez-Roux, Fernando Holguin, Yuling Hong, Russell V. Luepker, Murray A. Mittleman, Annette Peters, David Siscovick, Sidney C. Smith Jr, Laurie Whitsel, Joel D. Kaufman (2010)
Particulate Matter Air Pollution and Cardiovascular Disease: An Update to the Scientific Statement From the American Heart Association (AHA)
Circulation, vol. 121, pp. 2331-2378

Brooks et al. (1999)

T.M. Brooks, S.L. Pimm and J. O. Oyugi (1999)
Time Lag between deforestation and Bird Extinction in Tropical Forest Fragments
Conservation Biology, vol. 13, no. 5, pp. 1140-1150

Bronzizio and Moran (2008)

Eduardo S. Bronzizio and Emilio F. Moran
Human dimensions of climate change: the vulnerability of small farmers in the Amazon
Philosophical Transaction of the Royal Society B, vol.363, pp.1803-1809

Brown and Funk (2009)

Molly E. Brown and Christopher C. Funk (2009)
Food Security Under Climate Change
Science, Vol. 319, no. 5863, pp. 580-581

Brown and Lall (2006)

C. Brown and U. Lall (2006)
Water and Economic Development: The Role of Variability and a Framework for Resilience
Natural Resources Forum, vol 30, pp. 306-317

Burke et al. (2009)

M. B. Burke, E. Miguel, S. Satyanath, J. A. Dykema, and D. B. Lobell (2010)
Warming increases the risk of civil war in Africa
Proceedings of the National Academy of Sciences of the USA (PNAS), vol. 106, no. 49, pp. 20670-20674

Burke et al. (2011)

L. Burke, K. Reytar, M. Spalding and A. Perry (eds.) (2011)
Reefs at Risk Revisited
Washington, DC: World Resources Institute (WRI)

Burke et al (2010)

M. Burke, J. Dykema, D. Lobell, E. Miguel, S. Satyanath (2010)
Climate and civil war: is the relationship robust?
National Bureau Of Economic Research, Working Paper 16440.

Burke et al. (2011)

R. Burke, S. Clarke, C. Cooper (2011)
Occupational Health and Safety
Gower Publishing

Burns et al. (2011)

Douglas A. Burns (2011)
National Acid Precipitation Assessment, Program Report to Congress 2011: An Integrated Assessment
Washington, D.C.: Executive Office Of The President, National Science And Technology Council

Busch et al. (2011)

Jonah Busch, Fabiano Godoy, Will R. Turner and Celia A. Harvey (2011)
Biodiversity co-benefits of reducing emissions from deforestation under alternative reference levels and levels of finance
Conservation Letters, vol. 00, pp. 1-15

Buse et al. (2008)

Kent Buse, Eva Ludi and Marcella Vigneri (2008)
Sustaining and Scaling the Millennium Villages: Moving from rural investments to national development plans to reach the MDGs.
Formative Review of MVP. Synthesis Report
London, UK, Overseas Development Institute

Butchart et al. (2010)

S. H. M. Butchart, M. Walpole, B. Collen, A. van Strien, J. P.W. Scharlemann, R. E. A. Almond, J. E. M. Baillie, B. Bomhard, C. Brown, J. Bruno, K. E. Carpenter, G. M. Carr, J. Chanson, A. M. Chinery, J. Csirke, N. C. Davidson, F. Dentener, M. Foster, A. Galli, J. N. Galloway, P. Genovesi, R. D. Gregory, M. Hockings, V. Kapos, J.-F. Lamarque, F. Leverington, J. Loh, M. A. McGeoch, L. McRae, A. Minasyan, M. Hernández Morcillo, T. E. E. Oldfield, D. Pauly, S. Quader, C. Revenga, J. R. Sauer, B. Skolnik, D. Spear, D. Stanwell-Smith, S. N. Stuart, A. Symes, M. Tierney, T. D. Tyrrell, J.-C. Vié and R. Watson (2010)
Global Biodiversity: Indicators of Recent Declines

Science, vol. 328, no: 5982, pp. 1164-1168

Byatt et al. (2006)

I. Byatt, R.M. Carter, C. R. de Freitas, I. M. Goklany, D.Holland, R. S. Lindzen, I.Castles, D. Henderson, N. Lawson, R. McKittrick, J. Morris, A. Peacock, C. Robinson and R. Skidelsky (2006)
The Stern Review: A Dual Critique
World Economics, vol. 7, No. 4, pp.

Callaghan and Power (2010)

J. Callaghan and S. B. Power (2010).
Variability and decline in the number of severe tropical cyclones making land-fall over eastern Australia since the late nineteenth century.
Climate Dynamics, vol. 37, Issue 3-4, pp. 647-662

Callendar (1938)

Callendar, G. S. (1938).

The artificial production of carbon dioxide and its influence on temperature.

Quarterly Journal of the Royal Meteorological Society, vol. 64, Issue 275, pp. 223-240

Campbell-Lendrum and Corvalán (2007)

Diarmid Campbell-Lendrum and Carlos Corvalán (2007)

Climate Change and Developing-Country Cities: Implications For Environmental Health and Equity

Journal of Urban Health, vol. 84, Suppl. 1, pp. 109-117.

Camuffo (1992)

Dario Camuffo (1992)

Acid rain and deterioration of monuments: How old is the phenomenon?

Atmospheric Environment. Part B. Urban Atmosphere, vol.26:2, pp. 241-247

Canada NEB (1996)

Canada National Energy Board (1996)

Canada's Oil Stands. Opportunities and Challenges to 2015: An update

Retrieved: <http://www.neb-one.gc.ca/clf-nsi/mrgynfmtn/nrgyprpt/lnsd/pprntnsndchllngs20152006/pprntnsndchllngs20152006-eng.pdf>

Canada OPM (2006)

Canada Office of the Prime Minister (2006, July 14)

Address by the Prime Minister at the Canada-UK Chamber of Commerce

Notes for an Address by The Right Honourable Stephen Harper Prime Minister of Canada

CAPP (2011)

Canadian Association of Petroleum Production (2011)

Crude oil: Forecasts, Markets and Pipelines
CAPP

CAPP (2012)

Canadian Association of Petroleum Production (2012)

What Are Oil Sands?

Retrieved: <http://www.capp.ca/CANADAINDUSTRY/OILSANDS/ENERGY-ECONOMY/Pages/what-are-oilsands.aspx>

CARE (2012)

CARE (2012)

Update: Horn of Africa Food Security Emergency: July 2012

Retrieved:<http://www.care.org/emergency/Horn-of-Africa-food-poverty-crisis-Dadaab-2011/pdf/Horn-of-Africa-emergency-one-year-report-July-2012.pdf>

Castree et al. (eds.) (2009)

N.Castree, D. Demeritt, D. Liverman and B. Rhoads (eds) (2009)

A Companion to Environmental Geography
Blackwell Publishing Ltd

CBD (1992)

Convention on Biological Diversity (1992)

Convention on Biological Diversity
United Nations

CNA (2007)

The CNA Corporation (2007)

National Security and the Threat of Climate Change

CNA

Retrieved: <http://www.cna.org>

CDCEP (2008)

Centers for Disease Control and Prevention (2008)

Heat-Related Deaths Among Crop Workers—United States, 1992-2006

Morbidity and Mortality Weekly Report , vol. 57 pp. 649-653

CDCEP (2012)

Centers for Disease Control and Prevention

Various resources: Data & Statistics

<http://www.cdc.gov/DataStatistics/>

CEORE (2012)

Centre of Documentation, Research and Experimentation on Accidental Water Pollution Spills

Retrieved: <http://www.cedre.fr/en/spill/alphabetical-classification.php>

Center for Tankship Excellence (2012)

Center for Tankship Excellence (2012)

CTX version 4.6

Retrieved: http://www.c4tx.org/ctx/job/cdb/do_flex.html

Ceres (2010)

Ceres (2010)

Canada's Oil Sands Shrinking Window of Opportunity

Boston, MA, Ceres, Inc.

Retrieved: <http://www.ceres.org/resources/reports/oil-sands-2010/view>

Ceres (2011).

Ceres (2011)

Disclosing Climate Risks and Opportunities in SEC Filings: A Guide for Corporate executives, Attorneys and Directors.

Boston, MA, Ceres, Inc.

Retrieved: <http://www.ceres.org/resources/reports/disclosing-climate-risks-2011/view>

Ceron and Dubois (2004)

Jean-Paul Ceron and Ghislain Dubois (2004)

The potential Impacts of Climate Change on French Tourism

Current Issues in Tourism, vol. 8, no. 2. pp. 125-139

Chan et al. (2012)

Albert P.C. Chan, Michael C.H. Yam, Joanne W.Y. Chung and Wen Yi (2012)

Developing a heat stress model for construction workers

Journal of Facilities Management, vol. 10, iss. 1, pp.59 - 74

Charpin et al. (2009)

D. Charpin, C. Penard-Morand, C. Raheison, C. Kopferschmitt, F. Lavaud, D. Caillaud, I. Annesi-Maesano (2009)

Long-term exposure to urban air pollution measured through a dispersion model and the risk of asthma and allergy in children. *Bulletin de l'Académie Nationale de Médecine*, vol. 193, no. 6, pp. 1317-1329

Chaves et al. (2009)

M.M. Chaves, J. Flexas, and C. Pinheiro (2009)

Photosynthesis under Drought and Salt Stress: Regulation Mechanisms from Whole Plant to Cell

Annals of Botany, vol. 103, no. 4, pp. 551-560

Checkley et al. (2000)

W. Checkley, L. D Epstein, R. H Gilman, D. Figueroa, R. I Cama, J. A Patz, R. E Black (2000)

Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children

The Lancet, vol. 355, iss. 9202, pp. 442-450

Chen et al. (2008)

H. Chen, M.S. Goldberg and P.J. Villeneuve (2008)

A systematic review of the relation between long-term exposure to ambient air pollution and chronic diseases

Reviews on Environmental Health, vol. 23, no. 4, pp. 243-297

Cherwin (2009)

K.L. Cherwin (2009, August 3)

Effects of climate change on semi-arid grasslands: Does severe drought increase invasibility?

Presentation PS 3-38:

Paper presented in The 94th ESA (Ecological Society of America) Annual Meeting held in August 2-7, 2009

Cheung et al. (2009)

William W.L. Cheung, Vicky W.Y. Lam, Jorge L. Sarmiento, Kelly Kearney, Reg Watson and Daniel Pauly (2009)

Projecting global marine biodiversity impacts under climate change scenarios

Fish and Fisheries, vol.10:3, pp. 235-251

Cheung et al. (2010)

William W. L. Cheung, Vicky W. Y. Lam, Jorge L. Sarmiento, Kelly Kearney, Reg Watson, Dirk Zeller, and Daniel Pauly (2010)

Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change

Global Change Biology, vol. 16, no. 11, pp. 24-35.

Cheung et al. (2011)

William. L. Cheung, Vicky. W.Y. Lam, Jorge. L. Sarmiento, Kelly Kearney , Reg Watson and Daniel Pauly (2011)

The state of biodiversity and fisheries in regional seas

Fisheries Centre research reports, vol.19, no:3, pp:27-31

Chu et al. (2009)

J. T. Chu, J. Xia , C.-Y. Xu and V. P. Singh (2009)

Statistical downscaling of daily mean temperature, pan evaporation and precipitation for climate change scenarios in Haihe River, China

Theoretical and Applied Climatology, vol. 99, pp.149-161

Churchill and Matul (2012)

C. Churchill and M. Matul (eds.) (2012)

Protecting the poor: A microinsurance compendium . Volume II

Geneva, Switzerland, International Labour Office

Christian Aid (2007)

Christian Aid (2007)

Human tide: The forced migration crisis

UK, Christian Aid

Retrieved: <http://www.christianaid.org.uk/images/human-tide.pdf>

CIA (2012)

CIA (2012)

The World Factbook

Retrieved: <https://www.cia.gov/library/publications/the-world-factbook/>

CIESIN (2002)

Centre for International Earth Science Information Network (2002)

Country-level Population and Downscaled Projections based on the B2 Scenario, 1990-2100, [digital version]

Palisades, NY: CIESIN, Columbia University.

Retrieved: <http://www.ciesin.columbia.edu/datasets/downscaled>.

CIESIN Website (2012)

Center for International Earth Science Information Network (CIESIN)

Socioeconomic Data and Applications Center
<http://sedac.ciesin.columbia.edu/>

Cline (1992)

William R. Cline (1992)
The Economics of Global Warming
 Washington, DC, Institute for International Economics

Cline (2007)

William R. Cline (2007)
Global Warming and Agriculture: Impact Estimates by Country
 Washington, DC: Center for Global Development.

Climate Analytics (2012)

Climate Analytics (2012)
 The Climate Analysis Indicators Tool (CAIT): CAIT International (database)
 Retrieved: <http://www.wri.org/project/cait/>

Clune et al. (2012)

Stephen Clune, John Morrissey and Trivess Moore (2012)
 Size matters: House size and thermal efficiency as policy strategies to reduce net emissions of new developments
Energy Policy, vol. 48, pp.657-667

Cohen (2011)

M.A. Cohen (2011)
 Deepwater Drilling: Recommendations for a Safer Future
Resources, Winter/Spring 2011, no.177
 Resources For the Future

Cohen et al. (2005)

A.J. Cohen, H. Ross Anderson, B. Ostro, K.D. Pandey, M. Krzyzanowski, N. Künzli, K. Gutschmidt, A. Pope, I. Romieu, J.M. Samet, K. Smith (2005)
 The global burden of disease due to outdoor air pollution
Journal of Toxicology and Environmental Health, Part A., vol. pp. 1-7

Conway (2005)

Declan Conway (2005)
 From headwater tributaries to international river: Observing and adapting to climate variability and change in the Nile basin
Global Environmental Change, vol. 15, pp. 99-114

Corcoran et al. (2007)

E. Corcoran, C. Ravilious and M. Skuja (2007)
Mangroves of Western and Central Africa
 Cambridge, United Kingdom, UNEP World Conservation Monitoring Centre

Corti et al. (2009)

T. Corti, V. Muccione, P. Köllner-Heck, D. Bresch, and S. I. Seneviratne (2009)
 Simulating past droughts and associated building damages in France
Hydrology and Earth System Sciences Discussions, vol. 6, no. 2, pp. 1463-1487.

Costanza et al. (1997)

Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, & Marjan van den Belt (1997)
 The value of the world's ecosystem services and natural capital
Nature, vol. 387.

Costanza et al. (2007)

R Costanza, B Fisher, K Mulder, S Liu, T Christopher (2007)
 Biodiversity and ecosystem services: A multi-scale empirical study of the relationship between species richness and net primary production
Ecological Economics, vol. 61, no. 2-3, pp. 478-491.

Coups et al. (2008)

E. Coups, S. Manne, C. Heckman (2008)
 Multiple Skin Cancer Risk Behaviors in the U.S. Population
American Journal of Preventive Medicine, vol. 34, Iss. 2, pp. 87-93

Cowling et al. (2008)

R. M. Cowling, B. Egoh, A. T. Knight, P. J. O'Farrell, B. Reyers, M. u Rouget, D. J. Roux, A. Welz and A. Wilhelm-Rechman (2008)
 An operational model for mainstreaming ecosystem services for implementation
PNAS, vol. 105, no. 28, pp. 9483-9488

CRED/EM-DAT (2012)

Center for Research on the Epidemiology of Disasters (2012)
EM DAT - The International Disasters Database
 Retrieved: <http://www.emdat.be/advanced-search>

CREStS (2012)

Center for Remote Sensing of Ice Sheets (2012)
 Sea Level Rise Maps
 Haskell Indian Nations University.
 Retrieved: <https://www.cresis.ku.edu/data/sea-level-rise-maps>

Crossland et al. (1991)

C.J. Crossland, B.G. Hatcher and S.V. Smith (1991)
 Role of coral reefs in global ocean production
Coral Reefs, vol. 10, no. 2, pp. 55-64

Crowe et al. (2010)

J. Crowe, J. M. Moya-Boniilla, B. Román-Solano, and A. Robles-Ramírez (2010)
 Heat exposure in sugarcane workers in Costa Rica during the non-harvest season
Global Health Action, Nov 2010, vol. 3.

Crutzen et al (2010)

Paul. J. Crutzen
 Anthropocene man
Nature, vol. 467: 7317

Cruz and Alexander (2010)

M.G. Cruz and M.E. Alexander (2010)
 Assessing crown fire potential in coniferous forests of western North America: a critique of current approaches and recent simulation studies.
International Journal of Wildland Fire, vol. 19, pp. 377-398

CTI (2011)

The Carbon Tracker Initiative (2011)
Unburnable Carbon - Are the world's financial markets carrying a carbon bubble?
 Investor Watch
 Retrieved: <http://www.carbontracker.org/carbonbubble>

Curriero et al. (2002)

Frank C. Curriero, Karlyn S. Heiner, Jonathan M. Samet, Scott L. Zeger, Lisa Strug and Jonathan A. Patz (2002)
 Temperature and Mortality in 11 Cities of the Eastern United States
American Journal of Epidemiology, Vol. 155, no. 1, pp. 80-87.

Curtis (2004)

Ian A. Curtis (2004)
 Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and Delphi panel to assign weights to the attributes
Ecological Economics, vol. 50, pp. 163- 194

Dai (2011)

A. Dai (2011)
 Drought under Global Warming: A Review
Wiley Interdisciplinary Reviews: Climate Change, vol. 2, iss.1, pp. 45-65

D'Amato (2011)

Gennaro D'Amato (2011)
 Effects of climatic changes and urban air pollution on the rising trends of respiratory allergy and asthma
Multidisciplinary Respiratory Medicine, vol. 6, no. 1, pp. 28-37

Dameris (2010)

M. Dameris (2010)
 Depletion of the Ozone Layer in the 21st Century
Angewandte Chemie, vol. 49, pp. 489-491

Dawson et al. (2009)

J. Dawson, D. Scott and G. McBoyle (2009)
 Climate change analogue analysis of ski tourism in the northeastern USA
Climate Research, vol. 39, pp. 1-9

DARA and CVF (2010)

DARA and the Climate Vulnerable Forum (2010)
 Climate Vulnerability Monitor-"The State of the Climate Crisis"-2010 Report of the Climate Vulnerability Initiative.
 Fundación DARA Internacional.

Dasgupta (2007)

Partha Dasgupta (2007)
 Commentary: The Stern Review's Economics of Climate Change
National Institute Economic Review No. 199, Iss. 4

Dasgupta et al. (2009)

S. Dasgupta, B. Laplante, C. Meisner, D. Wheeler and J. Yan (2009)
 The impact of sea level rise on developing countries: a comparative analysis
Climatic Change, vol. 93, no. 3-4, pp.379-388

DCPP (2006)

World Bank (2006)
Disease Control Priorities in Developing Countries (2nd edition).
 New York: Oxford University Press
 Washington D.C., US: World Bank

De'ath et al. (2009)

G. De'ath, J.M. Lough, K. E. Fabricius (2009)
 Declining Coral Calcification on the Great Barrier Reef
Science, vol. 323, pp. 116-119

De Cian and Tavoni (2010)

E. De Cian and M. Tavoni (2010)
 The Role of International Carbon Offsets in a Second- best Climate Policy: A Numerical Evaluation.
 Nota di Lavoro 33.2010
 Fondazione Eni Enrico Mattei

de Dear and Brager (1998)

R. de Dear and G.S. Brager (1998)
 Developing an adaptive model of thermal comfort and preference
ASHRAE Transactions, vol. 108, part. I

Dennehy (2000)

P. Dennehy (2000)
 Transmission of rotavirus and other enteric pathogens in the home
Pediatric Infectious Disease Journal, vol. 19, iss. 10, pp. S103-S105

De Sherbinin et al. (2007)

Alex De Sherbinin, Andrew Schiller and Alex Pulsipher (2007)
 The vulnerability of global cities to climate hazards
Environment and Urbanization, vol. 19, no.1, pp. 39-64.

Dessai et al. (2009)

S. Dessai, M. Hulme, R. Lempert and R. Pielke Jr (2009)
Climate prediction: a limit to adaptation?, in W.N. Adger, I. Lorenzoni and K.L. O'Brien (eds) *Adapting to Climate Change: Thresholds, Values, Governance* (pp. 64-78)
Cambridge University Press

de Wit and Stankiewicz (2006)

Maarten de Wit and Jacek Stankiewicz (2006)
Changes in Surface Water Supply Across Africa with Predicted Climate Change
Science, vol. 311, pp. 1917-1921

Ding et al. (2011)

Y. Ding, M.J. Hayes, and M. Widhalm (2010)
Measuring Economic Impacts of Drought: A Review and Discussion
Disaster Prevention and Management, vol. 20, no. 4, pp. 434-446

DIVA (2003)

DINAS-COAST (2003)
Dynamic Interactive Vulnerability Assessment (DIVA)

Dixon et al. (2003)

Robert K. Dixon, Joel Smith and Sandra Guill (2003)
Life on the Edge: Vulnerability and Adaptation of African Ecosystems to Global Climate Change
Mitigation and Adaptation Strategies for Global Change, vol. 8, pp. 93-113

Dodman and Satterthwaite (2008)

David Dodman and David Satterthwaite (2008)
Institutional Capacity, Climate Change Adaptation and the Urban Poor
IDS Bulletin, vol. 39, no. 4
Institute of Development Studies (IDS)

Dolan and David (1992)

R. Dolan and R.E. Davis (1992)
An Intensity Scale for Atlantic Coast Northeast Storms.
Journal of Coastal Research, vol. 8, no. 4, pp. 840-843

Domingues et al. (2008)

Catia M. Domingues, John A. Church, Neil J. White, Peter J. Gleckler, Susan E. Wijffels, Paul M. Barker and Jeff R. Dunn (2008)
Improved estimates of upper-ocean warming and multi-decadal sea-level rise
Nature, vol. 453, pp. 1090-1093

Donat et al. (2011)

Donat M.G., G. C. Leckebusch, S. Wild, and U. Ulbrich (2011)
Future changes in European winter storm losses and extreme wind speeds inferred from GCM and RCM multi-model simulations
Natural Hazards and Earth System Sciences, vol. 11, no. 5, pp 1351-1370.

Donkelaar et al. (2010)

Aaron van Donkelaar, R. V. Martin, M. Brauer, R. Kahn, R. Levy, C. Verduzco, and P.J. Villeneuve (2010)
Global Estimates of Ambient Fine Particulate Matter Concentrations from Satellite-Based Aerosol Optical Depth: Development and Application
Environmental Health Perspectives, vol. 118, no. 6, pp. 847-855

Donner and Rodriguez (2008)

William Donner and Havidán Rodríguez (2008)
Population Composition, Migration and Inequality: The Influence of Demographic Changes on Disaster Risk and Vulnerability
Social Forces, vol. 87, no. 2, pp. 1089-1114

Donohoe (2003)

M. Donohoe (2003)
Causes and Health Consequences of Environmental Degradation and Social Injustice
Social Science & Medicine, vol. 56, pp. 573-587

Donovan and Butry (2009)

Geoffrey H. Donovan and David T. Butry (2009)
The value of shade: Estimating the effect of urban trees on summertime electricity use
Energy and Buildings, vol. 41, pp. 662-668

Dore (2005)

Mohammed H.I. Dore (2005)
Climate change and changes in global precipitation patterns: What do we know?
Environment International, vol. 31, pp.1167 - 1181

Douglas-Westwood (2010)

Douglas-Westwood/ New York (2010)
Global Deepwater Prospects-2010
Presentation for the Deep Offshore Technology International Conference held in Houston, Texas, 2 February 2010

Driscoll et al. (2001)

C.T. Driscoll, G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers (2001)
Acidic Deposition in the Northeastern United States: Sources and Inputs, Ecosystem Effects, and Management Strategies
BioScience, vol. 51, no. 3, pp. 180-198

Driscoll et al. (2004)

Tim Driscoll, Kyle Steenland, Deborah Imel Nelson, James Leigh (2004)
Occupational airborne particulates: Assessing the environmental burden of disease at national and local levels
Environmental Burden of Disease Series, no. 7.
Geneva, Switzerland: World Health Organization

Easterling (2011)

William E. Easterling (2011)
Guidelines for Adapting Agriculture to Climate Change
In: Hillel and Rosenzweig (eds.): *Handbook of Climate Change and Agroecosystems: Impacts, Adaptation, and Mitigation*
London, UK, Imperial College Press

EACC (2010)

Economics of Adaptation to Climate Change (2010)
Economics of Adaptation to Climate Change-Synthesis Report
The World Bank

ECLAC (2011)

Economic Commission for Latin America and the Caribbean (ECLAC) (2011)
An Assessment of the Economic Impact of Climate Change on the Tourism Sector in Barbados
United Nations ECLAC

Edenhofer et al. (2010)

O. Edenhofer, B. Knopf, T. Barker, L. Baumstark, E. Belleprat, B. Chateau, P. Criqui, M. Isaac, A. Kitous, S. Kypreos, M. Leimbach, K. Lessmann, B. Magné, S. Scricciu, H. Turton, D. P. van Vuuren (2010).
The Economics of Low Stabilization: Model Comparison of Mitigation Strategies and Costs
The Energy Journal, vol. 31 (Special Issue 1), pp.11-48

EDGAR (2012)

Emission Database for Global Atmospheric Research (EDGAR)
EDGAR 3.2 Fast Track 2000 dataset (32FT2000)
PBL Netherlands Environmental Assessment Agency
http://131.224.244.83/en/themesites/edgar/emission_data/edgar_32ft2000/index.html

Eisenack et al. (2012)

Klaus Eisenack, Rebecca Stecker, Diana Reckien and Esther Hoffmann (2012)
Adaptation to climate change in the transport sector: a review of actions and actors
Mitigation and Adaptation Strategies for Global Change, vol. 17, no. 5, pp.451-469

Elliot et al. (2011)

M. Elliott, A. Armstrong, J. Lobuglio, J. Bartram (2011)
Technologies for climate change adaptation: the water sector
Roskilde, Denmark: UNEP Risø Centre on Energy, Climate and Sustainable Development

Elsasser and Bürki (2002)

Hans Elsasser and Rolf Bürki (2002)
Climate change as a threat to tourism in the Alps
Climate Research, vol. 20, pp. 253-257
EM-DAT CRED (2012) - See: CRED (above)

Energy Information Administration Website (2012)

Energy Information Administration Website
Various sources

Engelhard (2011)

G. H. Engelhard, J. R. Ellis, M. R. Payn, R. Hofstede, and J. K. Pinnegar (2011)
Ecotypes as a concept for exploring responses to climate change in fish assemblages
ICES Journal of Marine Science, vol. 68, iss.3, pp. 580-591

Enserink (2010)

M. Enserink (2010)
Yellow Fever Mosquito Shows Up in Northern Europe
Science, vol. 329, no. 5993, p. 736

Environmental Protection Agency (2010)

Environmental Protection Agency (2010)
Various resources
<http://www.epa.gov/enviro/index.html>

Eon Energy Lab(2012)

Eon Energy Lab(2012)
What is Hydro Energy?
Retrieved: <http://www.eon-energylab.co.uk/what-is-hydro-energy/>

EPA-Ghana (2011)

Environmental Protection Agency (EPA)- Ghana (2011)
Ghana's Second National Communication to The UNFCCC, 2011
GEF, EPA and UNDP

Epstein (2001)

P.R. Epstein (2001)
Climate Change and Emerging Infectious Disease
Microbes and Infection, vol. 3, iss. 9, pp. 747-754

Epule et al. (2012)

Epule Terence Epule, Changhui Peng, Laurent Lepage and Zhi Chen
Rainfall and Deforestation Dilemma for Cereal Production in the Sudano-Sahel of Cameroon
Journal of Agricultural Science, vol. 4, no. 2;

ERC (2009)

Environmental Research Consulting (2009)
Largest Oil Spills Worldwide
Environmental Research Consulting

Esikuri ed. (1999).

Enos E .Esikuri, Hassan M . Hassan and Gunter W. Riethmacher (eds.) (1999)
Drylands, Poverty and Development. Proceedings of the June 15 and 16 ,1999 World Bank Round Table
The International Bank for Reconstruction and Development/ The World Bank

Etkin (2004)

Etkin, Dagmar Schmidt (2004)
Modeling Oil Spill Response and Damage Costs.
In *Proceedings of the 5th Biennial Freshwater Spills Symposium*
Washington, DC: US Environmental Protection Agency

Euskirchen et al. (2006)

E.S. Euskirchen, A.D. McGuire, D.W. Kicklighter, Q. Zhuang, J.S. Clein, R.J. Dargaville, D.G. Dye, J.S. Kimball, K.C. McDonald, J.M. Melillo, V.E. Romanovsky, and N.V. Smith (2006)

Importance of recent shifts in soil thermal dynamics on growing season length, productivity, and carbon sequestration in terrestrial high-latitude ecosystems
Global Change Biology, vol. 12, no. 4, pp. 731–750

Evans and Geerken (2004)

Jason Evans and Roland Geerken (2004)
Discrimination between climate and human-induced dryland degradation
Journal of Arid Environments, vol. 57, pp. 535–554

Falkenmark and Molden (2008)

Malin Falkenmark and David Molden (2008)
Wake Up to Realities of River Basin Closure
International Journal of Water Resources Development, vol. 24, no.2, pp. 201–215

FAO (2007)

FAO (2007)
Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities
Rome, Food and Agriculture Organization of the United Nations

FAO (2011)

FAO (2011)
The State of Food Insecurity in the World. How does international price volatility affect domestic economies and food security?
Rome, Food and Agriculture Organization of the United Nations

FAO (2012)

FAO (2012)
The State of World Fisheries and Aquaculture 2012
Rome, Food and Agriculture Organization of the United Nations

FAO AQUASTAT (2012)

FAO AQUASTAT (2012)
AQUASTAT Database
<http://www.fao.org/nr/water/aquastat/databases/index.stm>

FAO FISHSTAT (2012)

FAO FISHSTAT (2012)
FishStat Plus Database
<http://www.fao.org/fishery/statistics/software/fishstat/en>

FAOSTAT (2012)

FAOSTAT
Various Resources
<http://faostat.fao.org/>

Farber et al. (2002)

Stephen C. Farber, Robert Costanza, Matthew A. Wilson (2002)
Economic and ecological concepts for valuing ecosystem services
Ecological Economics, vol. 41, pp.375–392

Feng and Kobayashi (2009)

Zhaozhong Feng and Kazuhiko Kobayashi (2009)
Assessing the impacts of current and future concentrations of surface ozone on crop yield with meta-analysis
Atmospheric Environment, vol. 43, Iss. 8, pp 1510–1519

Feng and Liu (2012)

Xi Zhou Feng and Zheng Ping Liu (2012)
Discussion on Permafrost Hazards of Railway Engineering and Prevention Measures: A Case Study on Qinghai-Tibet Railway
Advanced Materials Research, vols. 550–553, pp. 2493–2497

Ficke et al. (2007)

Ashley D. Ficke, Christopher A. Myrick, Lara J. Hansen (2007)
Potential impacts of global climate change on freshwater fisheries
Reviews in Fish Biology and Fisheries, vol. 17, no. 4, pp. 581–613

Fisk (2000)

William J. Fisk (2000)
Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency
Annu. Rev. Energy Environ. vol. 25, pp. 537–66

Foell et al (2011)

W. Foell, S. Pachauri, D. Spreng, H.Zerriffi (2011)
Household cooking fuels and technologies in developing economies
Energy Policy, vol. 39, Issue 12, pp.7487–7496

Fraser et al. (2011)

E. D. G. Fraser, A. J. Dougill, K. Hubacek, C. H. Quinn, J. Sendzimir, and M. Termansen (2011)
Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions
Ecology and Society, vol. 16, no. 3, iss. 3

Fredén (2011)

Fredrik Fredén (2011).
Impacts of dams on lowland agriculture in the Mekong River catchment
Seminar series nr 207
Bachelor's degree thesis in Physical Geography, Department of Earth and Ecosystem Sciences, Lund University, Sweden

Friedler (2001)

Eran Friedler (2001)
Water reuse - an integral part of water resources management: Israel as a case study
Water Policy, vol. 3, pp. 29–39

Friedlingstein et al (2010).

P. Friedlingstein, R. A. Houghton, G. Marland, J. Hackler, T. A. Boden, T. J. Conway, J. G. Canadell, M. R. Raupach, P. Ciais & C. Le Quééré (2010)
Update on CO emissions.
Nature Geoscience vol 3, pp. 811–812

Friedman (2009)

Thomas L. Friedman (2009)
Hot, Flat, and Crowded: Why The World Needs A Green Revolution – and How We Can Renew Our Global Future
Farrar, Straus & Giroux

Fullerton et al. (2008)

D. G. Fullerton, N. Bruce and S. B. Gordon (2008)
Indoor air pollution from biomass fuel smoke is a major health concern in the developing world
Transactions of the Royal Society of Tropical Medicine and Hygiene, vol. 102, no. 9, pp. 843–851.

Füssel (2009)

Hans-Martin Füssel (2009)
Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. In: *World Development Report 2010* (Background note)
The World Bank.

Füssel (2010)

Hans-Martin Füssel (2010)
How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: A comprehensive indicator-based assessment
Global Environmental Change, vol. 20 , issue 4, pp. 597 – 611

Füssel (2012)

Hans-Martin Füssel (2012):
Vulnerability of Coastal Populations, in: O. Edenhofer, J. Wallacher, H. Lotze-Campen, M. Reder, B. Knopf and J. Müller (eds) : Climate Change, Justice and Sustainability Linking Climate and Development Policy (chapter 5, pp. 45–57)
Dordrecht, Netherlands: Springer Science+Business Media

Gallup and Sachs (2001)

J.L. Gallup and J.D. Sachs (2001)
The Economic Burden of Malaria
American Journal of Tropical Medical Hygiene, vol. 64, suppl. 1, pp. 85–96

Gardiner (2004)

Stephen M. Gardiner (2004)
Ethics and Global Climate Change
Ethics, vol. 114 , pp. 555–600

Garfunkel ed. (2010)

Adam Garfunkel (ed.) (2010)
Universal Ownership. Why environmental externalities matter to institutional investors ?
United Nations Environment Programme Finance Initiative (UNEP FI) and The Principles for Responsible Investment (PRI).

Garg et al. (2009)

A. Garg, R.C. Dhiman, S. Bhattacharya, and P.R. Shukla (2009)
Development, Malaria and Adaptation to Climate Change: A Case Study from India
Environmental Management, vol. 43, no. 5, pp. 779–789

Geist and Lambin (2004)

Helmut J. Geist and Eric F. Lambin (2004)
Dynamic Causal Patterns of Desertification
BioScience, vol. 54, no. 9, pp. 817–829

Geng et al. (2001)

S.Geng, Y. Zhou, M. Zhang and K. S. Smallwood (2011)
A Sustainable Agro-ecological Solution to Water Shortage in the North China Plain (Huabei Plain)
Journal of Environmental Planning and Management, vol. 44, Iss. 3, pp. 345–355

Geoworldmap (2012)

Geoworldmap
Geobytes' GeoWorldmap Database
Retrieved: <http://www.geobytes.com/FreeServices.htm>

GFH (2009)

Global Humanitarian Forum (2009)
Human Impact Report : Climate Change-The Anatomy of a Silent Crisis
Geneva, Switzerland: Global Humanitarian Forum.

Ghana SS (2010)

Ghana Statistical Service (2010)
Population and Housing Census (PHC)
Accra, Ghana Statistical Service (GSS)

Giesy et al. (2010)

J.P. Giesy, J.C. Anderson, and S.B. Wiseman (2010)
Alberta oil sands development
Proceedings of the National Academy of Sciences of the United States (PNAS), vol. 107, no.3, pp. 951–952

Gilad et al. (2003)

Oren Gilad, Susan Yun, Mark A. Adkison, Keith Way, Neil H. Willits, Herve Bercovier and Ronald P. Hedrick (2003)
Molecular comparison of isolates of an emerging fish pathogen, koi herpesvirus, and the effect of water temperature on mortality of experimentally infected koi
Journal of General Virology, vol.84, no:10, pp.2661–2667

Gilchrest et al. (1999)

B.A. Gilchrest, M.S. Eller, A.C. Geller, and M. Year (1999)

The Pathogenesis of Melanoma Induced by Ultraviolet Radiation
New England Journal of Medicine, vol. 340, pp. 1341-1348

GIM (2012)

Generation Investment Management LLP(2012)
Sustainable Capitalism

Retrieved: <http://www.generationim.com/media/pdf-generation-sustainable-capitalism-v1.pdf>

Gisladdottir and Stocking (2005)

G. Gisladdottir and M. Stocking (2005)
Land Degradation Control and its Global Environmental Benefits

Land degradation & Development, vol. 16, pp. 99-112

Giuffrida et al. (2002)

A. Giuffrida, R. Fiunes and W. Savedoff (2002)
Occupational Risks in Latin America and the Caribbean: Economic and Health Dimensions
Health Policy and Planning, vol. 17, no.3, pp. 235-246

Glantz (ed.) (1987)

Michael H. Glantz (ed.) (1987)
Drought and Hunger in Africa
Cambridge University Press

Glewwe and Jacoby (1993)

Paul Glewwe and Hanan Jacoby (1993)
Delayed Primary School Enrollment and Childhood Malnutrition in Ghana: An Economic Analysis

Living Standards Measurement Study Working paper, No. 98

Washington, DC, The International Bank for Reconstruction and Development/ The World Bank.

GoA (2012)

Government of Alberta (2012)
Alberta Energy: Facts and Statistics
Retrieved <http://www.energy.gov.ab.ca/OilSands/791.asp> Page

Gonzalez et al. (2010)

P. Gonzalez, R. P. Neilson, J. M. Lenihan and Raymond J. Drakep (2010)

Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change

Global Ecology and Biogeography, vol.19, iss. 6, pp.755-768

Gooroochurn and Sinclair (2005)

Nishaal Gooroochurn and M. Thea Sinclair (2005)

Economics of tourism taxation: Evidence from Mauritius

Annals of Tourism Research, vol. 32, iss. 2, pp.478-498

Gosling et al. (2009)

S.N. Gosling, J.A. Lowe, G.R. McGregor, M. Pelling, and B.D. Malamud (2009)

Associations Between Elevated Atmospheric Temperature and Human Mortality: A Critical Review of the Literature
Climatic Change, vol. 92, no. 3-4, pp. 299-341

Graff Zivin and Neidell (2010)

Joshua Graff Zivin Matthew J. Neidell (2010)
Temperature and the Allocation of Time: Implications for Climate Change

NBER Working Paper Series . Working Paper 15717

National Bureau of Economic Research
Retrieved: <http://www.nber.org/papers/w15717>

Graham and Reilly (2011)

B. Graham, W.K. Reilly (2011)

Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling

Report to the President National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling

Grant (2010)

J.K. Grant (2010)

What Can We Learn From The 2010 BP Oil Spill?: Five Important Corporate Law and Life Lessons

McGeorge Law Review, Vol. 42, p. 809, 2011

Gray (1997)

Tim. S. Gray (1997)

Marine biodiversity: patterns, threats and conservation needs

Biodiversity and Conservation, vol.6, no.1, pp. 153-175

Greenpeace USA (2009)

Greenpeace USA (2009, May 22)

Broad Coalition Criticizes Climate Bill

Retrieved: <http://www.greenpeace.org/usa/en/media-center/news-releases/broad-coalition-criticizes-cl/>

Gregory et al. (2009)

P.J. Gregory, S. N. Johnson, A. C. Newton and J. S. I. Ingram (2009)

Integrating pests and pathogens into the climate change/ food security debate
Journal of Experimental Botany, vol. 60, no. 10, pp. 2827-2838

Grieve and Short (2007)

C Grieve and K Short (2007)

Implementation of Ecosystem-Based Management in Marine Capture Fisheries - case studies from WWF's marine ecoregions

World Wide Fund for Nature

Grinsted et al. (2009)

Aslak Grinsted, J. C. Moore and S. Jevrejeva (2009)

Reconstructing sea level from paleo and projected temperatures 200 to 2100AD
Climate Dynamics, vol. 34,no. 4, pp.461-472

GWl (2008)

Global Water Intelligence (2008)

World water prices rise by 6.7%

Global Water Intelligence - Archive: Global Water Intelligence, Vol 9, Iss. 9

Retrieved: <http://www.globalwaterintel.com/archive/9/9/analysis/world-water-prices-rise-by-67.html>

Hales et al. (2000)

S. Hales, S. Kovats, and A. Woodward (2000)

What El Niño can tell us about human health and global climate change

Global Change & Human Health, vol. 1, iss. 1, pp. 66-77

Hallegatte (2005)

Stéphane Hallegatte (2005)

Accounting for Extreme Events in the Economic Assessment of Climate Change

Nota Di Lavoro 1.2005. Fondazione Eni Enrico Mattei Note di Lavoro Series Index.

Halpern et al. (2008)

B. S. Halpern, S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. Steneck and R. Watson (2008)

A Global Map of Human Impact on Marine Ecosystems

Science, vol. 319, no: 5865, pp.948-952

Hamududu and Killingtveit (2012)

Byman Hamududu and Aanund Killingtveit (2012)

Assessing Climate Change Impacts on Global Hydropower

Energies, vol. 5, pp. 305-322

Hamilton (2008)

L.S. Hamilton (2008)

Forests and Water. A thematic study prepared in the framework of the Global Forest Resources Assessment 2005

FAO Forestry Paper 155

Rome, Food and Agriculture Organization of the United Nations

Hamilton et al. (2005)

Jacqueline M. Hamilton, David J. Maddison, Richard S.J. Tol (2005)

Climate change and international tourism: A simulation study

Global Environmental Change, vol. 15, pp. 253-266

Hanna et al. (2011a)

E. G Hanna, T. Kjellstrom, Ch. Bennett and K. Dear (2011)

Climate Change and Rising Heat: Population Health Implications for Working People in Australia

Asia-Pacific Journal of Public Health, vol. 23, no. 2, suppl 14S-26S

Hancock et al. (2003)

P.A. Hancock and I. Vasmatzidis (2003)

Effects of heat stress on cognitive performance: the current state of knowledge

International Journal of Hyperthermia, vol. 19, no. 3, pp. 355-372

Hancock et al. (2007)

P.A. Hancock, J. M. Ross and J.L. Szalma (2007)

A meta-analysis of performance response under thermal stressors

Human Factors, vol. 49, iss. 5, pp. 851-877

Hansen (2006)

Jim Hansen (2006, 19 October)

The Planet in Peril- Part I: Global Warming, arctic ice melt and rising oceans will shrink nations and change world maps

YaleGlobalOnline

Retrieved: <http://yaleglobal.yale.edu/content/planet-peril-%E2%80%93part-i>

Hansen et al. (2005)

James Hansen, Larissa Nazarenko, Reto Ruedy, Makiko Sato, Josh Willis, Anthony Del Genio, Dorothy Koch, Andrew Lacis, Ken Lo, Surabi Menon, Tica Novakov, Judith Perlwitz, Gary Russell, Gavin A. Schmidt and Nicholas Tausnev (2005)

Earth's Energy Imbalance: Confirmation and Implications

Science, Vol. 308, no. 5727 pp. 1431-1435

Hansen et al. (2007)

J. Hansen, M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R. Miller, L. Nazarenko, K. Lo, G. A. Schmidt, G. Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N. Y. Kiang, D. Koch, G. Labov, J. Lerner, S. Menon, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, N. Unger, M. Yao, and S. Zhang (2007)

Dangerous human-made interference with climate: A GISS modelE study

Atmospheric Chemistry and Physics, vol. 7, pp. 2287-2312.

Hansen et al. (2008)

A. Hansen, P. Bi, M. Nitschke, P. Ryan, D. Pisaniello and G. Tucker (2008)

The Effect of Heat Waves on Mental Health in a Temperate Australian City

Environmental Health Perspectives, vol.116, no.10, pp. 1369-1375

Hansen et al. (2012)

J. Hansen, M. Sato, and R. Ruedy (2012)
Perception of climate change
PNAS PLUS (2012, August 6), doi:10.1073/pnas.1205276109

Hare (1997)

Bill Hare (1997)
Fossil fuels and Climate Protection: The Carbon Logic
Greenpeace International

Hare in Mastny (2009)

W. L. Hare (2009)
A Safe Landing for the Climate

In: Mastny (Ed.): *State of the World 2009: into a Warming World* (chapter 2)
World Watch Institute

Harley et al. (2006)

Christopher D. G. Harley, A. Randall Hughes, Kristin M. Hultgren, Benjamin G. Miner, Cascade J. B. Sorte, Carol S. Thornber, Laura F. Rodriguez, Lars Tomanek and Susan L. Williams (2006)
The impacts of climate change in coastal marine systems
Ecology Letters, vol. 9:2, pp. 228-241

Harris et al. (2007)

A. Harris, S. Rahman, F. Hossain, L. Yarborough, A. C. Bagtzoglou, G. Easson (2007)
Satellite-based Flood Modeling Using TRMM-based Rainfall Products
Sensors, vol. 7, pp. 3416-3427

Harrison et al. (1999)

S.J. Harrison, S.J. Winterbottom and C. Sheppard (1999)
The potential effects of climate change on the Scottish tourist industry
Tourism Management, vol. 20, Iss. 2, pp. 203-211

Hart (1996)

Stuart L. Hart (1996)
Beyond Greening: Strategies for a sustainable world
Harvard Business Review

Haya (2007)

Barbara Haya (2007)
Failed Mechanism: How the CDM is Subsidizing Hydro Developers and Harming the Kyoto Protocol
Berkeley, CA, International Rivers

Hella and Zavaleta (2009)

N. E. Heller, E. S. Zavaleta (2009)
Biodiversity management in the face of climate change: A review of 22 years of recommendations
Biological Conservation, vol. 142, pp. 14-32

Helm et al. (2010)

Helm, K. P., N. L. Bindoff, and J. A. Church (2010)
Changes in the global hydrological-cycle inferred from ocean salinity
Geophysical Research Letters, vol. 37, L18701

Hellmann et al. (2008)

J.J. Hellmann, J. E. Byers, B. G. Bierwagen and J. S. Dukes (2008)
Five Potential Consequences of Climate Change for Invasive Species
Conservation Biology, vol. 22, No. 3, pp. 534-543

Hewitt and Jackson eds. (2009)

C. Nick Hewitt and Andrea V. Jackson (2009)
Atmospheric Science for Environmental Scientists
Wiley- Blackwell Publishing

Hidalgo et al. (2009)

H. G. Hidalgo, T. Das, M. D. Dettinger, D. R. Cayan, D. W. Pierce, T. P. Barnett, G. Bala, A. Mirin, A. W. Wood, C. Bonfils, B. D. Santer, and T. Nozawa (2009)
Detection and Attribution of Streamflow Timing Changes to Climate Change in the Western United States
Journal of Climate, vol. 22 pp. 3838-3855

Hiddink and Hofstede (2008)

J. G. Hiddink and R. Ter Hofstede (2008)
Climate induced increases in species richness of marine fishes
Global Change Biology, vol. 14:3, pp. 453-460

Hill et al. (2004)

David J. Hill, J. Mark Elwood, Dallas R. English (2004)
Prevention of Skin Cancer
Kluwer Academic Publishers: the Netherlands

Hoegh-Guldberg (2011)

O. Hoegh-Guldberg (2011)
The current and future impacts of climate change and ocean acidification on the Great Barrier Reef
Report prepared for an objections hearing in the Land Court of Queensland regarding the proposed Wandoan Coal Mine

Hoegh-Guldberg et al. (2007)

O. Hoegh-Guldberg, P. J. Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira, N. Knowlton, C. M. Eakin, R. Iglesias-Prieto, N. Muthiga, R. H. Bradbury, A. Dubi, and M. E. Hatzioiols (2007)
Coral Reefs Under Rapid Climate Change and Ocean Acidification
Science, vol. 318, pp. 1737-1742

Hoegh-Guldberg and Bruno (2010)

Ove Hoegh-Guldberg and John F. Bruno (2010)
The Impact of Climate Change on the World's Marine Ecosystems
Science, vol. 328, no. 5985, pp. 1523-1528

Hoekstra et al. (2010)

Jonathan M. Hoekstra, Jennifer L. Molnar, Michael Jennings, Carmen Revenga, Mark D. Spalding, Timothy M. Boucher, James C. Robertson, Thomas J. Heibel, and Katherine Ellison (2010)
The Atlas of Global Conservation: Changes, Challenges, and Opportunities to Make a Difference
Berkeley: University of California Press
Retrieved: <http://preview.grid.unep.ch/index.php?preview=home&lang=eng>

Holm Olsen and Fenhann (2008)

K. Holm Olsen and J. Fenhann (2008)
A Reformed CDM - including new Mechanisms for Sustainable Development
Roskilde, Denmark, Capacity Development for CDM (CD4CDM) Project, UNEP Risø Centre

Holman et al. (2008)

Corey Holman, Bobbie Joyeux and Christopher Kask (2008)
Labor productivity trends since 2000, by sector and industry
Monthly Labor Review, February 2008, pp. 64-82

Hooper et al. (2012)

David U. Hooper, E. Carol Adair, Bradley J. Cardinale, Jarrett E. K. Byrnes, Bruce A. Hungate, Kristin L. Matulich, Andrew Gonzalez, J. Emmett Duffy, Lars Gamfeldt, Mary I. O'Connor (2012)
A global synthesis reveals biodiversity loss as a major driver of ecosystem change
Nature

Hope (2006)

Chris Hope (2006)
The Marginal Impact of CO2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern
The Integrated Assessment Journal, vol. 6, Iss. 1, pp. 19-56

HPN (2012)

Humanitarian Practice Network (2012)
Special feature: The crisis in the Horn of Africa
Humanitarian Exchange, no. 53
Overseas Development Institute (ODI)

Hübler et al. (2007)

Michael Hübler, Gernot Klepper, Sonja Peterson (2007)
Costs of Climate Change: The Effects of Rising Temperatures on Health and Productivity in Germany
Kiel Working Paper No. 1321
Kiel, Germany, Kiel Institute for the World Economy

Hughes et al. (2003)

T. P. Hughes, A. H. Baird, D. R. Bellwood, M. Card, S. R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J. B. C. Jackson, J. Kleypas, J. M. Lough, P. Marshall, M. Nyström, S. R. Palumbi, J. M. Pandolfi, B. Rosen, J. Roughgarden (2003)
Climate Change, Human Impacts, and the Resilience of Coral Reefs
Science, vol. 301, pp. 929-933

Hughes and Diaz (2008)

M.K. Hughes and H.F. Diaz (2008)
Climate variability and change in the drylands of Western North America
Global and Planetary Change, vol. 64, Iss. 3-4, pp. 111-118

Huifang Guo et al. (2012)

Huifang Guo, Zhigang Song, Shengyuan Yang (2012)
Corrosion of permeable concrete under simulated acid rain
Key Engineering Materials, vol: 517, pp. 352-356

Hunter (2003)

P.R. Hunter (2003)
Climate change and waterborne and vector-borne disease
Journal of Applied Microbiology, vol. 94, pp. 37S-46S

Huntington (2006)

Thomas G. Huntington (2006)
Evidence for intensification of the global water cycle: Review and synthesis
Journal of Hydrology, vol. 319, pp. 83-95

Hutchings et al. (2010)

Jeffery A. Hutchings, Cíilín Minto, Daniel Ricard, Julia K. Baum, Olaf P. Jensen (2010)
Trends in the abundance of marine fishes
Canadian Journal of Fisheries and Aquatic Sciences, vol. 67:8, pp. 1205-1210

IAP (2009)

Interacademy Panel on International Issues (2009)
IAP Statement on Tropical Forests and Climate Change
Retrieved: <http://www.interacademies.net/File.aspx?id=10070>

IBRD WB (2010)

The International Bank for Reconstruction and Development / The World Bank (2010)
Economics of Adaptation to Climate Change. Synthesis Report
Washington DC, The International Bank for Reconstruction and Development / The World Bank

ICI (2010)

Initiatives Conseil International (2010)
Etat des lieux autour du barrage de Bagré au Burkina Faso. Rapport Final
IUCN, The Global Water Initiative and International Institute for Environment and Development

Idso (1989)

S.B., Idso (1989)
Carbon dioxide and global change
Tempe, AZ (USA); Institute for Biospheric Research

IEA (2011)

International Energy Agency (2011)
World Energy Outlook 2011
Retrieved: <http://www.worldenergyoutlook.org>

IEA (2011a)

International Energy Agency (2011)
Energy for all. Financing access for poor. Special yearly excerpt of the world energy outlook 2011
OECD/IEA

IEA (2012a)

International Energy Agency (2012)
IEA Response System for Oil Supply Emergencies 2012
Paris, International Energy Agency
Retrieved: [http://www.iea.org/media/delegates/seq/meetings/march12/IEA-SEQ\(2012\)9.pdf](http://www.iea.org/media/delegates/seq/meetings/march12/IEA-SEQ(2012)9.pdf)

IEA (2012b)

International Energy Agency (2012)
Energy Statistics and Balances of Non-OECD Countries, Energy Statistics of OECD Countries, and Energy Balances of OECD Countries
Retrieved 2010: <http://www.iea.org/stats/index.asp>

IFP (2011)

IFP Énergies Nouvelles, Economics and Information Watch and Management Division (2011)
Investment in exploration-production and refining 2011
IFP Énergies Nouvelles

Ikuta et al. (2000)

K. Ikuta, T. Yada, S. Kitamura, N. Branch, F. Ito, F. M. Yamaguchi, M., T. Nishimura, T. Kaneko, M. Nagae, A. Ishimatsu, M. Iwata (2000)
Effects of Acidification on Fish Reproduction
IJNR Technical Report, No. 28.

Ikuta et al. (2008)

Kazumasa Ikuta, Takashi Yada, Shoji Kitamura, Toyoji Kaneko, Maki Nagae, Atsushi Ishimatsu and Munehiko Iwata (2008)
Effects of Acidification on Fish Reproduction
IJNR Technical Report No. 28

ILO (2005)

International Labor Office (2005)
Women's Employment: Global Trends and ILO Responses
ILO Contribution 49th Session of the Commission on the Status of Women, United Nations, New York

ILO (2012)

ILO (2012)
Various resources: LABORSTA Database
<http://laborsta.ilo.org/>

ILO (2011)

ILO (2011)
Global Employment Trends 2011: The challenge of a jobs recovery
Geneva, Switzerland, International Labour Office

IMF (2011)

IMF (2011)
World Economic Outlook (2011 data and statistics)
International Monetary Fund

IMFR (2012)

International Mining Fatality Review (2012)
NSW Government
Retrieved: <http://www.resources.nsw.gov.au/safety/publications/statistical-publications/international-mining-fatality-review>

IMF WEO (2012)

IMF World Economic Outlook Database (2012)
Retrieved: <http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/index.aspx>

Imhoff et al. (2004)

Imhoff Marc L., Lahouari Bounoua, Taylor Ricketts, Colby Loucks, Robert Harriss, and William T. Lawrence (2004)
Spatial Distribution of Net Primary Productivity (NPP)
Data distributed by the Socioeconomic Data and Applications Center (SEDAC)
<http://sedac.ciesin.columbia.edu/es/hanpp.html>

Immerzeel et al. (2012)

Walter W. Immerzeel, L. P. H. van Beek, M. Konz, A. B. Shrestha and M. F. P. Bierkens (2012)
Hydrological response to climate change in a glacierized catchment in the Himalayas
Climatic Change, vol. 110, pp. 721-736

Ingene et al. (2010)

Charles A. Ingene, Jianfeng Jiang and Rahul Govind (2010)
Labor Productivity in Retailing: A Modern Assessment
In: M. K. Brady and M. D. Hartline (Eds.): *Marketing Theory and Applications. 2010 AMA Winter Educators' Conference* (p.107)
Chicago, IL, U.S.A., American Marketing Association

IOM (2008)

IOM (2008)
Migration and Climate Change No. 31
IOM Migration Research Series
Geneva, Switzerland, International Organization for Migration

IPA (2012)

International Permafrost Association (2012)
What is Permafrost?
Retrieved: <http://ipa.arcticportal.org/resources/what-is-permafrost>

IPCC (1990)

Intergovernmental Panel on Climate Change (1990)
IPCC First Assessment Report (FAR). Overview Chapter.
Retrieved: http://www.ipcc.ch/ipccreports/1992%20IPCC%20Supplement/IPCC_1990_and_1992_Assessments/English/ipcc_90_92_assessments_far_overview.pdf

IPCC (1995)

Intergovernmental Panel on Climate Change (1995)
IPCC Second Assessment. Climate Change 1995
Retrieved: <http://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf>

IPCC (2002)

IPCC (2002)
Climate Change and Biodiversity. IPCC Technical Paper V
Retrieved: <http://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf>

IPCC (2000)

IPCC (2000)
IPCC Special Report Emissions Scenarios (SRES)
Retrieved: <http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf>

IPCC (2001)

IPCC (2001)
Climate Change 2001: Synthesis Report. Summary for Policymakers
Retrieved: <http://www.ipcc.ch/pdf/climate-changes-2001/synthesis-spm/synthesis-spm-en.pdf>

IPCC (2007)

IPCC (2007)
Fourth Assessment Report : Climate Change 2007 (AR4)
Geneva, Switzerland: GRID Arendal & Intergovernmental Panel on Climate Change

IPCC (2007b)

IPCC (2007b)
Technical Summary, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,
Cambridge, UK: Cambridge University Press.

IPCC (2012a)

IPCC (2012a)
Managing the risks of extreme events and disasters to advance Climate Change adaptation
Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)].
Cambridge, UK, and New York, NY, USA, Cambridge University Press

IPCC (2012b)

IPCC (2012b)
Renewable Energy Sources and Climate Change Mitigation
Special Report of the Intergovernmental Panel on Climate Change
Cambridge University Press
http://sren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf

IPCC Data (2012)

IPCC Data (2012)
IPCC Data Distribution Centre
Retrieved: <http://www.ipcc-data.org/>

Irish et al. (2008)

Jennifer L. Irish, Donald T. Resio, Jay J. Ratcliff (2008)
The Influence of Storm Size on Hurricane Surge
Journal of Physical Oceanography, vol. 38, no. 9, pp. 2003-2013

Isaac and van Vuuren (2009)

Morna Isaac and Detlef P. van Vuuren (2009)
Modeling global residential sector energy demand for heating and air conditioning in the context of climate change
Energy Policy, vol. 37, no. 2, pp. 507-521.

Isaac et al. (2008)

Morna Isaac, Detlef P. van Vuuren (2008)
Modeling global residential sector energy demand for heating and air conditioning in the context of climate change
Energy Policy, vol.37, iss. 2, pp. 507-521

Ismail and El Shamy (2009)

A.I.M. Ismail and A.M. El-Shamy (2009)
Engineering behaviour of soil materials on the corrosion of mild steel
Applied Clay Science, vol.42:3-4, pp. 356-362

ISO (1989)

ISO (1989)
ISO. Hot Environments—Estimation of the Heat Stress on Working Man, Based on the WBGT-Index (Wet Bulb Globe Temperature). ISO Standard 7243
Geneva, International Standards Organization; 1989

Jamison et al. (eds.) (2006)

D.T. Jamison, J. G. Breman, A. R. Measham, G. Alleyne, M. Claeson, D. B. Evans, P. Jha, A. Mills, P. Musgrove (2006)
Disease Control Priorities in Developing Countries
Oxford University Press and the World Bank

Jansson (2010)

Jansson, Tor (2010)
Success Factors in Microfinance Greenfielding. Washington, DC, US, World Bank
Retrieved: <https://openknowledge.worldbank.org/handle/10986/10488> License

Jetten and Focks (1997)

T.H. Jetten and D.A. Focks (1997)
Potential Changes in the Distribution of Dengue Transmission under Climate Warming
The American Journal of Tropical Medicine and Hygiene, vol. 57, no. 3, pp. 285-297

Jeziorski et al. (2008)

A. Jeziorski, N.D. Yan, A.M. Paterson, A.M. DeSellas, M.A. Turner, D.S. Jeffries, B. Keller, R.C. Weeber, D.K. McNicol, M.E. Palmer, K. McIver, K. Arseneau, B.K. Ginn, B.F. Cumming, and J.P. Smol (2008)
The Widespread Threat of Calcium Decline in Fresh Waters
Science, vol. 322, pp. 1374-1377

Jiangang (2011)

Niu Jiangang (2011)
Investigation on the properties of fly ash concrete attacked by acid rain
Electric Technology and Civil Engineering (ICETE), pp.2335-2339

Johns et al. (1997)

T.C. Johns, R.E. Carnell, J.F. Crossley, J.M. Gregory, J.F.B. Mitchell, C.A. Senior, S.F.B. Tett, and R.A. Wood, 1997
The second Hadley Centre coupled ocean-atmosphere GCM: Model description, spinup and validation.
Climate Dynamics, vol 13, p103-134.
Retrieved: <http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/hadcm2>

Johnson et al (eds.) (2006)

Pierre-Marc Johnson, Karel Mayrand and Marc Paquin (eds.) (2006)
Governing Global Desertification: Linking Environmental Degradation, Poverty and Participation
Hampshire, UK: Ashgate Publishing

Johnstone et al. (2005)

R. Johnstone, C. Mayhew, M. Quinlan (2005)
Outsourcing Risk? The Regulation of Occupational Health and Safety Where Subcontractors Are Employed
Comparative Labor Law and Policy Journal, vol. 22, pp. 351-394

Jones and Phillips eds. (2011)

A L Jones and M Phillips eds. (2011)
Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism
CABI

Jonkeren et al. (2007)

O. Jonkeren, P. Rietveldt, J. van Ommeren (2007)
Climate Change and Inland Waterway Transport: Welfare Effects of Low Water Levels on the River Rhine
Journal of Transport Economics and Policy, vol. 41, iss. 3, pp. 387-411.

Jonkman et al. (2008)

S.N. Jonkman, M. Bočkarjova, M. Kok and P. Bernardini (2008)
Integrated hydrodynamic and economic modelling of flood damage in the Netherlands
Ecological Economics, vol. 66, no. 1, pp.77 – 90

Jorgenson and Vu (2011)

D. Jorgenson, and K. Vu (2011)
Technology and Labor Productivity
Development Outreach, vol. 13, Iss. 1

Jung et al. (2010)

M. Jung, M. Reichstein, P. Ciais, S. I. Seneviratne, J. Sheffield, M. L. Goulden, G. Bonan, A. Cescatti, J. Chen, R. de Jeu, A. J. Dolman, W. Eugster, D. Gerten, D. Gianelle, N. Gobron, J. Heinke, J. Kimball, B. E. Law, L. Montagnani, Q. Mu, B. Mueller, K. Oleson, D. Papale, A. D. Richardson, O. Roupsard, S. Running, E. Tomelleri, N. Viovy, U. Weber, C. Williams, E. Wood, S. Zaehle and K. Zhang (2010)
Recent decline in the global land evapotranspiration trend due to limited moisture supply
Nature (Letters), vol. 467, pp. 951-954

Kaczmarek et al. (eds.) (1996)

Z. Kaczmarek, K. M. Strzpek, L. Somlyódy, V. Priazhinskaya (1996)
Water Resources Management in the Face of Climatic/Hydrologic Uncertainties
Springer

Kang et al. (2004)

S. Kang, X. Su, L. Tong, P. Shi, X. Yang, Y. Abe, T. Du, Q. Shen and J. Zhang (2004)
The impacts of human activities on the water-land environment of the Shiyang River basin, an arid region in northwest China
Hydrological Sciences—Journal—des Sciences Hydrologiques, vol. 49, no.3, pp. 413-427

Kaplan (1952)

Lewis D. Kaplan (1952)
On the pressure dependence of radiative heat transfer in the atmosphere
Journal of Meteorology, vol. 9, no. 1.

Kaufmann et al. (2011)

R. K. Kaufmann, I. H. Kauppib, M. L. Mann, and J. H. Stock (2011)
Reconciling anthropogenic climate change with observed temperature 1998–2008
Proceedings of the National Academy of Sciences of the USA (PNAS), vol. 108, no. 29, pp.11790–11793

Kawaguchi et al. (2011)

S. Kawaguchi, H. Kurihara, R. King, L. Hale, T. Berli, J.P. Robinson, A. Ishida, M. Wakita, P. Virtue, S. Nicol and A. Ishimatsu (2011)
Will krill fare well under Southern Ocean acidification?
Biology Letters, vol.7, pp. 288-291

Kelly et al. (2010)

E.N. Kelly, D.W. Schindler, P.V. Hodson, J.W. Short, R. Radmanovich, and C.C. Nielsen (2010)
Oil sands development contributes elements toxic at low concentrations to the Athabasca River and its tributaries
Proceedings of the National Academy of Sciences of the United States (PNAS), vol 107, no 37

Kelly and Goulden (2008)

Anne E. Kelly and Michael L. Goulden (2008)
Rapid shifts in plant distribution with recent climate change
Proceedings of the National Academy of Sciences (PNAS), vol. 105, no. 33, pp. 11823-11826

Kennedy and Munce (2003)

W.L. Kennedy and T.A. Munce (2003)
Invited Review: Aging and Human Temperature Regulation
Journal of Applied Physiology, vol. 95, pp. 2598-2603

Khan (2007)

M. S. A. Khan (2007)
Disaster preparedness for sustainable development in Bangladesh
Disaster Prevention and Management: An International Journal, vol. 17, no. 5, pp. 662-671

Khan and Schwatz (2007)

M.E. Kahn and J. Schwatz (2007)
Urban Air Pollution Progress Despite Sprawl: The "Greening" of the Vehicle Fleet.
Journal of Urban Economics, vol. 63, no. 3, pp. 775-787,

Kharas (2010)

Homi Kharas (2010)
The Emerging Middle Class In Developing Countries
OECD Development Centre

Kharin et al. (2007)

Viatcheslav V. Kharin, Francis W. Zwiers, Xuebin Zhang, and Gabriele C. Hegerl (2007)
Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations
Journal of Climate, vol. 20, pp. 1419-1444.

Kingombe (2011)

Christian Kingombe (2011)
Achieving pro-poor growth through investment in rural feeder roads: the role of impact evaluation
ODI Background Notes, August 2011
Overseas Development Institute

Kleeman et al. (1999)

M. J. Kleeman, J. J. Schauer and G. R. Cass (1999)
Size and Composition Distribution of Fine Particulate Matter Emitted from Wood Burning, Meat Charbroiling, and Cigarettes
Environmental Science and technology, vol. 33, iss.20, pp. 3516-3523

Klein et al. (2001)

R. J. T. Klein, R. J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston and E. N. Buckley (2001)
Technological Options for Adaptation to Climate Change in Coastal Zones
Journal of Coastal Research, vol. 17, no. 3, pp. 531-543

Kiparsky et al. (2012)

Michael Kiparsky, Anita Milman, and Sebastian Vicuña (2012)
Climate and Water: Knowledge of Impacts to Action on Adaptation
Annual Review of Environment and Resources, vol. 37

Kjellstrom et al. (2009 a)

Kjellstrom T., Kovats R.S., Lloyd S.J., Holt T., Tol R.S. (2009)
The Direct Impact of Climate Change on Regional Labor Productivity
Archives of Environmental & Occupational Health, vol. 64, no. 4.

Kjellstrom et al. (2009 b)

Tord Kjellstrom, Ingvar Holmer and Bruno Lemke (2009 b)
Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change
Global Health Action 2009

Kjellstrom et al (2009d)

T. Kjellstrom, I. Holmer, B. Lemke (2009 b)
Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change
Global Health Action, vol.2

Kjellstrom ed. (2009)

Tord Kjellstrom (2009)
Global Health Action Special Volume 2009.
Climate change and global health: linking
science with policy. Heat, work and health:
implications of climate change
Sweden, Umeå University, Co-Action Publishing

Knutson et al (2010)

T. Knutson, C. Landsea and K. Emanuel (2010)
Tropical Cyclones and Climate Change
In: C. L. Chan and J. D. Kepert (eds.): *Global
Perspectives on Tropical Cyclones: From
Science to Mitigation*
World Scientific Publishing

Knutti et al. (2008)

R. Knutti, M. R. Allen, P. Friedlingstein, J.
M. Gregory, G. C. Hegerl, G. A. Meehl, M.
Meinshausen, J. M. Murphy, G.-K. Plattner, S. C.
B. Raper, T. F. Stocker, P. A. Stott, H. Teng, and T.
M. L. Wigley (2008)
A Review of Uncertainties in Global Temperature
Projections over the Twenty-First Century
Journal of Climate, vol. 21, no. 11, pp.
2651-2663.

Koenig and Abegg (1997)

Urs Koenig and Bruno Abegg (1997)
Impacts of Climate Change on Winter Tourism in
the Swiss Alps
Journal of Sustainable Tourism, vol. 5, no. 1,
pp.46-58

Koetse and Rietveld (2009)

Mark J. Koetse, Piet Rietveld (2009)
The impact of climate change and weather on
transport: An overview of empirical findings
Transportation Research Part D, vol. 14, pp.
205-221

Kolokotroni et al. (2010)

M. Kolokotroni, M. Davies, B. Croxford, S.
Bhuiyan and A. Mavrogiani (2010)
A validated methodology for the prediction
of heating and cooling energy demand for
buildings within the Urban Heat Island: Case-
study of London
Solar Energy, vol. 84, iss. 12, pp. 2246-2255,

KPMG (2008)

KPMG (2008)
Climate Changes your Business. KPMG's review
of the business risks and economic impacts as
sector level
KPMG International

Kramer et al. (2008)

Koen Kramer, Stefan J. Vreugdenhil, D.C. van der
Werf (2008)
Effects of flooding on the recruitment, damage
and mortality of riparian tree species: A field
and simulation study on the Rhine floodplain
Forest Ecology and Management, vol. 255, iss.
11, pp.3893-3903

Krawchuk et al. (2009)

Meg A. Krawchuk, Max A. Moritz, Marc-André
Parisien, Jeff Van Dorn, Katharine Hayhoe
(2009)
Global Pyrogeography: the Current and Future
Distribution of Wildfire
PLoS ONE, vol. 4, no. 4, iss. 4, pp.
e5102-e5102

Krugman (2009)

P. Krugman (2009, September 6))
How Did Economists Get It So Wrong?
The New York Times
Retrieved: http://www.nytimes.com/2009/09/06/magazine/06Economic.html?_r=1

Kshirsagar et al. (2007)

N. Kshirsagar, N. Mur, U. Thatte, N. Gogtay,
S. Viviani, M. Préziosi, C. Elie, H. Findow, G.
Carlone, R. Borrow, V. Parulekar, B. Plikaytis, P.
Kulkarni, N. Imbault, and F.M. LaForce (2007)
Safety, Immunogenicity, and Antibody
Persistence of a New Meningococcal Group A
Conjugate Vaccine in Health Indian Adults
Vaccine, vol. 25, suppl. 1, pp. A101-A107

Kuik et al. (2008)

O. Kuik, B. Buchner, M. Catenacci, A. Gorla, E.
Karakaya and R. S. J. Tol (2008)
Methodological aspects of recent climate
change damage cost studies
The Integrated Assessment Journal, vol. 8, iss.
1, pp. 19-40

Kumar (2012)

Harendra Kumar (2012)
Human Health Hazards in Relation to
Environmental Damage: A Review
Advances in Asian Social Science, vol. 1, no. 1,
PP. 135- 138

Kumari et al. (2007)

B. Padma Kumari, A. L. Londhe, S. Daniel and D.
B. Jadhav (2007)
Observational evidence of solar dimming:
Offsetting surface warming over India
Geophysical Research Letters, vol. 34, L21810

Kurukulasuriya et al. (2006)

P. Kurukulasuriya, R.Mendelsohn, R. Hassan, J.
Benhin, T. Deressa, M. Diop, H.Mohamed Eid, K.
Yerfi Fosu, G. Gbetibouo, S. Jain, A. Mahamadou,
R. Mano, J.Kabubo-Mariara, S. El-Marsafawy,
E. Molua, S. Ouda, M. Ouedraogo, I. Se'ne, D.
Maddison, S. Niggol Seo, and Ariel Dinar (2006)
Will African Agriculture Survive Climate Change?
The World Bank Economic Review, vol. 20, no. 3

Kurz et al. (2008)

W. A. Kurz, C. C. Dymond, G. Stinson, G. J.
Rampley, E. T. Neilson, A. L. Carroll, T. Ebata and
L. Safranyik (2008)
Mountain pine beetle and forest carbon
feedback to climate change
Nature (Letters), Vol. 452

Laan et al. (2011)

T. Laan, Ch. Beaton and B. Presta (2011)
*Strategies for Reforming Fossil-Fuel Subsidies:
Practical lessons from Ghana, France and
Senegal*
International Institute for Sustainable
Development(IISD)

LaForce et al. (2007)

F.M. LaForce, K. Konde, S. Viviani, M. Préziosi
(2007)
The Meningitis Vaccine Project
Vaccine, vol.25, suppl. 2, pp. A97-A100

LaForce and Okwo-Bele (2011)

F.M. LaForce and J. Okwo-Bele (2011)
Eliminating Epidemic Group A Meningococcal
Meningitis in Africa through a New Vaccine
Health Affairs, vol. 30, no. 6, pp. 1049-1057

Laguna and Capelle-Blancard (2010)

M-A. Laguna, G. Capelle-Blancard (2010,
may 5)
How does the stock market respond to
petrochemical disasters?
*Vox, Research-based policy analysis and
commentary from leading economists*
Retrieved: [http://www.voxeu.org/article/
how-does-stock-market-respond-petrochemical-
disasters?quicktabs_tabbed_recent_articles_
block=1](http://www.voxeu.org/article/how-does-stock-market-respond-petrochemical-disasters?quicktabs_tabbed_recent_articles_block=1)

Larsen and Goldsmith (2007)

Peter Larsen and Scott Goldsmith (2007)
How much Might Climate Change Add to Future
Costs for Public Infrastructure?
Understanding Alaska, Research Summary,
no. 8.
Institute of Social and Economic Research,
University of Alaska Anchorage

Larssen et al. (2006)

Thorjorn Larssen, Espen Lydersen, Dagang
Tang, Yi He, Jixi Gao, Haiying Liu, Lei Duan,
Hans M. Seip, Rolf D. Vogt, Jan Mulder, Min
Shao,Yanhui Wang, He Shang, Xiaoshan Zhang,
Svein Solberg, Wenche Aas, Tonje Økland, Odd
Eilertsen, Valt er Angell, Quanru Liu, Dawei
Zhao, Renjun Xiang, Jinshong Xiao and Jiahai
Luo (2006)
Acid Rain in China
Environmental Science & Technology (January
15, 2006) pp.418- 425
American Chemical Society

Larson et al. (2001)

K.J Larson, H Baóagaoglu, M.A Mariño (2001)
Prediction of optimal safe ground water
yield and land subsidence in the Los Banos-
Kettleman City area, California, using a
calibrated numerical simulation model
Journal of Hydrology, vol. 242, iss. 1-2, pp.
79-102

Last et al. (2010)

Peter. R. Last, William. T. White, Daniel. C.
Gledhill, Alistair. J. Hobday, Rebecca Brown,
Graham. J. Edgar and Gretta Pecl (2010)
Long-term shifts in abundance and distribution
of a temperate fish fauna: a response to climate
change and fishing practices
Global Ecology and Biogeography, vol. 20:1,
pp. 58-72

Lavell (2008)

Allan Lavell (2008)
*Relationships between Local and Community.
Disaster Risk Management and Poverty
Reduction: A Preliminary Exploration.*
Background paper for: Global Assessment
Report on Disaster Risk Reduction (2009)
Geneva, ISDR (International Strategy for
Disaster Reduction) Secretariat. United Nations

Leakey et al. (2009)

Andrew D. B. Leakey, Elizabeth A. Ainsworth, Carl
J. Bernacchi, Alistair Rogers, Stephen P. Long
and Donald R. Or (2009)
Elevated CO2 effects on plant carbon, nitrogen,
and water relations: six important lessons
from FACE
Journal of Experimental Botany, vol. 60, no. 10,
pp. 2859-2876

Leblanc et al. (2008)

M.J. Leblanc, P.Tregoning, G. Ramillien, S.O.
Tweed, and A. Fakes (2008)
Basin-Scale, Integrated Observations of
the Early 21st Century Multityear Drought in
Southeast Australia
Water Resources Research, vol. 45

Lee et al. (2003)

Lee David J., Gómez-Marín Orlando, Lam Byron
L, Zheng D Diane (2003)
Visual impairment and unintentional injury
mortality: the National Health Interview Survey
1986-1994
American journal of ophthalmology, vol. 136,
no. 6, pp. 1152-1154.

Lee et al. (2003b)

Yung-Ling Lee, Ying-Chu Lin, Tzuen-Ren Hsiue,
Bing-Fang Hwang, Yueliang Leon Guo (2003)
Indoor and Outdoor Environmental Exposures,
Parental Atopy, and Physician-Diagnosed
Asthma in Taiwanese Schoolchildren
Pediatrics, vol. 112, no.5, pp. 389-395

Lee and Jetz (2008)

Tien Ming Lee and Walter Jetz (2008)
Future battlegrounds for conservation under
global change
Proceedings of the Royal Society B, vol. 275,
pp. 1261-1270

Lehner et al. (2001)

Bernhard Lehner, Gregor Czisch and Sara Vassolo (2001)

Europe's Hydropower Potential Today and in the Future

In: Lehner B. et al.: *EuroWasswer: Model-based assessment of European water resources and hydrology in the face of global change*. Kassel World Water Series 5, Ch. 8, pp. 8.1-8.22.

Kassel, Germany: Center for Environmental Systems Research, University of Kassel

Lehner et al. (2005)

Bernhard Lehner, Gregor Czisch and Sara Vassolo (2005)

The impact of global change on the hydropower potential of Europe: a model-based analysis
Energy Policy, vol. 33, iss. 7, pp. 839-855,

Leisner and Ainsworth (2011)

Courtney P. Leisner and Elizabeth A. Ainsworth (2011)

Quantifying the effects of ozone on plant reproductive growth and development
Global Change Biology, vol. 18, iss. 2, pp. 606-616

Le Manach et al. (2012)

Fredéric Le Manach, Charlotte Gough, Alasdair Harris, Frances Humber, Sarah Harper and Dirk Zeller (2012)

Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar

Marine Policy, vol. 36:1, pp. 218-225

Lempert and Schlesinger (2000)

R. J. Lempert and M.E. Schlesinger (2000)

Robust Strategies for Abating Climate Change
Climatic Change, vol. 45, no. 3-4, pp. 387-401

Lesnoff et al. (2012)

M. Lesnoff, C. Corniaux, and P. Hiernaux (2012)

Sensitivity Analysis of the Recovery Dynamics of a Cattle Population Following Drought in the Sahel Region

Ecological Modelling, vol. 232, pp. 28-39

Lewis et al. (2011)

S. L. Lewis, P. M. Brando, O. L. Phillips, G. M. F. van der Heijden and D. Nepstad (2011)

The 2010 Amazon Drought

Science, Vol. 331, p.554

Likens et al. (1996)

G.E. Likens, C.T. Driscoll and D.C. Buso (1996)

Long-Term Effects of Acid Rain: Response and recovery of a Forest Ecosystem

Science, New Series, vol. 272, no. 5259, pp. 244-246

Lin et al. (2009)

S. Lin, M. Luo, R.J. Walker, X. Liu, S. Hwang, and R. Chinery (2009)

Extreme High Temperatures and Hospital Admissions for Respiratory and Cardiovascular Diseases

Epidemiology, vol. 20, iss. 5, pp. 738-746

Lin et al. (2011)

Z. Lin, F. Niu, H. Liu, J. Lu (2011)

Disturbance-related thawing of a ditch and its influence on roadbeds on permafrost
Cold Regions Science and Technology, vol. 66, iss. 2-3, pp. 105-114

Lin et al. (2011b)

Cui Lin, San-Juan Chen, Wen He, Li-Cai Zhao (2011b)

Effect of Acid Rain on Corrosion Behavior of Mild Steel

Journal of Iron and Steel Research, vol. 23:6, pp. 18-23

Linnerooth-Bayer and Melcher (2006)

J. Linnerooth-Bayer and R. Melcher (2006)

Insurance for Assisting Adaptation to Climate Change in Developing Countries: A Proposed Strategy

Climate Policy, vol. 6, no. 6, pp. 621-636

Long et al. (2005)

Stephen P. Long, Elizabeth A. Ainsworth, Andrew D. B. Leakey and Patrick B. Morgan (2005)

Global food insecurity. Treatment of major food crops with elevated carbon dioxide or ozone under large-scale fully open-air conditions suggests recent models may have overestimated future yields

Phil. Trans. R. Soc. B, vol. 360, pp. 2011-2020

Lobell et al. (2008)

David B. Lobell, Marshall B. Burke, Claudia Tebaldi, Michael D. Mastrandrea, Walter P. Falcon and Rosamond L. Naylor.

Prioritizing Climate Change Adaptation Needs for Food Security in 2030

Science, vol. 319, pp.607-610

Long et al. (2006)

Stephen P. Long, Elizabeth A. Ainsworth, Andrew D. B. Leakey, Josef Nothberger, Donald R. Ort (2006)

Food for Thought: Lower-Than- Expected Crop Yield Stimulation with Rising CO2 Concentrations

Science, vol. 312, pp. 1918- 1921

Lorius et al. (1985)

C. Lorius, C. Ritz, J. Jouzel, L. Merlivat and N. I. Barkov (1985)

A 150,000-year climatic record from Antarctic ice

Nature, vol. 316, pp. 591-596.

Lotze-Campen et al. (2012)

H. Lotze-Campen, C. Müller, A. Popp and H.-M. Füssel (2012)

Food Security in a Changing Climate

In: O. Edenhofer, J. Wallacher, H. Lotze-Campen, M. Reeder, B. Knopf and J. Müller (eds.): *Climate Change, Justice and Sustainability* (pp. 33-43)

London and New York, Springer Dordrecht Heilderberg

Lovins (2010)

Amory B. Lovins (2010)

Profitable Solutions to Climate, Oil, and Proliferation

AMBIO: A Journal of the Human Environment, vol. 39, no. 3, pp.236-248

Ludi (2009)

Eva Ludi (2009)

Climate change, water and food security

ODI Background Notes, Background Note March 2009

Ly (1980)

Cheng K Ly (1980)

The role of the Akosombo Dam on the Volta river in causing coastal erosion in central and eastern Ghana (West Africa)

Marine Geology, vol. 37, Iss. 3-4, pp. 323-332,

Lucas et al. (2006)

R. Lucas, T. McMichael, W. Smith and B. Armstrong (2006)

Solar Ultraviolet Radiation: Global Burden of Disease from Solar Ultraviolet Radiation

Environmental Burden of Disease Series, no. 13 Geneva, Switzerland, WHO Public Health and the Environment

Luecke (2006)

Christina L. Luecke (2006)

Gender differences during heat strain at critical WBGT

Graduate School Theses and Dissertations. University of South Florida (USF). Paper 2609.

Retrieved: <http://scholarcommons.usf.edu/etd/2609>

Lütken (2012)

Soren E. Lütken (2012)

Penny Wise , Pound Foolish? Is the original intention of cost efficient reduction through the CDM being fulfilled?

UNEP Risoe Climate Working Paper Series No. 1

UNEP Risoe Centre

Macdonald et al. (2005)

R.W. Macdonald, T. Harner and J. Fyfe (2005)

Recent climate change in the Arctic and its impact on contaminant pathways and interpretation of temporal trend data

Science of the Total Environment, vol. 342, Iss. 1-3, pp.5-86,

Mace et al. (2005)

Georgina Mace, Hillary Masundire, Jonathan Baillie (2005).

Biodiversity

in: R. Hassan, R. Scholes and N. Ash (eds.): *Ecosystems and Human Well-being: Current State and Trends* (Chapter 4)

Millennium Ecosystem Assessment

Maldives MEEW (2007)

Maldives Ministry of Environment, Energy and Water (2007)

National Adaptation Programme of Action (NAPA)

Republic of Maldives, Ministry of Environment, Energy and Water

Malhi et al. (2008)

Y. Malhi, J. Timmons Roberts, R.A. Betts, T.J. Killeen, W. Li, C.A. Nobre (2008)

Climate Change, Deforestation, and the Fate of the Amazon

Science, vol. 319, no. 5860, pp. 169-172

Marengo et al. (2011)

Jose A. Marengo, Javier Tomasella, Lincoln M. Alves, Wagner R. Soares, and Daniel A. Rodriguez (2011)

The drought of 2010 in the context of historical droughts in the Amazon region

Geophysical Research Letters, vol. 38, L12703

Marriott (2008)

A. Marriott (2008)

Extending Health and Safety Protection to Informal Workers: an analysis of small scale mining in KwaZulu-Natal

Research Report No. 76

Durban: School of Development Studies, University of KwaZulu-Natal.

Martens (1998)

W.J.M. Martens (1998)

Health Impacts of Climate Change and Ozone Depletion: An Ecopedidemiologic Modeling Approach

Environmental Health Perspectives, vol. 106, Suppl.1, pp. 241-251

Martens et al. (1999)

P. Martens, R.S. Kovats, S. Nijhof, P. de Vries, M.T.J. Livermore, D.J. Bradley, J. Cox, and A.J. McMichael (1999)

Climate Change and Future Populations at Risk of Malaria

Global Environment Change, vol. 9, suppl. 1, pp. S89-S107

Mathers and Loncar (2005)

Mathers CD, Loncar D. (2005)

Updated projections of global mortality and burden of disease, 2002-2030: data sources, methods and results

Working Paper, World Health Organization, Geneva

Mathers and Loncar (2006)

Mathers CD, Loncar D. (2006)
Projections of global mortality and burden of disease from 2002 to 2030
PLoS Medicine, vol. 3, no. 11

Maturu (1979)

N. Rao Maturu (1979)
Nutrition and Labour Productivity
International Labour Review, vol. 118, no. 1

Mayewski and White (2002)

Paul Andrew Mayewski and Frank White (2002)
The Ice Chronicles: the Quest to Understand Global Climate Change
Lebanon, New Hampshire, U.S.A., University Press of New England

Mc Adam (2011)

Jane Mc Adam (2011)
Climate Change Displacement and International Law: Complementary Protection Standards. Legal and Protection Policy Research Series
Geneva, Switzerland, United Nations High Commissioner for Refugees (UNHCR)

McCay (2004)

D.F. McCay (2004)
Estimation of potential impacts and natural resource damages of oil
Journal of Hazardous Materials, vol. 107, pp. 11-25

McCluney et al. (2012)

K. E. McCluney, J. Belnap, S.L. Collins, A. L., González, E.M. Hagen, J. Nathaniel Holland, B. P. Kotler, F.T. Maestre, S.D. Smith, and B. O. Wolf (2012)
Shifting species interactions in terrestrial dryland ecosystems under altered water availability and climate change
Biological Reviews, vol. 87, iss. 3, pp. 563-582

McGuire (2009)

D. McGuire (2009)
U.S. Global Climate Change Impacts Report, Alaska Region
American Geophysical Union, Fall Meeting 2009, abstract #GC23B-07

McKibben (2012)

Bill McKibben (2012, July 19)
Global Warming's Terrifying New Math
Rolling Stone Magazine
Retrieved: <http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719>

McKinnon and Utley (2005)

S. Helgerman McKinnon and R. Utley (2005)
Heat Stress: Understanding Factors and Measures Helps SH&E Professionals Take a Proactive Management Approach
Professional Safety, April 2005, pp. 41-47

McKinsey & Company (2009)

McKinsey & Company (2009)
Charting our Water Future: Economic Frameworks to Inform Decision Making
Munich: 2030 Water Resources Group

McMahon et al. (2010)

S. M. McMahon, G.G. Parker and D. R. Miller (2010)
Evidence for a recent increase in forest growth
Proceedings of the National Academy of Sciences (PNAS), vol. 10, no. 8, pp. 3611-3615

McMichael et al. (2006)

A.J. McMichael, R.E. Woodruff, and S. Hales (2006)
Climate change and human health: present and future risks
Lancet, vol. 367, pp. 859 - 69

McMillan and Rodrik (2012)

Margaret McMillan and Dani Rodrik (2012)
Globalization, Structural Change, and Productivity Growth
IFPRI Discussion Paper 01160
International Food and Policy Research Institute

McNabola and Gill (2009)

Aonghus McNabola and Laurence William Gill (2009)
The Control of Environmental Tobacco Smoke: A Policy Review
International Journal of Environmental Research and Public Health, vol. 6, iss.2, pp. 741-758

McNeil and Letschert (2008)

McNeil Michael A. and Letschert Virginia E. (2008)
Future Air Conditioning Energy Consumption in Developing Countries and what can be done about it: The Potential of Efficiency in the Residential Sector.
Lawrence Berkeley National Laboratory

McCright and Dunlap (2011)

Aaron M. McCright and Riley E. Dunlap (2011)
The Politicization of Climate Change and Polarization in the American Public's Views of Global Warming, 2001-2010
The Sociological Quarterly, vol. 52, pp. 155-194

McSweeney et al. (2012)

C. McSweeney, M. New and G. Lizcano (2012)
UNDP Climate Change Country Profiles: Ghana
Retrieved: <http://country-profiles.geog.ox.ac.uk>

Meinshausen et al (2009)

M.Meinshausen, N. Meinshausen, W. Hare, S.C.B. Raper, K. Frieler, R. Knutti, D. J. Frame and M. R. Allen (2009)
Greenhouse-gas emission targets for limiting global warming to 2 °C
Nature (Letters), vol 458, pp. 1158-1163

Mellanby (ed.) (1988)

Kenneth Mellanby (ed.) (1988)
Air Pollution, Acid Rain and the Environment
New York, US: Elsevier Science Publishing Co.

Memon et al. (2011)

Rizwan Ahmed Memon, Dennis Y. C. Leung, Chun-Ho Liu and Michael K. H. Leung (2011)
Urban heat island and its effect on the cooling and heating demands in urban and suburban areas of Hong Kong
Theoretical and Applied Climatology, vol. 103, no. 3-4, pp. 441-450

Mendelsohn et al. (2011)

Mendelsohn R., Kerry E., and Chonabayashi S. (2011)
The Impact of Climate Change on Global Tropical Storms Damages
Policy Research Working Paper no. 5562
The World Bank

Mendelsohn et al (2012)

Robert Mendelsohn, Kerry Emanuel, Shun Chonabayashi and Laura Bakkensen (2012)
The impact of climate change on global tropical cyclone damage
Nature Climate Change, vol. 2, pp.205-209

Mendelsohn (2003)

Robert Mendelsohn (2003)
Assessing the market damages from Climate Change in Griffin (ed): *Global Climate Change: The Science, Economics and Politics*
Northampton, MA, USA, Edgar Elwar Publishing Limited

Messner and Meyer (2005)

Frank Messner and Volker Meyer (2005)
Flood damage, vulnerability and risk perception – challenges for flood damage research
In: J. Schanze, E. Zeman and J.Marsalek (eds.): *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures* (pp. 149-167)
Nato Science Series, Springer Publisher.

Mehta (2010)

P. Mehta (2010)
Science behind Acid Rain: Analysis of its Impacts and Advantages on Life and Heritage Structures
South Asian Journal of Tourism and Heritage, vol. 3, no. 2, pp. 123-132

Michelozzi et al. (2009)

P. Michelozzi, G. Accetta, M. De Sario, D. D'ippoliti, C. Marino, M. Baccini, A. Biggeri, H.R. Anderson, K. Katsouyanni, F. Ballester, L. Bisanti, E. Cadum, B. Forsberg, F. Forastiere, P.G. Goodman, A. Hojs, U. Kirchmayer, S. Medina, A. Paldy, C. Schindler, J. Sunyer, C.A. Perucci, and on behalf of the PHEWE Collaborative Group (2009)
High Temperature and Hospitalizations for Cardiovascular and Respiratory Causes in 12 European Cities
American Journal of Respiratory and Critical Care Medicine, vol. 179, no. 5, pp. 383-389

Miles et al. (2004)

Lera Miles, Alan Grainger and Oliver Phillips (2004)
The impact of global climate change on tropical forest biodiversity in Amazonia
Global Ecology and Biogeography, vol. 13, pp. 553-565

Miller et al. (2008)

N.L. Miller, K. Hayhoe, J. Jin and M. Auffhammer (2008)
Climate, Extreme Heat, and Electricity Demand in California
Journal of Applied Meteorology and Climatology, vol. 47, pp.1834-1844

Millard-Ball and Schipper (2011)

Adam Millard-Ball and Lee Schipper (2011)
Are We Reaching Peak Travel? Trends In Passenger Transport In Eight Industrialized Countries
Transport Reviews, vol. 31, iss. 3

Millennium Ecosystem Assessment (2005)

Millennium Ecosystem Assessment (2005)
Millennium Assessment Report: Ecosystems and Human Well-Being
Washington D.C., US: World Resources Institute
<http://www.maweb.org/en/index.aspx>

Mills (2005)

Evan Mills (2005)
Insurance in a Climate of Change
Science, vol. 309, pp. 1040-1044

Min (2007)

Hong-Ghi Min (2007)
Estimation of Labor Demand Elasticity for the RMSM-LP: Revised Minimum Standard Model for Labor and Poverty Module
International Business & Economics Research Journal, vol. 6, no. 7, pp. 29-34.

Mirza et al. (2003)

M. M. Q. Mirza, R. A. Warrick and N. J. Ericksen (2003)
The Implications of Climate Change on Floods of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh
Climatic Change, vol. 57, Issue 3, pp. 287 - 318

Mishra et al. (1999a)

Mishra V.K., Retherford R.D., Smith K.R. (1999a)
Biomass Cooking Fuels and Prevalence of Blindness in India
Journal of Environmental Medicine, vol. 1, pp. 189-199.

Mishra et al. (1999b)

Mishra V.K., Retherford R.D., Smith K.R. (1999b)
Biomass Cooking Fuels and Prevalence of Tuberculosis in India
International Journal of Infectious Diseases, vol. 3, no. 3, pp. 119-129.

Mishra et al. (2005)

Vinod Mishra, Robert D. Retherford, Kirk R. Smith (2005)

Cooking smoke and tobacco smoke as risk factors for stillbirth

International Journal of Environmental Health Research, vol.5:16, pp. 397-410

Molesworth et al. (2003)

A.M. Molesworth, L.E. Cuevas, S.J. Connor, A.P. Morse, and M.C. Thomson (2003)

Environmental Risk and Meningitis Epidemics in Africa

Emerging Infectious Diseases, v. 9, no. 10, pp. 1287-1293

Molina et al., (2009)

M. Molina, D. Zaelke, K. Madhava Sarma, S. Andersen, V. Ramanathan and D. Kaniaru (2009)

Reducing Abrupt Climate Change Risk Using the Montreal Protocol and Other Regulatory Actions to Complement Cuts in CO2 Emissions

PNAS, vol. 106, no. 49, pp. 20626-20621

Morrison et al. (2009)

J. Morrison, M. Morikawa, M. Murphy and P. Schulte (2009)

Water Scarcity and Climate Change: Growing Risks for Businesses and Investors.

Boston, MA, Ceres.

Morse et al. (2009)

W. C. Morse, J. L. Schedlbauer, S. E. Sesnie, B. Finegan, C. A. Harvey, S. J. Hollenhorst, K. L. Kavanagh, D. Stoian, and J. D. Wulffhorst (2009)

Consequences of Environmental Service Payments for Forest Retention and Recruitment in a Costa Rican Biological Corridor

Ecology and Society, vol. 14, no.1, iss. 23

Mortimore (2003)

Michael Mortimore (2003)

Is There A New Paradigm of Dryland Development?

Annals of Arid Zone, vol. 42, iss. 3&4, pp. 459-481

Morton (2007)

John F. Morton (2007)

The impact of climate change on smallholder and subsistence agriculture

PNAS, vol. 104 no. 50, pp. 19680-19685

Moser and Rose (2012)

Christoph Moser and Andrew K. Rose (2012)

Why Do Trade Negotiations Take So Long?

Paper presented for CEEI Conference (November 2011) "European Integration in a Global Economic Setting – CESEE, China and Russia

Motiram and Vakulabharanam (2007)

Sripad Motiram and Vamsi Vakulabharanam (2007)

Corporate and Cooperative Solutions for the Agrarian Crisis in Developing Countries

Review of Radical Political Economics, vol. 39, pp. 360-367

Muehlenbachs et al. (2011)

Lucija Muehlenbachs, Mark A. Cohen, and Todd Gerarden (2011)

Preliminary Empirical Assessment of Offshore Production Platforms in the Gulf of Mexico

Resources for the Future Discussion Paper 10-66
Resources for the Future

Mueller and Quisumbing (2011)

Valerie Mueller and Agnes Quisumbing (2011)

How Resilient are Labour Markets to Natural Disasters? The Case of the 1998 Bangladesh Flood

Journal of Development Studies, vol. 47, iss. 12

Muller (2012)

R. A. Muller (2012, July 28)

The Conversion of a Climate-Change Skeptic
The New York Times

Retrieved: <http://www.nytimes.com/2012/07/30/opinion/the-conversion-of-a-climate-change-skeptic.html?pagewanted=all>

Müller et al. (2007)

B. Müller, N. Höhne and C. Ellermann (2007)

Differentiating (Historic) Responsibilities for Climate Change. Summary Report

Paper launched at a SBSTA.27 special side event on "Scientific and methodological aspects of the Proposal by Brazil" in Nusa Dua, Bali, 5 December 2007

Munasinghe (1993)

Mohan Munasinghe (1993)

Environmental Economics and Biodiversity Management in Developing Countries

Ambio, Vol. 22, No. 2/3, pp. 126-135

Munday et al. (2008)

Philip. L. Munday, Geoffrey. P. Jones, Morgan. S. Pratchett, Ashley. J. Williams (2008)

Climate change and the future for coral reef fishes

Fish and Fisheries, vol.9:3, pp. 261-285

Munich Re (2010)

NatCat SERVICE/Munich Re (2010)

TOPICS GEO. Natural catastrophes 2010: Analyses, assessments, positions

Retrieved: <http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx>

Munich Re (2012)

NatCat SERVICE/Munich Re (2012)

Statistics on natural catastrophes

Retrieved: <http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx>

Munton et al. (ed.) 1999

D. Munton, M. Soroos, E. Nikitina and M. Levy (1999)

Acid Rain in Europe and North America

In: Oran R. Young (ed.): *The Effectiveness of International Environmental Regimes: Causal Connections Behavioral Mechanisms* (pp. 155-248)

Massachusetts Institute of Technology

Murray et al. (2012)

S.J. Murray, P.N. Foster and I.C. Prentice (2012)

Future global water resources with respect to climate change and water withdrawals as estimated by a dynamic global vegetation model
Journal of Hydrology, Vols. 448-449, pp. 14-29

Mustafa (1990)

Mohamad G. Mustafa (1990)

Biochemical basis of ozonotoxicity

Free Radical Biology and Medicine, vol. 9, iss. 3, pp. 245-265

Narita et al. (2011)

D. Narita, K. Rehdanz, R. Tol (2011)

Economic Costs of Ocean Acidification: A Look into the Impacts on Shellfish Production

Working Paper no. WP391

Economic and Social Research Institute (ESRI)

NASA Climate (2012)

NASA Climate (2012)

Global Climate Change Portal at the Earth Science Communications Team at

National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory/California Institute of Technology

Retrieved: <http://climate.nasa.gov>

NASA GISS (2012)

NASA Goddard Institute for Space Studies (2012)

Surface Temperature Dataset

Retrieved: <http://www.giss.nasa.gov/>

Nelleman et al. (2011)

Nelleman, C., Verma, R., and Hislop, L. (eds). 2011.

Women at the frontline of climate change: Gender risks and hopes. A Rapid Response Assessment.

United Nations Environment Programme, GRID-Arendal

Nelson et al. (2001)

Nelson, F. E., Anisimov O.A., and Shiklomanov N.I. (2001)

Model output from the 'frost index' permafrost model: variations in circumpolar frozen ground conditions and modeled future conditions

Boulder, CO: National Snow and Ice Data Center

Nelson et al. (2002)

F. E. Nelson, O. A. Anisimov And N. I. Shiklomanov (2002)

Climate Change and Hazard Zonation in the Circum-Arctic Permafrost Regions

Natural Hazards, vol. 26, pp. 203-225,

Nelson et al. (2009)

G.C. Nelson, M. W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee (2009)

Climate Change: Impact on Agriculture and Costs of Adaptation

Washington, D.C.: International Food Policy Research Institute

Nicholls and Cazenave (2010)

Robert J. Nicholls and Anny Cazenave (2010)

Sea-Level Rise and Its Impact on Coastal Zones
Science, vol.328, pp. 1517-1520

Nicholson et al. (1998)

S.E. Nicholson, C.J. Tucker, and M.B. Ba (1998)

Desertification, Drought, and Surface Vegetation: An Example from the West African Sahel

Bulletin of the American Meteorological Society, vol. 79, iss. 5, pp. 815-829

Niehaus et al. (2002)

M. D. Niehaus, S. R. Moore, P.D. Patrick, L. L. Derr, B. Lornz, A. A. Lima and R. L. Guerrant (2002)

Early Childhood Diarrhea is Associated with Diminished Cognitive Function 4 to 7 Years Later in Children in a Northeast Brazilian Shantytown

American Journal of Tropical Medicine and Hygiene, vol. 66, no. 5, pp. 590-593

Niemelä et al. (2002)

R. Niemelä, M. Hannula, S. Rautio, K. Reijula and J. Railio (2002)

The effect of air temperature on labour productivity in call centres - a case study.

Energy and Buildings, vol. 34, iss. 8, pp. 759-764

NIOSH (1986)

National Institute for Occupational Safety and Health (1986)

Occupational Exposure to Hot Environments. Revised Criteria 1986

Publication No. 86-113

U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control. NIOSH

NOAA NESDIS (2012)

National Environmental Satellite, Data and Information Service (NESDIS) (2012)

National Climatic Data Center

Retrieved: <http://www.nesdis.noaa.gov/ClimateResources.html>

Nohara et al. (2006)

Daisuke Nohara, Akio Kitoh, Masahiro Hosaka, and Taikan Oki (2006)
Impact of Climate Change on River Discharge Projected by Multimodel Ensemble
J. Hydrometeorol., vol. 7, no 5., pp. 1076-1089.

Nordhaus (2006)

William D. Nordhaus (2006)
Geography and macroeconomics: New data and new findings
Proceedings of the National Academy of Sciences of the USA (PNAS), vol. 103, no. 10, pp.3510-3517

Nordhaus (2007)

William D. Nordhaus (2007)
A Review of the Stern Review on the Economics of Climate Change
Journal of Economic Literature, vol. XLV , pp. 686-702

Nordhaus (2008)

William D. Nordhaus (2008)
A Question of Balance. Weighing the Options on Global Warming Policies
New Haven & London, Yale University Press

Nordhaus (2010)

William D. Nordhaus (2010)
Economic aspects of global warming in a post-Copenhagen environment
Proceedings of the National Academy of Sciences of the USA (PNAS), PNAS Early edition, June 14, 2010
Retrieved: <http://www.pnas.org/content/early/2010/06/10/1005985107.full.pdf+html>

Nordhaus (2011)

William D. Nordhaus (2011)
Integrated Economic and Climate Modeling
Cowles Foundation Discussion Paper No. 1839
New Haven, Connecticut, Cowles Foundation For Research In Economics, Yale University
Retrieved: <http://cowles.econ.yale.edu/>

Nordhaus (2012)

William D. Nordhaus (2012, April 26)
In the Climate Casino: An Exchange (response)
The New York Review of Books
Retrieved: <http://www.nybooks.com/articles/archives/2012/apr/26/climate-casino-exchange/?pagination=false>

Nordhaus and Boyer (1999)

W. Nordhaus and J. Boyer (1999)
Roll the DICE Again: Economic Models of Global Warming ("manuscript edition")
Cambridge, Massachusetts. MIT Press

Nordhaus and Boyer (2000)

William D. Nordhaus and Joseph Boyer (2000)
Warming the World: Economic Models of Global Warming
Cambridge, Massachusetts, Massachusetts Institute of Technology

Nordling et al. (2008)

E. Nordling, N. Berglind, E. Melén, G. Emenius, J. Hallberg, F. Nyberg, G. Pershagen, M. Svartengren, M. Wickman, T. Bellander (2008)
Traffic-Related Air Pollution and Childhood Respiratory Symptoms, Function and Allergies
Epidemiology, vol. 19, Iss. 3, pp. 401-408

Nowak et al. (2006)

D. J. Nowak, D.E. Crane and J.C. Stevens (2006)
Air pollution removal by urban trees and shrubs in the United States
Urban Forestry and Urban Greening, vol. 4, pp.115-123

NSIDC (2008)

National Snow and Ice Data Center (NSIDC) (2008, June)
Glaciers
Retrieved: http://nsidc.org/sotc/glacier_balance.html

NSIDC (2012)

National Snow and Ice Data Center (NSIDC) (2012)
Arctic Sea Ice Extent
Retrieved: http://nsidc.org/arcticseaicenews/files/2000/08/N_stddv_timeseries1.png

Nutbeam (2000)

D. Nutbeam (2000)
Health Literacy as a Public Health Goal: A Challenge for Contemporary Health Education and Communication Strategies into the 21st Century
Health Promotion International, vol. 15, no. 3, pp. 259-267

NWP (2012)

Netherlands Water Partnership (2012, January 24)
Dutch consortium granted contract to assist Vietnamese government in long term Mekong Delta plan
Dutch Water Sector
Retrieved: <http://www.dutchwatersector.com/news/news/2012/01/dutch-consortium-granted-contract-to-assist-vietnamese-government-in-long-term-mekong-delta-plan/>

ODI (2010)

Overseas Development Institute (2010)
Millennium Development Goals Report Card. Learning from Progress
London, UK, ODI
Retrieved: <http://www.odi.org.uk/resources/details.asp?id=4908&title=mdgs-progress>

OECD (2012)

OECD (2012)
OECD Environmental Outlook to 2050: The Consequences of Inaction

OECD CRS (2012)

OECD Creditor Reporting System (2012)
OECD Stats Extracts Data base
Retrieved: <http://stats.oecd.org/Index.aspx?DataSetCode=CRSNEW>

Okafor et al. (2009)

P. C. Okafor, U. J. Ekpe, U. J. Ibok, B. O. Ekpo, E. E. Ebenso And C. O. Obadimu (2009)
Atmospheric Corrosion of Mild Steel in The Niger Delta Region of Nigeria. Part 1: Characterization of The Calabar, Cross River State Environment
Global Journal of Environmental Sciences, vol. 8, no. 1, pp. 9 - 18

Olefs et al. (2009)

M. Olefs, M. Kuhn and A. Fischer (2009)
The effect of climate change on the runoff behaviour of glacierised Alpine catchments with regard to reservoir power stations
EGU General Assembly 2009, held 19-24 April, 2009 in Vienna, Austria
Retrieved: <http://meetings.copernicus.org/egu2009>

Olivier et al. (2012)

J.G.J. Olivier, G. Janssens-Maenhout, J.A.H.W. Peters (2012)
Trends in global CO2 emissions; 2012 Report
The Hague: PBL Netherlands Environmental Assessment Agency; Ispra: Joint Research Centre.

Olsen et al. (2011)

M. S. Olsen, T. V. Callaghan, J. D. Reist, L. O. Reiersen, D. Dahl-Jensen, M. A. Granskog, B. Goodison, G. K. Hovelsrud, M. Johansson, R. Kallenborn, J. Key, A. Klepikov, W. Meier, J. E. Overland, T. D. Prowse, M. Sharp, W. F. Vincent, J. Walsh (2011)
The Changing Arctic Cryosphere and Likely Consequences: An Overview
Ambio, vol. 40, pp. 111-118

Olson and Morton (2012)

K. R. Olson and L. Wright Morton (2012)
The impacts of 2011 induced levee breaches on agricultural lands of Mississippi River Valley
Journal of Soil and Water Conservation, vol. 67, no. 1, pp. 5A-10A

O'Neill et al. (2005)

Jim O'Neill, Dominic Wilson, Roopa Purushothaman and Anna Stupnytska (2005)
How Solid are the BRICs?
Global Economics Paper, Issue no. 134
Goldman Sachs Economic Research
Retrieved: <https://portal.gs.com>

O'Reilly et al. (2003)

O'Reilly C.M., Alin S.R., Plisnier P.D., Cohen A.S., McKee B.A. (2003)
Climate Change decreases aquatic ecosystem productivity of Lake Tangayik, Africa
Nature, vol. 424, no. 6950, pp. 766-768.

OSDG (2009)

The Oil Sand Development Group (2009)
Extracting Oil Sands – In-Situ and Mining Methods; Fact Sheet, Oct 2009
Retrieved: <http://www.oilsandsdevelopers.ca/wp-content/uploads/2009/06/Extraction-Fact-Sheet-October-2009.pdf>

Oteng-Ababio et al. (2011)

Martin Oteng-Ababio, Kwadwo Owusu and Kwasi Appeaning Addo (2011)
The vulnerable state of the Ghana coast: The case of Faana-Bortianor
JAMBA: Journal of Disaster Risk Studies, vol. 3, no.2., pp. 429-442

Oxelheim and Wihlborg (2008)

I. Oxelheim and C. Wihlborg (2008)
Corporate Decision-Making With Macroeconomic Uncertainty: Performance And Risk Management.
Oxford, UK, Oxford University Press

Oxfam (2012)

Oxfam (2012)
Food Crisis in Sahel
Retrieved September 2012: <http://www.oxfam.org/en/sahel>

Oygard et al. (1999)

Ragnar Oygard, Trond Vedeld and Jens Aune (1999)
Good Practices in Drylands Management
Washington, DC: The International Bank for Reconstruction and Development/ The World Bank

Pagiola (2006)

Stefano Pagiola (2006)
Payments for Environmental Services in Costa Rica
Munich Personal RePEc Archive (MPRA) Paper No. 2010

Palmer et al. (2008)

M. A. Palmer, C. A. Reidy Liermann, C. Nilsson, M. Flörke, J. Alcamo, P. S. Lake, and N. Bond (2008)
Climate change and the world's river basins: anticipating management options. *Frontiers in Ecology and the Environment*, vol. 6, iss. 2, pp. 81-89.

Pandey et al. (eds.) (2007)

S. Pandey, H. Bhandari, and B. Hardy (2007)
Economic Cost of Drought and Farmers' Coping Mechanisms: A Study of Rainfed Rice Systems in Eastern India
Los Baños (Philippines): International Rice Research Institute

Pandey et al. (2010)

V. Pandey, M.S. Babel, S. Shrestha and F. Kazama (2010)
Vulnerability of freshwater resources in large and medium Nepalese river basins to environmental change
Water science and technology, vol. 61, no. 6, pp. 1525-1534

Parker et al. (2006)

T.J. Parker, K.M. Clancy, and R.L. Mathiasen (2006)

Interactions among fire, insects and pathogens in coniferous forests of the interior western United States and Canada

Agricultural and Forest Entomology, vol. 8, pp. 167-189

Parry et al. (2004)

M.L. Parry, C. Rosenzweig, A. Iglesias, M. Livermore, G. Fischer (2004)

Effects of climate change on global food production under SRES emissions and socio-economic scenarios

Global Environmental Change, vol. 14, pp. 53-67

Parry et al. (2009)

Martin Parry, Alex Evans, Mark W. Rosegrant and Tim Wheeler (2009)

Climate change and hunger: Responding to the challenge

Rome, Italy, World Food Programme

Parry et al. (2009b)

M. Parry, N. Arnell, P. Berry, D. Dodman, S. Fankhauser, C. Hope, S. Kovats, R. Nicholls, D. Satterthwaite, R. Tiffin and Tim Wheeler (2009b)

Assessing the Costs of Adaptation to Climate Change- A review of the UNFCCC and other recent estimates

International Institute for Environment and Development (IIED)

Patz et al. (1996)

J.A. Patz, P.R. Epstein, T.A. Burke, and J.M. Balbus (1996)

Global climate Change and Emerging Infectious Diseases

The Journal of the American Medical Association, vol. 275, no. 3, pp. 217-223

Patz et al. (2005)

J.A. Patz, D. Campbell-Lendrum, T. Holloway, and J.A. Foley (2005)

Impact of Regional Climate Change on Human Health

Nature, vol. 438, pp. 310-317

Pavlenko and Glukhareva (2010)

V. I. Pavlenko, E. K. Glukhareva (2010)

Development of Oil and Gas Production and Transportation Infrastructure of Russian West Arctic Offshore Regions

Proceedings of the Ninth ISOPE Pacific/Asia Offshore Mechanics Symposium held in Busan, Korea, November 14-17, 2010

Peduzzi et al. (2012)

P. Peduzzi, B. Chatenoux, H. Dao, A. De Bono, C. Herold, J. Kossin, F. Mouton, and O. Nordbeck (2012)

Global trends in tropical cyclone risk

Nature Climate Change, vol. 2, no. 6, pp. 89-294.

Pelling and Uitto (2001)

Mark Pelling and Juha I. Uitto (2001)

Small island developing states: natural disaster vulnerability and global change

Environmental Hazards, vol. 3, pp. 49-62

Pereira et al. (2002)

L. Santos Pereira, T. Oweis and A. Zairi (2002)

Irrigation management under water scarcity

Agricultural Water Management, vol. 57, Iss. 3, pp. 175-206

Pereira et al. (2010)

H. M. Pereira, P.W. Leadley, V. Proença, R. Alkemade, J. P. W. Scharlemann, J. F. Fernandez-Manjarrés, M. B. Araújo, P. Balvanera, R. Biggs, W. W. L. Cheung, L. Chini, H. D. Cooper, E. L. Gilman, S. Guénette, G. C. Hurtt, H. P. Huntington, G. M. Mace, T. Oberdorff, C. Revenga, P. Rodrigues, R.J. Scholes, U. Rashid Sumaila, Matt Walpole (2010)

Scenarios for Global Biodiversity in the 21st Century

Science, vol. 330, pp. 1496-1501

Pereira de Lucena et al. (2009)

A.F. Pereira de Lucena, A. Salem Szklo, R. Schaeffer, R. Rodrigues de Souza, B. Soares Moreira, C. Borba, I. Vaz Leal da Costa, A. O. Pereira Júnior, S. H. Ferreira da Cunha (2009)

The vulnerability of renewable energy to climate change in Brazil

Energy Policy, vol. 37, iss. 3, pp. 879-889

Pereira de Lucena et al. (2010)

A.F. Pereira de Lucena, R. Schaeffer and A. Salem Szklo (2010)

Least-cost adaptation options for global climate change impacts on the Brazilian electric power system

Global Environmental Change, vol. 20, no. 2, pp. 342-350

Perez-Lombard et al. (2008)

Perez-Lombard L., Ortiz J. and Pout C. (2008)

A Review on Buildings Energy Consumption Information

Energy and Buildings, vol. 40, no. 3, pp. 394-398.

Perry et al. (2005)

Allison. L. Perry, Paula. J. Low, Jim. R. Ellis, John D. Reynolds (2005)

Climate Change and Distribution Shifts in Marine Fishes

Science, vol. 308, no. 5730, pp. 1912-1915

Peters et al. (2012).

Glen P. Peters, Gregg Marland, Corinne Le Quéré, Thomas Boden, Josep G. Canadell & Michael R. Raupach (2012).

Rapid growth in CO2 emissions after the 2008-2009 global financial crisis

Nature Climate Change, vol 2, pp. 2-4.

Petit et al. (1999)

J. R. Petit, J. Jouzel, D. Raynaud, N. I. Barkov, J.-M. Barnola, I. Basile, M. Bender, J. Chappellaz, M. Davisk, G. Delaygue, M. Delmotte, V. M. Kotlyakov, M. Legrand, V.Y. Lipenkov, C. Lorius, L. Pe'pin, C. Ritz, E. Saltzman and M. Stievenard (1999)

Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica

Nature, vol. 399, pp. 429-436

Pfeffer et al. (2008)

W. T. Pfeffer, J. T. Harper and S. O'Neel (2008)

Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise

Science, vol. 321 no. 5894, pp. 1340-1343

Pielke et al. (2008)

R. A. Pielke Jr., J. Gratz, Ch. W. Landsea, D. Collins, M. A. Saunders and R. Musulin (2008)

Normalized Hurricane Damage in the United States: 1900-2005

Natural Hazards Review, February 2008, pp.29-42

Pilcher et al. (2002)

J.J. Pilcher, E. Nadler and C. Busch (2002)

Effects of hot and cold temperature exposure on performance: a meta-analytic review.

Ergonomics, vol. 45, no. 10 pp. 682-698.

Ping et al. (2011)

Liu Ping, Xia Fei, Pan Jiayong, Chen Yiping, Peng Huaming and Chen Shaohua (2011)

Discuss on Present Situation and Countermeasures for Acid Rain Prevention and Control in China

Environmental Science and Management, vol. 12

Plass (1956)

Gilbert N. Plass (1956)

The Carbon Dioxide Theory of Climatic Change

Tellus, vol. 8, Iss. 2, pp. 140-154

Pope et al. (2002)

C. Arden Pope III, Richard T. Burnett, Michael J. Thun, Eugenia E. Calle, Daniel Krewski, Kazuhiko Ito and George D. Thurston (2002)

Lung Cancer, Cardiopulmonary mortality, and long-term exposure to fine particulate air pollution

Journal of American Medical Association, vol.287, no.9, pp. 1132-1141

Pope et al. (2009)

C. Arden Pope III, M. Ezzati, and D. W. Dockery (2009)

Fine-Particulate Air Pollution and Life Expectancy in the United States

The New England Journal of Medicine, vol. 360, no. 4, pp. 376-386.

Pope et al. (eds.) (2010)

V. Pope, J. Lowe, L. Kendon, F. Carroli and S. Tempest (eds.) (2010)

Advance : Improved science for mitigation policy advice

Met office. Hadley Centre

Portmann et al. (2010)

Portmann, F.T., Siebert S., and Döll P. (2010)

Global Data Set of Monthly Irrigated and Rainfed Crop Areas Around the Year 2000 (MIRCA2000)

Frankfurt, Germany: The Institute of Physical Geography, University of Frankfurt

Retrieved: <http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/MIRCA/index.html>

Postel and Thompson (2005)

Sandra L. Postel and Barton H. Thompson, Jr. (2005)

Watershed protection: Capturing the benefits of nature's water supply services

Natural Resources Forum, vol. 29, pp. 98-108

Priyadarshi (2009)

Shishir Priyadarshi (2009)

Reforming Global Trade in Agriculture: A Developing- Country Perspective

Carnegie Endowment for International Peace

Prospero and Lamb (2003)

J.M. Prospero and P.J. Lamb (2003)

African Droughts and Dust Transportation to the Caribbean: Climate Change Implications

Science, vol. 302, pp. 1024-1027

Prudhomme et al. (2002)

C. Prudhomme, N.Reynard and S. Crooks (2002)

Downscaling of global climate models for flood frequency analysis: where are we now?

Hydrological Processes, vol. 16, pp.1137-1150

Puigdefábregas (1998)

J. Puigdefábregas (1998)

Ecological Impacts of Global Change on Drylands and Their Implications for Desertification

Land Degradation & Development, vol. 9, pp. 393-406

Quarantelli (2001)

E.L. Quarantelli (2001)

Statistical and Conceptual Problems in the Study of Disasters

Disaster Prevention and Management, vol. 10, no. 5, pp. 325-338

Quarantelli (2003)

E. L. Quarantelli (2003)
Urban Vulnerability to Disasters in Developing Countries: Managing Risks
In: A. Kreimer, M. Arnold, and A. Carlin (Eds.): *Building Safer Cities. The Future of Disaster Risk* (p.211-231)
Disaster Risk Management Series No. 3
Washington, D.C., The International Bank for Reconstruction and Development / The World Bank

Radić and Hock (2011)

Valentina Radić and Regine Hock (2011)
Regionally differentiated contribution of mountain glaciers and ice caps to future sea-level rise
Nature Geoscience (Letters), vol. 4, pp. 91-94

Rahmstorf (2009)

Stefan Rahmstorf (2009)
A Semi- Empirical Approach to Projecting Future Sea-Level Rise
Science, vol. 315, pp. 368-370

Raleigh (2010)

C. Raleigh (2010)
Political Marginalization, Climate Change, and Conflict in African Sahel States
International Studies Review, vol. 12, pp.69-86

Ramanathan and Carmichael (2008)

V. Ramanathan and G. Carmichael (2008)
Global and regional climate changes due to black carbon
Nature Geoscience, vol. 1, pp. 221-227

Ramanathan and Fen (2009)

V. Ramanathan, Y. Feng (2009)
Air pollution, greenhouse gases and climate change: Global and regional perspectives
Atmospheric Environment, vol. 43, pp. 37-50

Ramanathan et al. (2008)

V. Ramanathan, M. Agrawal, H. Akimoto, M. Auffhammer, S. Devotta, L. Emberson, S.I. Hasnain, M. Iyengarasan, A. Jayaraman, M. Lawrence, T. Nakajima, T. Oki, H. Rodhe, M. Ruchirawat, S.K. Tan, J. Vincent, J.Y. Wang, D. Yang, Y.H. Zhang, H. Atrup, L. Barregard, P. Bonasoni, M. Brauer, B. Brunekreef, G. Carmichael, C.E. Chung, J. Dahe, Y. Feng, S. Fuzzi, T. Gordon, A.K. Gosain, N. Htun, J. Kim, S. Mourato, L. Naeher, P. Navasumrit, B. Ostro, T. Panwar, M.R. Rahman, M.V. Ramana, M. Rupakheti, D. Settachan, A. K. Singh, G. St. Helen, P.V. Tan, P.H. Viet, J. Yinlong, S.C. Yoon, W.-C. Chang, X. Wang, J. Zelikoff and A. Zhu (2008)
Atmospheric Brown Clouds: Regional Assessment Report with Focus on Asia.
Nairobi, Kenya, United Nations Environment Programme (UNEP)

Ramankutty and Foley (1999)

N. Ramankutty and J. A. Foley (1999)
Estimating historical changes in global land cover: Croplands from 1700 to 1992
Global Biogeochemical Cycles, vol. 13, no. 4, pp. 997-1027

Ramos et al. (2004)

J. Ramos, J. Villa, A. Ruiz, R. Armstrong and J. Matta (2004)
Cancer Epidemiology, Biomarkers and Prevention: UV Dose Determines Key Characteristics of Nonmelanoma Skin Cancer
Cancer Epidemiology Biomarkers Prevention, vol. 13, no.12, pp. 2006-2011

Ramsey (1995)

J.D. Ramsey (1995)
Task performance in heat: a review.
Ergonomics, vol. 38, no. 1, pp. 154-65.

Ratter et al. (2012)

B. M.W. Ratter, K. H.I. Philipp and H. von Storch (2012)
Between hype and decline: recent trends in public perception of climate change
Environmental Science and Policy, Vol. 18, pp. 3-8

Ravallion et al. (2007)

Martin Ravallion, Shaohua Chen and Prem Sangraula (2007)
New Evidence on the Urbanization of Global Poverty
Development Research Group, World Bank.

Reeve and Toumi (1999)

N. Reeve and R. Toumi (1999)
Lightning activity as an indicator of climate change
Quarterly Journal of the Royal Meteorological Society, vol. 131, iss. 608, pp. 1539-1565

Reilly et al. (2007)

J. Reilly, S. Paltsev, B. Felzer, X. Wang, D. Kicklighter, J. Melillo, R. Prinn, M. Sarofim, A. Sokolov, C. Wang (2007)
Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone
Report No. 149
MIT Joint Program on the Science and Policy of Global Change

Reiter (2001)

P. Reiter (2001)
Climate Change and Mosquito-Borne Disease
Environmental Health Perspective, vol. 109, suppl. 1, pp. 141-161

Restuccia et al. (2004)

D. Restuccia, D. Tao Yang and X. Zhu (2004)
Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis
Journal of Monetary Economics, vol. 55, no.2, pp. 234-250

Reynolds et al. (2011)

J. F. Reynolds, A. Grainger, D. M. Stafford Smith, G. Bastin, L. Garcia-Barrios, R. J. Fernandez, M. A. Janssen, N. Ju " Rgens, R. J. Scholes, A. Veldkamp, M. M. Verstraete, G. Von Maltitz And P. Zdruli (2011)
Scientific Concepts for an Integrated Analysis of Desertification
Land Degradation & Development, vol. 22, pp. 166-183

Riahi et al. (2007)

Keywan Riahi, Arnulf Grübler and Nebojsa Nakicenovic (2007)
Scenarios of long-term socio-economic and environmental development under climate stabilization
Technological Forecasting & Social Change, vol. 74, pp. 887-935

Rijnsdorp et al. (2009)

Adriaan. D. Rijnsdorp, Myron. A. Peck, Georg. H. Engelhard, Christian Mollmann, John. K. Pinnegar (2009)
Resolving the effect of climate change on fish populations
Ices Journal of Marine Science, vol. 66:7, pp. 1570-1583

RiskMetrics Group (2010)

Yulia Reuter, Doug Cogan, Dana Sasarean, Mario López Alcalá, and Dinah Koehler (2010)
Canada's Oil Sands Shrinking Window of Opportunity
Boston, MA: CERES

Robine et al. (2008)

JM. Robine, SLK. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, JPMichel and FR. Herrmann (2008)
Death toll exceeded 70000 in Europe in Europe during the summer of 2003
C R Biol, vol. 331, pp. 171-178

Rodríguez Díaz et al. (2007)

J. A. Rodríguez Díaz, E. K. Weatherhead, J. W. Knox and E. Camacho (2007)
Climate change impacts on irrigation water requirements in the Guadalquivir river basin in Spain
Regional Environmental Change, vol. 7, no. 3, pp. 149-159

Roe and Elliot (2004)

Dilys Roe and Joanna Elliott (2004)
Poverty reduction and biodiversity conservation: rebuilding the bridges
Oryx, Vol 38, No. 2, pp. 137-139

Roesch et al. (2012)

Roesch, A.; Wild, M.; Ammann, C. (2012)
Global dimming and brightening - evidence and agricultural implications
EGU General Assembly 2012, held 22-27 April, 2012 in Vienna, Austria, p.14479

Rogers and Hall (2003)

P. Rogers and A. W. Hall (2003)
Effective Water Governance
Tec. Background Papers No. 7
Global Water Partnership

Rohde et al (2012)

Robert Rohde, Richard A. Muller, Robert Jacobsen, Elizabeth Muller, Saul Perlmutter, Arthur Rosenfeld, Jonathan Wurtele, Donald Groom and Charlotte Wickham (2012)
A New Estimate of the Average Earth Surface Land Temperature. Spanning 1753 to 2011
Submitted to the Third Santa Fe Conference on Global and Regional Climate Change
Manuscript # 2012JD018202
Berkeley Earth
Retrieved: <http://berkeleyearth.org/pdf/results-paper-july-8.pdf>

Romanovsky et al. (2010)

V. E. Romanovsky, S.S. Marchenko, M. Brubaker (2010)
Current and Projected Changes in Permafrost and Societal Impacts of Permafrost Degradation (Invited)
American Geophysical Union, Fall Meeting 2010, abstract #GC54A-10

Rooney et al. (2012)

R.C. Rooney, S.E. Bayley, and D.W. Schindler (2012)
Oil sands mining and reclamation cause massive loss of peatland and stored carbon
Proceedings of the National Academy of Sciences of the United States, vol. 109, no. 13, pp. 4933-4937

Rosenberg and Beard (2011)

R. Rosenberg and C.B. Beard
Vector-borne Infections
Emerging Infectious Diseases, vol. 17, no.5, pp. 769-770

Rosegrant et al. (2002)

Mark W. Rosegrant, Ximing Cai and Sarah A. Cline (2002)
World water and Food to 2025 dealing with scarcity
International Food Policy Research Institute

Rothberg et al. (2008)

Michael B. Rothberg, Sarah D. Haessler, and Richard B. Brown (2008)
Complications of Viral Influenza
The American Journal of Medicine, no. 121, pp. 258-264.

RSNZ (2010)

The Royal Society of New Zealand (2010)
Sea Level Rise
Emerging Issues, September 2010
Retrieved: www.royalsociety.org.nz

Rubel and Kottek (2010)

Franz Rubel and Markus Kottek (2010)
Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification
Meteorologische Zeitschrift, vol. 19, no. 2, pp. 135-141.

Rubin (2009)

Jeff Rubin (2009)
Why Your World is About to Get a Whole Lot Smaller: Oil and the End of Globalisation
London, Great Britain, Virgin Books- Random House

Rudeva and Gulev (2007)

Irina Rudeva And Sergey K. Gulev (2007)
Climatology of Cyclone Size Characteristics and Their Changes during the Cyclone Life Cycle
Monthly Weather Review, vol. 135, pp. 2568-2587

Ruesch and Gibbs (2008)

Ruesch Aaron and Holly K. Gibbs (2008)
New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000
Carbon Dioxide Information Analysis Center
Oak Ridge, Tennessee: Oak Ridge National Laboratory
<http://cdiac.ornl.gov>

Sabater and Tockner (2010)

Sergj Sabater and Klement Tockner (2010)
Effects of Hydrologic Alterations on the Ecological Quality of River Ecosystems
The Handbook of Environmental Chemistry, vol. 8, pp. 15-39

Sabine and Feely (2007)

Christopher L. Sabine and Richard A. Feely (2007)
The Oceanic Sink for Carbon Dioxide
in D.S. Reay C. N.Hewitt, K.A. Smith and J. Grace (eds.): *Greenhouse Gas Sinks* (pp. 31-49)
CAB International

Sahin and Hall (1996)

Vildan Sahin and Michael J. Hall (1996)
The effects of afforestation and deforestation on water yields
Journal of Hydrology, vol. 178, pp. 293-309

Saleska et al. (2011)

S.R. Saleska, N. Restrepo-Coupe, K.T. Wiedemann, R. da Silva, D. Amaral, B.J. Christoffersen, J. Wu, L.F. Alves, P.B. Camargo, R.C. Oliveira, A.R. Huete, K. Didan and R. Solano (2011)
Amazon Forest Vegetation and Carbon Dynamics under Drought and Flood
American Geophysical Union, Fall Meeting 2011, abstract #B23E-01

Salick and Byg (2007)

Jan Salick and Anja Byg (2007)
Indigenous Peoples and Climate Change
Oxford, UK: Tyndall Centre for Climate Change Research,

Samuelson and Nordhaus (1948)

Paul Anthony Samuelson and William D. Nordhaus (1948)
Economics. 19th Edition, International Edition.
McGraw-Hill/Irwin 2010 – first published 1948

Saraiya et al. (2004)

M. Saraiya, K. Glanz, P. Briss, P. Nichols, C. White, D. Das, J. Smith, B. Tannor, A. Hutchinson, K. Wilson, N. Gandhi, N. Lee, B. Rimer, R. Coates, J. Kerner, R. Hiatt, P. Buffler and P. Rochester (2004)
Interventions to Prevent Skin Cancer by Reducing Exposure to Ultraviolet Radiation: A Systematic Review
American Journal of Preventative Medicine, vol. 27, no. 5, pp. 422-266

Sari and Soytaş (2008)

Ramazan Sari and Ugur Soytaş (2008)
Are global warming and economic growth compatible? Evidence from five OPEC countries?
Applied Energy, vol. 86, pp. 1887-1893

Scarborough (2011)

H. Scarborough (2011)
Intergenerational equity and the social discount rate
Australian Journal of Agricultural and Resource Economics, vol.55 pp., no.2, 145-158

SCBD (2010)

Secretariat of the Convention on Biological Diversity (2010)
Global Biodiversity Outlook 3
Montréal, Secretariat of the Convention on Biological Diversity

Schönning and Stenström (2004)

C. Schönning and T.A. Stenström (2004)
Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems
Report 2004-1. Stockholm: Swedish Environmental Institute (SEI)

Severson-Baker and Reynolds (2005)

C. Severson-Baker and M. Reynolds (2005)
Oil Sands Fever; The environmental implications of Canada's Oil Sands Rush
The Pembina Institute
Retrieved: <http://www.pembina.org/pub/203>

Schipper and Pelling (2006)

L. Schipper and M. Pelling, M. (2006)
Disaster risk, climate change and international development: scope for, and challenges to integration
Disasters, vol. 30, iss. 1, pp. 19-38

Shah et al. (2000)

J.Shah, T. Nagpal, T. Johnson, M. Amann2, G. Carmichael, W. Foell, C. Green, J.-P. Hettelingh, L. Hordijk, J. Li, C. Peng, Y. Pu, R. Ramankutty and D. Streets (2000)
Integrated Analysis for Acid Rain in Asia: Policy Implications and Results of RAINS-ASIA Model
Annual Review of Energy and the Environment, vol. 25:1, pp. 339- 375

Shakhova et al. (2008)

N. Shakhova, I. Semiletov, A. Salyuk, D. Kosmach (2008)
Anomalies of methane in the atmosphere over the East Siberian shelf: Is there any sign of methane leakage from shallow shelf hydrates?
EGU General Assembly 2008, Geophysical Research Abstracts, vol. 10, EGU2008-A-01526 (2004)

Shakhova et al. (2010)

N. Shakhova, I. Semiletov, A. Salyuk, D. Kosmach and O. Gustafsson (2010)
Extensive methane venting to the atmosphere from sediments of the East Siberian Arctic Shelf
Science, vol. 327, pp. 1246-1250

Sheffield et al. (2011)

Perry E. Sheffield, Kim Knowlton, Jessie L. Carr, and Patrick L. Kinney (2011)
Modeling of Regional Climate Change Effects on Ground-Level Ozone and Childhood Asthma
American Journal of Preventive Medicine, vol. 41, no. 3, pp. 251-257.

Sheffield and Wood (2008)

Justin Sheffield and Eric F. Wood (2008)
Projected changes in drought occurrence under future global warming from multi - model, multisenario, IPCC AR4 simulations
Climate Dynamics, vol. 31, no.1, pp 79 - 105.

Sherwood and Huber (2010)

Steven C. Sherwood and Matthew Huber (2010)
An adaptability limit to climate change due to heat stress
Proceedings of the National Academy of Sciences of the USA (PNAS), vol. 107, no.21, pp.9552-9555

Shvidenko et al. (2005)

Anatoly Shvidenko, Charles Victor Barber and Reidar Persson (2005)
Forest and Woodland Systems
In: R. Hassan, R. Scholes and N. Ash (eds.): *Ecosystems and Human Well-being: Current State and Trends* (Chapter 21)
Millennium Ecosystem Assessment

Silverman et al. (2009)

J. Silverman, B. Lazar, L. Cao, K. Caldeira and J. Erez (2009)
Coral reefs may start dissolving when atmospheric CO2 doubles
Geophysical Research Letters, vol. 36, L05606, pp. 1-5

Simons (2010)

Craig Simons (2010)
The Green Guru: Mohamed Nasheed
The Daily Beast, Newsweek .
Retrieved: <http://www.thedailybeast.com/>

SCBD (2009)

Secretariat of the Convention on Biological Diversity (2009)
Biodiversity, Development and Poverty Alleviation: Recognizing the Role of Biodiversity for Human Well-being.
Montreal, SCBD

Scheffran et al. (2012)

J. Scheffran, M. Brzoska, J. Kominek, P.M. Link, J. Schilling (2012)
Climate Change and Violent Conflict
Science, vol. 336, pp.869-871

Schlenker and Roberts (2009)

W. Schlenker and M. J. Roberts (2009)
Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change
Proceedings of the National Academy of Sciences of the USA (PNAS), vol. 106, no. 37, pp.15594-15598

Scott (2003)

Daniel Scott (2003)
Climate Change and Tourism in the Mountain Regions of North America
Paper presented in the 1st International Conference on Climate Change and Tourism, Djerba, Tunisia, 9-11 April 2003

Scott (2011)

Daniel Scott (2011)
Why sustainable tourism must address climate change
Journal of Sustainable Tourism, vol. 19, iss. 1, pp. 17-34

Scott et al. (2009)

Daniel Scott, Chris de Freitas and Andreas Matzarakis (2009)
Adaptation in the Tourism and Recreation Sector
Biometeorology, vol. 1, no. 1, pp. 171-194

Scott et al. (2010)

Daniel Scott, Paul Peeters and Stefan Gössling (2010)
Can tourism deliver its "aspirational" greenhouse gas emission reduction targets?
Journal of Sustainable Tourism, vol. 18, iss. 3, pp. 393-408

Smith et al. (2000)

Kirk R Smith, Jonathan M Samet, Isabelle Romieu, Nigel Bruce (2000)
Indoor air pollution in developing countries and acute lower respiratory infections in children
Thorax, International Journal of Respiratory Medicine, vol. 55:6, pp. 518-532

Smith et al. (2001)

J. B. Smith, H.J. Schellnhuber and M. M. Qader Mirza (2001)

Vulnerability to Climate Change and Reasons for Concern: A Synthesis (chapter 19)

In: *IPCC Third Assessment Report: Climate Change 2001 (TAR). Working Group II: Impacts, Adaptation and Vulnerability* (pp. 915-159).

Retrieved: <http://ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap19.pdf>

Smith et al. (2011)

S. J. Smith, J. van Aardenne, Z. Klimont, R. J. Andres, A. Volke and S. Delgado Arias

Anthropogenic sulfur dioxide emissions: 1850-2005

Atmospheric Chemistry and Physics, vol. 11, pp. 1101-1116

Smit and Wandel (2006)

B. Smit and J. Wandel (2006)

Adaptation, adaptive capacity and vulnerability
Global Environmental Change, vol. 16, iss. 3, pp. 282-292,

Sokolov et al. (2009)

A. P. Sokolov, P. H. Stone, C. E. Forest, R. Prinn, M. C. Sarofim, M. Webster, S. Paltsev, and C. A. Schlosser (2009)

Probabilistic Forecast for Twenty-First-Century Climate Based on Uncertainties in Emissions (Without Policy) and Climate Parameters
Journal of Climate, vol. 22, pp. 5175-5204.

Solonin and Katsyuba (2003)

Y.G. Solonin and E.A. Katsyuba (2003)

Thermoregulation and Blood Circulation in Adults during Short-Term Exposure to Extreme Temperatures

Human Physiology, vol. 29, no. 2, pp. 188-194

Solow (1956)

Robert M. Solow (1956)

A Contribution to the Theory of Economic Growth

The Quarterly Journal of Economics, vol. 70, no. 1, pp. 65-94

Srinivasan et al. (2010)

U.T.Srinivasan, W. L. Cheung, R. Watson and U. Rashid Sumaila (2010)

Food security implications of global marine catch losses due to overfishing

Journal of Bioeconomics, vol. 12, no.3, pp.183-200.

Stanhill and Cohen (2000)

Gerald Stanhill and Shabtai Cohen (2000)

Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences

Agricultural and Forest Meteorology, vol. 107, pp. 255-278

Steiger (2011)

Steiger Robert (2011)

The impact of snow scarcity on ski tourism: an analysis of the record warm season 2006/2007 in Tyrol (Austria)

Tourism Review, vol. 66, no. 3, pp. 4 - 13.

Stern (2006)

Nicholas Stern (2006)

The Stern Review on the Economic Effects of Climate Change
London, HM Treasury

Stidger (2001)

R W Stidger (2001)

Alaska Dot Deals With Permafrost Thaws

Better Roads, vol. 71, no. 6, pp. 30-31

Stifel et al. (2012)

David Stifel, Bart Minten, and Bethlehem Koro (2012)

Economic Benefits and Returns to Rural Feeder Roads: Evidence from a Quasi-Experimental Setting in Ethiopia

ESSP II Working Paper 40

International Food Policy Research Institute and Ethiopian Development Research Institute

Stoddard et al. (2003)

Stoddard, J. L., J. S. Kahl, F.A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster (2003)

Response of surface water chemistry to the Clean Air Act Amendments of 1990

EPA/620/R-03/001

Corvallis, Or: U.S. Environmental Protection Agency

Storm and Naastepad (2009)

S. Storm and C.W.M. Naastepad (2009)

Labor Market Regulation and Productivity Growth: Evidence for Twenty OECD Countries (1984-2004)

Industrial Relations: A Journal of Economy and Society, vol. 48, iss. 4, pp. 629- 654

Stromberg et al. (2010)

J. C. Stromberg, S. J. Lite and M. D. Dixon (2010)

Effects of stream flow patterns on riparian vegetation of a semiarid river: Implications for a changing climate.

River Research and Applications, vol. 26, Iss. 6, pp. 712-729.

Stuart et al. (2004)

S. N. Stuart, J. S. Chanson, N. A. Cox, B. E. Young, A. S.L. Rodrigues, D. L. Fischman, R. W.Waller (2004)

Status and Trends of Amphibian Declines and Extinctions Worldwide

Scienceexpress, 14 October 2004

Su et al. (2009)

Zhao-gui Su, Zhong-an Jiang and Zhong-qiang Sun (2009)

Study on the heat hazard of deep exploitation in high-temperature mines and its evaluation index
Procedia Earth and Planetary Science, vol. 1, Iss. 1, pp. 414-419

Sullivan (2011)

Caroline A. Sullivan (2011)

Quantifying water vulnerability: a multi-dimensional approach

Stochastic Environmental Research and Risk Assessment, vol. 25, no. 4, pp. 627-640

Sultan et al. (2005)

B. Sultan, K. Labadi, J. Guégan, and S. Janicot (2005)

Climate Drives the Meningitis Epidemics Onset in West Africa

PLoS Medicine, vol.2, no.1

Sumaila and Cheung (2010)

Ussif Rashid Sumaila and William W. L. Cheung (2010)

Cost of Adapting Fisheries to Climate Change
Development and climate change discussion paper, no. 5.

Washington D.C., The Worldbank

Retrieved:<http://documents.worldbank.org/curated/en/2010/08/12779737/cost-adapting-fisheries-climate-change>

Sutton and Costanza (2002)

Paul C. Sutton and Robert Costanza (2002)

Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation
Ecological Economics, vol. 41, pp. 509-527

Swaeln et al. (1995)

Swaeln, G.M., Meijers, J.M.M. and Slangen, J.J.M. (1995)

Risk of gastric cancer in pneumoconiotic coal miners and the effect of respiratory impairment
Occupational and Environmental Medicine, vol. 52, pp. 606-610.

Swinnen and Squicciarini (2012)

Johan Swinnen and Pasquaria Squicciarini (2012)

Mixed Messages on Prices and Food Security
Science, Vol. 335, no. 6067, pp. 405-406

Swiss Re (2010)

Swiss Re (2010)

Natural catastrophes and man-made disasters in 2009: catastrophes claim fewer victims, insured losses fall

Sigma, No. 1/2010

Zurich, Switzerland, Swiss Reinsurance Company Ltd.

Swiss Re (2011)

Swiss Re (2011)

Natural catastrophes and man-made disasters in 2010: a year of devastating and costly events
Sigma, No. 1/2011

Zurich, Switzerland, Swiss Reinsurance Company Ltd.

Swiss Re (2012)

Swiss Re (2012)

Natural catastrophes and man-made disasters in 2011: historic losses surface from record earthquakes and floods

Sigma, No. 2/2012

Zurich, Switzerland, Swiss Reinsurance Company Ltd.

Syed et al. (2010)

Tajdarul H. Syed, James S. Famiglietti, Don P. Chambers, Josh K. Willis, and Kyle Hilburn (2010)

Satellite-based global-ocean mass balance estimates of interannual variability and emerging trends in continental freshwater discharge

PNAS, vol. 107, no. 42, pp. 17916-17921

Tabarelli et al. (2010)

M. Tabarelli, A. Venceslau Aguiar, M.C. Ribeiro, J.P. Metzger, C.A. Peres (2010)

Prospects for biodiversity conservation in the Atlantic Forest: Lessons from aging human-modified landscapes

Biological Conservation, vol. 143, Iss. 10, pp. 2328-2340

Tachie-Obeng et al. (2012)

E. Tachie-Obeng, E. Edwin Gyasi, S. Adiku, B. Hewitson, M. Abekoe and G. Ziervogel (2011)

Farmer adaptation options to climate change: A case study of maize production in savanna and transitional zones of Ghana.

PhD Thesis University of Ghana and University of Cape Town

Tarnocai et al. (2009)

C. Tarnocai, J. G. Canadell, E. A. G. Schuur, P. Kuhry, G. Mazhitova and S. Zimov (2009)

Soil organic carbon pools in the northern circumpolar permafrost region

Global Biogeochemical Cycles, vol. 23, GB2023

Taylor et al. (2007)

Richard Taylor, Robert Gumming, Alistair Woodward, Megan Black (2007)

Passive smoking and lung cancer: a cumulative meta-analysis

Australian and New Zealand Journal of Public Health, vol. 25:3, pp. 203-211

TCT and McKinsey & Co (2008)

The Carbon Trust and McKinsey & Co (2008)
Climate change – a business revolution? How tackling climate change could create or destroy company value
The Carbon Trust
Retrieved: <http://www.carbontrust.com/media/84956/ctc740-climate-change-a-business-revolution.pdf>

Tebaldi et al. (2011)

C. Tebaldi, J. M. Arblaster, and R. Knutti (2011)
Mapping model agreement on future climate projections
Geophysical Research Letters, vol. 38, L23701, 5 pp

Teh et al. (2008)

Louise Teh, William W.L. Cheung, Andy Cornish, Clarus Chu and U. Rashid Sumaila, (2008)
A survey of alternative livelihood options for Hong Kong's fishers
International Journal of Social Economics, vol. 35, Iss. 5, pp.380 - 395

Tenenbaum (2009)

David J. Tenenbaum (2009)
Oil Sands Development: A Health Risk Worth Taking?
Environmental Health Perspectives, vol. 117, no. 4, pp. A150-A156

The Royal Society (2005)

The Royal Society (2005)
A guide to facts and fictions about climate change
Retrieved:http://royalsociety.org/uploadedFiles/Royal_Society_Content/News_and_Issues/Science_Issues/Climate_change/climate_facts_and_fictions.pdf

Thomas et al. (2004)

Chris D. Thomas, Alison Cameron, Rhys E. Green, Michel Bakkenes, Linda J. Beaumont, Yvonne C. Collingham, Barend F. N. Erasmus, Marínez Ferreira de Siqueira, Alan Grainger, Lee Hannah, Lesley Hughes, Brian Huntley, Albert S. van Jaarsveld, Guy F. Midgley, Lera Miles, Miguel A. Ortega-Huerta, A. Townsend Peterson, Oliver L. Phillips, and Stephen E. Williams (2004)
Extinction risk from climate change
Nature, vol. 427, no. 8, pp. 145-148

Thomson et al. (2009)

M.C. Thomson, I. Jeanne, and M. Djingarey (2009)
Dust and Epidemic Meningitis in the Sahel: A Public Health and Operational Research Perspective
IOP Conference Series: Earth and Environmental Science, vol. 7

Tilman et al. (2002)

D. Tilman, K. G. Cassman, P.A. Matson, R. Naylor and S. Polasky (2002)
Agricultural sustainability and intensive production practices
Nature (insight review articles), vol. 418 , pp. 671-677

Tol (2009)

Richard S. J. Tol (2009)
The Economic Effects of Climate Change
Journal of Economic Perspectives, vol. 23, no. 2, pp. 29-51

Tol (2010)

Richard S.J. Tol (2010)
The Costs And Benefits Of EU Climate Policy For 2020
Copenhagen Consensus Center

Tol (2011)

Richard S. J. Tol. (2011) :
The social cost of carbon.
ESRI working paper, No. 377
Dublin, Economic and Social Research Institute (ESRI)
Retrieved: <http://hdl.handle.net/10419/50128>

Tol and Yohe (2006)

G. Yohe, M. E. Schlesinger and N. G. Andronova (2006)
Reducing the risk of a collapse of the Atlantic thermohaline circulation
The Integrated Assessment Journal, vol. 6, Iss. 1 , Pp. 57-73

Tol and Yohe (2007)

Richard S. J. Tol and Gary W. Yohe (2007)
Climate Change. A Stern Reply to the Reply to the Review of the Stern Review
World Economics, vol. 8 , No. 2, pp.153-159

Törnqvist et al. (2008)

Torbjörn E. Törnqvist, Davin J. Wallace, Joep E. A. Storms, Jakob Wallinga, Remke L. Van Dam, Martijn Blaauw, Mayke S. Derksen, Cornelis J. W. Klerks, Camiel Meijneken and Els M. A. Snijders (2008)
Mississippi Delta subsidence primarily caused by compaction of Holocene strata
Nature Geoscience (Letters), vol. 1, pp.173-176

Toulemon and Barbieri (2006)

Toulemon Laurent and Magali Barbieri (2006)
The Mortality Impact of the August 2003 Heat Wave in France
Paper prepared for presentation at the 2006 Population of America Association Meeting, Los Angeles, March 30-April 1st.

Trenberth (2011)

K.E. Trenberth (2011)
Changes in Precipitation with Climate Change
Climate Research, 47, pp. 123-138

Trenberth (2012)

Kevin E. Trenberth (2012)
Framing the way to relate climate extremes to climate change
Climatic Change, 2012, pp. 1-8

Tryse (2010)

David Tryse (2010)
Oil Spill Database
<http://earth.tryse.net/oilspill.html>

Turner II et al. (2007)

B.L. Turner II, E.F. Lambin, and A. Reenberg (2007)
The Emergence of Land Change Science for Global Environmental Change and Sustainability
Proceedings of the National Academy of Sciences, vol. 104, no. 52, pp.20666-20671

Tyndall (1869)

John Tyndall (1969)
Heat considered as a mode of motion
New York, D. Appleton & Company (Google eBook)
Retrieved:<http://books.google.ch/books?id=1Vs9AAAAYAAJ&hl=es&pg=PR1#v=onepage&q&f=false>

UN (2011)

UN (2011)
Global Drylands: A UN system-wide response
United Nations Environment Management Group

UN (2012)

UN (2012)
The Millennium Development Goals Report 2012
New York, United Nations

UNCCD (2010)

UN Convention to Combat Desertification (2010)
Drylands Soil . Sustaining life on earth
United Nations Convention to Combat Desertification
Bonn :UN Convention to Combat Desertification (UNCCD) Secretariat
Retrieved:<http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/DrylandsSoilUNCCDBrochureFinal.pdf>

UNCCD (2011)

UN Convention to Combat Desertification (2011)
Desertification: a visual synthesis
Bonn: UN Convention to Combat Desertification (UNCCD) Secretariat
Retrieved:<http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/Desertification-EN.pdf>

UNDP (2007)

UNDP (2007)
Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World
United Nations Development Programme (UNDP), United Nations

UNDP (2011)

UNDP (2011)
Human development report 2011
United Nations Development Programme (UNDP), United Nations

UNECE (2012)

UNECE (2012)
UNECE Statistical Database
Retrieved: <http://w3.unece.org/pxweb/>

UNECE (2012a)

UNECE (2012a)
Transport Division Database
Carriage of goods by Inland Waterways (million, tonne-km)
Retrieved: http://w3.unece.org/pxweb/dialog/varval.asp?ma=ZZZ_TRInlWaterTonKm_r&path=../database/STAT/40-TRTRANS/06-TRInlWater/&lang=1&ti=Carriage+of+goods+by+Inland+Waterways+%28million%2C+tonne-km%29

UNEP/GRID Website

UNEP/GRID Website
Global Risk Data Platform

UNEP (2002)

United Nations Environment Programme (2002)
Global Environment Outlook 3: Past, present and future perspectives
London, UK: UNEP -Earthscan Publications

UNEP (2002b)

United Nations Environment Programme (2002b)
Environmental Effects of Ozone Depletion and It's Interactions with Climate Change: 2002 Assessment
Secretariat for The Vienna Convention for the Protection of the Ozone Layer, The Montreal Protocol on Substances that Deplete the Ozone Layer United Nations Environment Programme

UNEP (2005)

United Nations Environment Programme (2005)
Geo Year Book, An overview of our changing environment
Retrieved: <http://www.unep.org/geo/yearbook>

UNEP (2010)

UNEP Finance Initiative (2010)
Universal Ownership: Why environmental externalities matter to institutional investors
PRI Association and UNEP Finance Initiative

UNEP (2011)

UNEP (2011)
Bridging the Emissions Gap
United Nations Environment Programme (UNEP)

UNEP Risoe (2012)

UNEP Risoe (2012)
CDM/JI Pipeline Analysis and Database
Retrieved: <http://www.cdmpipeline.org>

UNESCO (2010)

UNESCO, World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) (2010)

The Ethical Implications of Global Climate Change

Paris, France, United Nations Educational, Scientific and Cultural Organization

UNFCCC (1992)

UNFCCC (1992)

United Nations Framework Convention on Climate Change

Retrieved: <http://unfccc.int/resource/docs/convkp/conveng.pdf>

UNFCCC (2009)

UNFCCC (2009)

UN Climate Conference at Copenhagen (COP15)

Retrieved: <http://unfccc.int/resource/docs/2009/cop15/eng/107.pdf>

UN-HABITAT (2012)

UN-HABITAT (2012)

Urban Indicators

UN-HABITAT Global Urban Indicators database

Retrieved: <http://www.unhabitat.org/stats/Default.aspx>

UNHRC (2008)

United Nations Human Rights Council (2008)

Resolution 7/23. Human rights and climate change

Retrieved: http://ap.ohchr.org/documents/E/HRC/resolutions/A_HRC_RES_7_23.pdf

UNHRC (2009)

United Nations Human Rights Council (2009)

Resolution 10/4. Human rights and climate change

Retrieved: http://ap.ohchr.org/documents/E/HRC/resolutions/A_HRC_RES_10_4.pdf

UNHRC (2011)

United Nations Human Rights Council (2011)

Resolution 18/22 Human rights and climate change

Retrieved: <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/G11/167/48/PDF/G1116748.pdf?OpenElement>

UN CHS (2010)

United Nations Compendium of Housing Statistics

Compendium of Human Settlements Statistics

Retrieved: <http://unstats.un.org/unsd/demographic/sconcerns/housing/housing2.htm>

UNISDR (2009)

UNISDR (2009)

Global Assessment Report on Disaster Risk Reduction.

Geneva, Switzerland, United Nations

UNISDR (2011)

UNISDR (2011)

Global Assessment Report on Disaster Risk Reduction

Geneva, Switzerland, United Nations, International Strategy for Disaster Reduction

UNISDR (2012)

United Nations Office for Disaster Risk Reduction (2012)

Terminology On Disaster Risk Reduction

Retrieved: <http://www.unisdr.org/eng/librariy/lib-terminology-eng%20home.htm>

UN Pop Div. (2012)

UN Department of Economic and Social Affairs Population Division (2012)

World population Database

Retrieved: <http://www.un.org/esa/population/unpop.htm>

UNSD (2010)

United Nations Statistics Division (2010)

UNSD Statistical Databases

<http://unstats.un.org/unsd/databases.htm>

UNSD (2012)

United Nations Statistics Division (2012)

UNSD Statistical Databases

<http://unstats.un.org/unsd/databases.htm>

UNWTO (2012)

United Nations World Tourism Organization (2012)

Tourism Indicators

Retrieved: <http://www.unwto.org/facts/eng/ITA&TR.htm>

US CB Website (2000)

United States Census Bureau Website

Historical Census of Housing Tables. Home Values

Census of Housing

Retrieved: <http://www.census.gov/hhes/www/housing/census/historic/values.html>

UoC and Vietnam MPI (2010)

University of Copenhagen and Ministry of Planning and Investment of Vietnam(2010)

The Fisheries Sector in Vietnam: A Strategic Economic Analysis

Retrieved:http://www.ciem.org.vn/home/en/upload/info/attach/13018993735150_FishReportUoCCIEM.pdf

USDAF (2003)

USDAF (2003)

Heat Stress Control and Heat Casualty Management

Technical Bulletin Medical 507 /Air Force Pamphlet 48-152 (I)

Headquarters, Department of the Army and Air Force

US DoT (2010)

U.S. Department of Transportation (2010)

Freight Transportation: Global Highlights, 2010

Washington, DC, U.S. Department of Transportation

US EIA (2011)

U.S. Energy Information Administration (2011)

The International Energy Outlook 2011

Retrieved: [http://www.eia.gov/ieo/pdf/0484\(2011\).pdf](http://www.eia.gov/ieo/pdf/0484(2011).pdf)

US EPA (2007)

United States Environment Protection Agency (2007)

Measuring Acid Rain

Retrieved: <http://www.epa.gov/acidrain/measure/index.html>

US EPA (2010)

United States Environment Protection Agency (2010)

Effects of Acid Rain – Materials

Retrieved: <http://www.epa.gov/acidrain/effects/materials.html>

US Forest Service (2010)

US Forest Service (2010)

Potential vegetation distribution (average for 1961-1990) simulated using the MC1 model with CRU (TS 2.0) historical climate at a half degree spatial grain over the globe

Data Basin Dataset, PNW Research Station
Retrieved: <http://www.arcgis.com/home/item.html?id=b2b92d2efcdc40738e9f1ce6ff49fde2>

US State Dpt. (2012)

US State Department (2012, August 2)

Remarks at Dartmouth College by Todd Stern, Special Envoy for Climate Change in Hanover, NH

Under Secretary for Economic Growth, Energy, and the Environment. Bureau of Oceans and International Environmental and Scientific Affairs. US State Department

Retrieved: <http://www.state.gov/e/oes/rls/remarks/2012/196004.htm>

Uyarra et al. (2005)

M. C. Uyarra, I. M. Côte, J. A. Gill, J. R. T. Tinch, D. Viner and A. R. Watkinson (2005)

Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states

Environmental Conservation, vol. 32, iss. 1, pp. 11-19

Van Noort et al. (2012)

Van Noort S.P., Águas R., Ballesteros S., and Gomes M.G. (2012)

The role of weather on the relation between influenza and influenza-like illness

Journal of Theoretical Biology, no. 298, pp. 131-137

Vanat (2011)

Vanat Laurent (2011)

2011 International report on mountain tourism - Overview of the key industry figures for ski resorts May 2011

France: Institut de la Montagne

Van den Bergh (2009)

Jeroen C. J. M. van den Bergh (2009)

Safe climate policy is affordable—12 reasons
Climatic Change, vol. 101, no. 3-4, pp. 339-385

Van Veen et al. (1991)

J. A. Van Veen, E. Lijerth, L. J. A. Lekkerkerk and S. C. van de Geijn (1991)

Carbon Fluxes in Plant-Soil Systems at Elevated Atmospheric CO₂ Levels

Ecological Applications, vol. 1, no. 2, pp. 175-181

Vecchia et al. (Eds.) (2007)

P. Vecchia, M. Hietanen, B. Stuck, E. Van Deventer, S. Niu (eds.) (2007)

Protecting Workers from Ultraviolet Radiation

International Commission on Non-Ionizing Radiation Protection (ICNIRP)

Vecchiato (2012)

R. Vecchiato (2012)

Environmental uncertainty, foresight and strategic decision making: An integrated study.

Technological Forecasting and Social Change, vol. 79, Issue 3, pp. 436-447

Veitch and Clout (eds.) (2004).

C. R. Veitch and M. N. Clout (eds.) (2004)

Turning the tide: the eradication of invasive species (proceedings of the international conference on eradication of island invasives)

Occasional Paper of the IUCN Species Survival Commission No.27

Verbruggen and Marchohi (2010)

A. Verbruggen and M.A. Marchohi (2010)

Views on peak oil and its relation to climate change policy

Energy Policy, vol. 38, pp. 5572-5581

Verheyen (2005)

Roda Verheyen (2005)

Climate Change Damage and International Law: Prevention, Duties and State Responsibility (Developments in International Law)

Martinus Nijhoff Publishers

Veron (2008)

J. E. N. Veron (2008)

Mass extinctions and ocean acidification: biological constraints on geological dilemmas

Coral Reef Research, vol. 27, pp. 459-472

Veron et al. (2009)

J. E. N. Veron, O. Hoegh-Guldberg, T.M. Lenton, J.M. Lough, D.O. Obura, P. Pearce-Kelly, C.R.C. Sheppard, M. Spalding, M.G. Stafford-Smith, and A.D. Rogers (2009)

The coral reef crisis: The critical importance of <350 ppm CO₂

Marine Pollution Bulletin, vol. 58, pp. 1428-1436.

Verstraete et al. (2009).

Michel M Verstraete, Robert J Scholes, and Mark Stafford Smith (2009)

Climate and desertification: looking at an old problem through new lenses

Frontiers in Ecology and the Environment, vol. 7, pp. 421-428

Vietnam MONRE (2008)

Vietnam Ministry Of Natural Resources and Environment (2008)

National Target Program to Respond to Climate Change. Draft. (Unofficial Translation of Vietnamese Draft Version of 27/7/2008)

Hanoi, Vietnam

Retrieved:<http://www.isg-mard.org.vn/VHDocs/NationalPrograms/NTP%20RespondtoClimateChange.pdf>

Vietnam MONRE (2010)

Vietnam Ministry Of Natural Resources and Environment (2010)

Vietnam's Second National Communication to the United Nations Framework Convention on Climate Change.

Hanoi, Vietnam

Vietnam NCCS (2011)

Vietnam National Climate Change Strategy (2011)

National Climate Change Strategy

Retrieved:http://www.dwf.org/sites/lauretest.drupalgardens.com/files/Vietnam%20Climate%20Change%20Strategy.en_.pdf

Vilà et al. (2007)

M. Vilà, J. D. Corbin, J. S. Dukes, J. Pino, S. D. Smith (2007)

Linking Plant Invasions to Global Environmental Change

in Canadell JG, Pataki D, Pitelka L (eds) : *Terrestrial Ecosystems in a Changing World* (chapter 8)

Berlin Heidelberg, The IGBP Series, Springer-Verlag

Vörösmarty et al. (2000)

C.J. Vörösmarty P. Green, J. Salisbury and R. B. Lammers (2000)

Global Water Resources: Vulnerability from Climate Change and Population Growth *Science*, vol. 289,

Vörösmarty et al. (2010)

C.J. Vörösmarty, P.B. McIntyre, M.O. Gessner, D.Dudgeon, A.Prusevich, P.Green, S.Giessen, S.E. Bunn, C.A. Sullivan, C.Reidy Liermann, and P.M. Davies (2010)

Global threats to human water security and river biodiversity

Nature, vol. 467, pp. 555-561.

Wacker et al. (2006)

John G. Wacker, Chen-Lung Yang, Chwen Sheu (2006)

Productivity of production labor, non-production labor, and capital: An international study

International Journal of Production Economics, vol. 103, no. 2, pp. 863-872.

Wall (1998)

Geoffrey Wall (1998)

Implications of Global Climate Change for Tourism and Recreation in Wetland Areas

Climatic Change, vol. 40, no. 2, pp. 371-389

Wallace (2000)

J.S. Wallace (2000)

Increasing agricultural water use efficiency to meet future food production

Agriculture, Ecosystems and Environment, vol. 82, pp. 105-119

Wang et al. (2009)

Bin Wang et al. (2009)

The Effect of Acid Rain on Vegetation by Using Remote Sensing Monitoring in Zhejiang Province

Journal of Anhui Agricultural Sciences, vol. 23

Wang et al. (2010)

Hai-qiao Wang, Zu-yun Zou, Shi-qiang Chen and Yi-qun Li (2010)

Improving thermal comfort of high-temperature environment of heading face

through dehumidification

Journal Of Coal Science And Engineering (China), vol. 16, no. 4, pp. 389-393

Ward (2009)

Peter L. Ward (2009)

Sulfur dioxide initiates global climate change in four ways

Thin Solid Films, vol. 517, pp. 3188-3203

Ward et al. (2010)

Philip J Ward, Kenneth M Strzepek, W Pieter Pauw, Luke M Brander, Gordon A Hughes and Jeroen C J H Aerts (2010)

Partial costs of global climate change adaptation for the supply of raw industrial and municipal water: a methodology and application

Environmental Research Letters, vol. 5, no. 4

Warner et al. (2009)

Warner, K.; Ehrhart, C.; Sherbinin, A. de; Adamo, S.; Chai-Onn, T.(2009)

In search of shelter: mapping the effects of climate change on human migration and displacement

London, UK, Climate Change CARE International

Watson et al. (2012)

Reg A Watson, William W L Cheung, Jonathan A Anticamara, Rashid U Sumaila, Dirk Zeller and Daniel Pauly (2012)

Global marine yield halved as fishing intensity redoubles

Fish and Fisheries, vol. 10, pp. 235-251

Waugh et al. (2009)

D. W. Waugh, L. Oman, S. R. Kawa, R. S. Stolarski, S. Pawson, A. R. Douglass, P. A. Newman, J. E. Nielsen (2009)

Impacts of climate change on stratospheric ozone recovery

Geophysical Research Letters, vol. 36

Weart (2011)

Spencer Weart (2011)

The Discovery of Global Warming (website)

Retrieved: <http://www.aip.org/history/climate/index.htm>

Welch et al. (2010)

Jarrod R. Welch, Jeffrey R. Vincent, Maximilian Auffhammer, Piedad F. Moya, Achim Dobermann, and David Dawe (2010)

Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures

PNAS, vol. 107, no. 33, pp. 14562-14567

Wei et al. (2009)

Ma Wei, Cheng Guodong, Wu Qingbai (2009)

Construction on permafrost foundations: Lessons learned from the Qinghai-Tibet railroad *Cold Regions Science and Technology*, vol.59, Iss. 1, pp. 3-11

Weitzman (2007)

Martin L. Weitzman (2007)

A Review of The Stern Review on the Economics of Climate Change

Journal of Economic Literature, vol. XLV, pp. 703-724

Weitzman (2009)

M. L. Weitzman (2009)

On modeling and interpreting the economics of catastrophic climate change

The Review of Economics and Statistics .vol. XCI, No. 1

Wentzel (1982)

Ursachen des Waldsterbens in Mitteleuropa *Allgemeine Forst Zeitschrift*, Vol. 43, pp. 1365-1368.

Werner and Simmons (2009)

Adrian D. Werner and Craig T. Simmons (2009) Impact of Sea-Level Rise on Sea Water Intrusion in Coastal Aquifers

Ground Water, vol. 47, no. 2, pp. 197-204

WFCL (2004)

Wildland Fire Leadership Council (2004)

Large Fire Suppression Costs, Strategies for Cost Management. A report to the Wildland Fire Leadership Council from the Strategic Issues Panel on Fire Suppression Costs

USDA Forest Service

Retrieved: http://www.fs.fed.us/fire/ibp/cost_accounting/costmanagement_aug_04.pdf

Wheeler (2011)

Wheeler David (2011)

Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance

CGD Working Paper 240

Washington, D.C.: Center for Global Development

<http://www.cgdev.org/content/publications/detail/1424759>

WHO (1997)

World Health Organisation (1997)

Health and Environment in Sustainable Development: Five Years after the Earth Summit

WHO (1999)

WHO (1999)

WHO Infectious Diseases Report

Geneva, Switzerland: World Health Organization

WHO (2002)

WHO (2002)

The World Health Report 2002. Reducing Risks, Promoting Healthy Life

Geneva, Switzerland: World Health Organization

WHO (2002a)

WHO (2002a)

Global Solar UV Index: A Practical Guide

Geneva, Switzerland: World Health Organization Retrieved: <http://www.who.int/uv/>

WHO (2003)

D. Campbell-Lendrum, A. Pruss-Ustun, C. Corvalan (2003)

How much disease could climate change cause?

In: AJ McMichael, D. Campbell-Lendrum, C. Corvalan, K.L. Ebi, Ak. Githeko, JS. Scheraga (eds.) *Climate Change and health: risks and responses* (pp. 133-155)

Geneva, Switzerland: World Health Organization

WHO (2004)

Majid Ezzati, Alan D. Lopez, Anthony Rodgers and Christopher J.L. Murray (eds) (2004)

Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors

Geneva, Switzerland: World Health Organization

WHO (2006)

WHO (2006)
WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005. Summary of risk assessment
 Geneva, Switzerland: World Health Organization

WHO (2009)

WHO (2009)
Global health risks: mortality and burden of disease attributable to selected major risks.
 Geneva, Switzerland: World Health Organization

WHO (2010)

Lucien Manga, Magaran Bagayoko, Tim Meredith and Maria Neira (eds) (2010)
Overview of health considerations within National Adaptation Programmes of Action for climate change in least developed countries and small island states.
 Geneva, Switzerland: World Health Organization

WHO (2011)

WHO (2011)
 Meningococcal Meningitis
 Fact sheet N° 141, December 2011
 Retrieved: <http://www.who.int/mediacentre/factsheets/fs141/en/#>

WHO BDD (2000)

WHO Burden of Diseases Database (2000)
 Global Burden of Disease Data, 2000

WHO BDD (2011)

WHO Burden of Diseases Database (2011)
 Global Burden of Disease Data, 2011
The Global Health Observatory (GHO)
 Retrieved: <http://apps.who.int/ghodata/#>

WHO Website (2012)

WHO Website
Global Health Atlas
 Retrieved: <http://apps.who.int/globalatlas/dataQuery/default.asp>

WHO and RBMP (2010)

WHO and Roll Back Malaria Partnership (2010)
 Malaria Funding & Resource Utilization: The First Decade of Roll Back Malaria
RBM Progress & Impact Series, vol. 1

Wiafe (2010)

George Wiafe (2010)
 Coastal and Continental Shelf Processes in Ghana
 Department of Oceanography and Fisheries, University of Ghana
 Retrieved: <http://www.onr.navy.mil/reports/FY10/cgwiafe.pdf>

Wilby and Dessai (2010)

Robert L. Wilby and Suraje Dessai (2010)
 Robust adaptation to climate change
Weather, vol. 65, no. 7

Wilkinson et al. (2012)

Sally Wilkinson, Gina Mills, Rosemary Illidge and William J. Davies (2012)
 How is ozone pollution reducing our food supply?
Journal of Experimental Botany, vol. 63, no. 2, pp. 527-536

Wilkinson and Salvat (2012)

Clive Wilkinson and Bernard Salvat (2012)
 Coastal resource degradation in the tropics: Does the tragedy of the commons apply for coral reefs, mangrove forests and seagrass beds?
Marine Pollution Bulletin, vol. 64, Iss. 6, pp. 1096-1105

Williams (2011)

James Bryan Williams (2011)
 Strengthening Climate Cooperation, Compliance & Coherence
 Social Science Research Network (SSRN)
 Retrieved: <http://ssrn.com/abstract=1740585> or <http://dx.doi.org/10.2139/ssrn.1740585>

Wittig et al. (2009)

V.E. Wittig, E.A. Ainsworth, S. L. Naidu, D. F. Karnosky and S. P. Long (2009)
 Quantifying the impact of current and future tropospheric ozone on tree biomass, growth, physiology and biochemistry: a quantitative meta-analysis
Global Change Biology, vol. 15, pp. 396-424

WMO (2012)

World Meteorological Organization (2012)
 Emission Scenarios
 Retrieved: http://www.wmo.int/pages/themes/climate/emission_scenarios.php

Wolf (2009)

B.O. Wolf (2009)
 Catastrophic avian mortality during heat waves and drought: the role of climate change and extreme events
 Presentation COS 101-7
 Paper presented in The 94th ESA (Ecological Society of America) Annual Meeting held in August 2-7, 2009

World Bank (2012)

World Bank (2012)
Various resources: World DataBank
<http://data.worldbank.org/indicator>

World Bank (2005)

World Bank (2005)
 Bolivia Urban Infrastructure for the Poor Project
 Concept Sheet submitted 2006
<http://www.worldbank.org/projects/P083979/bolivia-urban-infrastructure-project?lang=en>

World Bank (2010)

World Bank (2010)
World Development Report 2010: Climate and Development.
 Washington D.C., US: The International Bank for Reconstruction and Development/ The World Bank
<http://go.worldbank.org/ZXULQ9SCCO>

World Economic Forum (2011)

World Economic Forum (2011)
The Global Economic Burden of Non-communicable Diseases
 A report by the World Economic Forum and the Harvard School of Public Health
 Geneva: World Economic Forum

World Energy Council (2010)

World Energy Council (2010)
2010 Survey of Energy Resources
 London, United Kingdom: World Energy Council

World Population Prospects (2011)

World Population Prospects (2011)
Various resources
 Population Division, UN-DESA
http://esa.un.org/unpd/wpp/unpp/panel_population.htm

World Resources Institute Website(2012)

World Resources Institute Website
Reefs at Risk base GIS data
 Retrieved: <http://www.wri.org/publication/content/7911>

WRI (2009)

World Resources Institute (2009)
 World Greenhouse Gas Emissions: 2005
 World Resources Institute
 Retrieved: <http://www.wri.org/chart/world-greenhouse-gas-emissions-2005>

WTTC Website (2012)

World Travel and Tourism Council Website
Economic Data Search Tool
 Retrieved: <http://www.wtcc.org/research/economic-data-search-tool/>

WWAP (2009)

World Water Assessment Programme (2009)
 The United Nations World Water Development Report 3: Water in a Changing World. Paris: UNESCO, and London: Earthscan.

WWF (2012)

WWF International (2012)
 Living Planet Report 2012: Biodiversity, biocapacity and better choices
 WWF Zoological Society of London, Global Footprint Network and Global Footprint Network

Wu et al. (2010)

Peili Wu, Richard Wood, Jeff Ridley, and Jason Lowe (2010)
 Temporary acceleration of the hydrological cycle in response to a CO2 rampdown
Geophysical Research Letters, vol. 37, L12705

Xu et al. (2010)

Jianfeng Xu, Ayman Eltahir, Paul Jukes (2010)
 Warm Pipeline in Permafrost: A Sensitivity Study of the Major Thermal Properties
 Paper presented in the ASME 2010 29th International Conference on Ocean, Offshore and Arctic Engineering (OMAE2010) June 6-11, 2010, Shanghai, China
 Paper no. OMAE2010-20495 pp. 793-799

Yang et al. (2005)

S. L. Yang, J. Zhang, J. Zhu, J. P. Smith, S. B. Dai, A. Gao and P. Li (2005)
 Impact of dams on Yangtze River sediment supply to the sea and delta intertidal wetland response
Journal of Geophysical Research, vol. 110

Yamamoto et al. (2012)

T. Yamamoto, N. Hanasaki, K. Takahashi, Y. Hijioaka (2012)
 An Impact Assessment of Climate Change on Global Water Resources by Using a Water Scarcity Index Considering Seasonal Water Variability
Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering), vol. 67, Iss. 4, pp. I-259-I-264

Yang and Zhu (2011)

Rang-Hong Yang and Ben-Zhen Zhu (2011)
 Stability analysis of Qinghai-Tibet railway slope embankment in permafrost regions-
Rock and Soil Mechanics, vol. 7

Yardley et al. (2011)

Jane Yardley, Ronald J. Sigal and Glen P. Kenny (2011)
 Heat health planning: The importance of social and community factors
Global Environmental Change, vol. 21, iss. 2, pp. 670-679

Yohe et al (2006)

G. Yohe, M. E. Schlesinger and N. G. Andronova (2006)
 Reducing the risk of a collapse of the Atlantic thermohaline circulation
The Integrated Assessment Journal, Vol. 6, Iss. 1 Pp. 57-73

Zanobetti and Schwartz (2009)

Antonella Zanobetti and Joel Schwartz (2009)
 The Effect of Fine and Coarse Particulate Air Pollution on Mortality: A National Analysis
Environmental Health Perspectives, vol. 117, no. 6, pp. 897-903

NAVIGATOR

SEVERITY

Severity shows the scale of the overall or absolute global impact of a given indicator and the breadth of effects internationally. "Major" impacts might involve, for example, tens of billions of dollars of economic damage or over 100,000 deaths on average per year. Other indicators estimate much lower levels of damage or even positive net impacts, in which case the severity may be assessed as "Minimal".

SCALE (FROM MOST TO LEAST)

- Major
- Serious
- Select Concern
- Minimal

CONFIDENCE

Confidence shows the level of confidence that the research team attributes to the indicator, based on a multi-point assessment. Judgements are made in relation to the set of indicators that make up the Monitor assessment only; so, for example, the research team has more confidence in indicators labelled "Robust" than in indicators labelled "Speculative". Some experts may however consider the robust indicators to still possess inadequate confidence, or speculative indicators to exceed simple speculation. A 3-point scale is used to evaluate whether each criterion reviewed contributes or detracts from the overall level of confidence.

CONFIDENCE LEVEL SCALE (FROM MOST TO LEAST)

- Robust
- Indicative
- Speculative

CRITERIA PER INDICATOR

- Science - Level of certainty/agreement in science on the basic parameters involved
- Architecture - Strength of the underlying model, with preference for global/multi-country and higher resolution studies
- Climate (Only applies to the Climate section) - Level of certainty/agreement in science on the magnitude of change in key climate change variables, such as rainfall or temperature
- Data - Quality of the socio-economic data sets used, with preference for accurate, updated, comprehensive and comparable data

MDG EFFECT

The Millennium Development Goals (MDGs) represent the international community's eight primary objectives for poverty reduction to be achieved by 2015. The MDG Effect indicates an impact for specific MDGs. One of the eight goals relates to an international partnership for development and is not relevant to the Monitor's impact analysis. Any of the other seven goals are highlighted whenever an indicator assesses a Climate or Carbon effect that is understood to specifically undermine one or another of these goals.

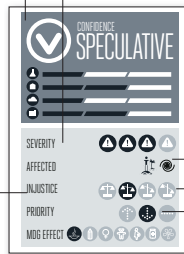
(For more information on the MDGs visit: www.un.org/millenniumgoals)

- End Poverty and Hunger
- Achieve Universal Primary Education
- Promote Gender Equality
- Reduce Child Mortality
- Improve Maternal Health
- Combat HIV/AIDS, Malaria and other diseases
- Ensure Environmental Sustainability

AFFECTED GROUPS

Affected Groups indicates the specific population segments or communities particularly affected or susceptible to the impacts of a given indicator. The groups may be socially, economically, geographically or otherwise defined depending on the impacts under examination.

- River basins
- Small islands
- Mountainous communities
- Industrialized countries
- Cities
- Subsistence farmers
- Humid tropical countries
- Outdoor occupations
- Middle income countries
- Pregnant women
- Elderly
- Farmers
- Indigenous groups
- Deforestation zones
- Heavily labouring workers
- Tropical countries
- Dryland communities
- Water-Intensive industries
- Arid regions
- Infants
- Small children/infants
- Children
- Cyclone belt countries
- Africa
- Arctic communities
- Low-elevation coastal communities
- Coastal cities
- Lower income communities
- Chronic disease sufferers
- Outdoor workers
- Fishermen
- Rural populations with poor energy access
- Remote communities
- Sahel meningitis belt
- Young adults
- Livelihoods derived from fishing
- Energy companies
- Beach resorts
- Low-elevation winter resorts
- Densely populated river ways
- Women
- Oil sand host communities
- Coastal communities
- Tropical forest zones
- Newly-industrialized countries
- Transition economies
- Industrialized countries
- Lower-income groups
- Coal miners
- Vehicle drivers
- Coal and gas power plant workers
- Fair-skinned
- Developed countries
- China
- Subsistence fisherfolk
- SIDS
- Arid forested zones



PRIORITY

(Only applies to Climate section)

Priority shows the amount of support a specific effect area has received through international climate funding. It denotes the level of priority that the effect or set of effects assessed by one Monitor indicator has, as reflected in international climate finance expenditures for adaptation. "High priority" denotes higher levels of funding from developed countries, targeting the issue in affected developing countries. "Low" or "no priority" is given to concerns for which financial support has been marginal or virtually absent. The OECD Creditor Reporting System sub-sector flows for 2010 have been used as the basis for the analysis (OECD CRS, 2012).

PRIORITY OF EFFECTS IN INTERNATIONAL CLIMATECHANGE FINANCE FLOWS SCALE (FROM MOST TO LEAST)

- High priority
- Low priority
- Not a priority

INJUSTICE

(Only applies to Climate section)

Injustice shows how unjust or not a given effect is on the global scale. It denotes the level of injustice of a specific effect or set of effects as they are assessed by one of the Monitor's indicators. Injustice is highest when the affected countries have least responsibility for climate change and at its lowest when impacts are shared the most among countries with high responsibility. The four-point score is defined by statistical quartiles, so the level of injustice is also relative only to the Monitor's Climate section indicators themselves. Responsibility for climate change is based on total country GHG emissions from 1990-2005 (Mueller et al, 2007).

DISTRIBUTION OF CLIMATE CHANGE IMPACTS VERSUS RESPONSIBILITY FOR CLIMATE CHANGE

SCALE (FROM LEAST TO MOST)

- Least unjust
- Most unjust

TITLE

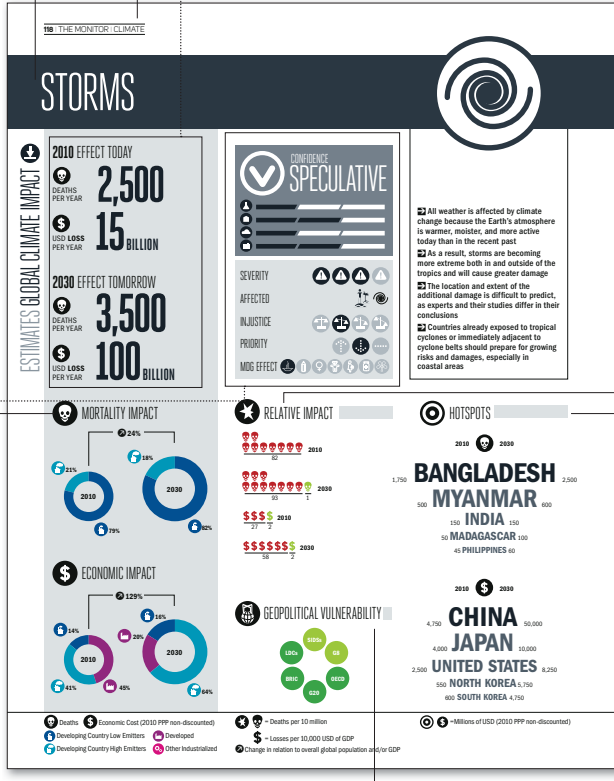
CHAPTER TITLE



2010 DATA



2030 DATA



RELATIVE IMPACT

Relative Impact shows how countries with different levels of vulnerability experience impact relative to their size. Climate or Carbon impact is shown as a share of country-level population (for mortality) or country-level wealth/GDP (for economic) for countries with Acute or Moderate vulnerability levels for the years 2010 and 2030. The scale varies per indicator and is provided at the bottom of each page.

Additional deaths due to climate/carbon per 100 share of population - yearly average

Additional economic costs due to climate/carbon per share of GDP - yearly average

- Acute
- Moderate

N/A indicates that the item is not applicable to this indicator

PEAK IMPACT

Peak Impact illustrates how severe certain time-specific impacts can become. Historical maximums in impact are cited from the relevant databases with the year of occurrence provided alongside disaster data from that year. Peak impacts in no way imply any assumed attribution to climate change or not. They serve simply to illustrate the maximum scale of individual impacts that have been attained in the recent past (2000-2012).

- Top 5 historical yearly losses (2000-2012) by number of deaths
- Top 5 historical yearly losses (2000-2012) by economic costs

MORTALITY & ECONOMIC IMPACT

This section displays both the global impact of climate change as it is distributed across the key Monitor country groups, and as the change in impact over time, as a share of overall global population (for mortality) or wealth/GDP (for economic). These are presented either using pie charts or (as percentage shares) or as bar charts (for indicators with positive and negative impacts) showing shares of the total impact by absolute amount.

- Developed
- Developing Country Low Emitters
- Developing Country High Emitters
- Other Industrialized

GEOPOLITICAL VULNERABILITY

Geopolitical vulnerability provides the average vulnerability level in 2030 for all countries comprising key geopolitical groupings. The groups covered range from Least Developed Countries (LDCs) or Small Island Developing States (SIDS), to the Brazil-Russia-India-China (BRIC) nations, or members of the Organization for Economic Co-operation and Development (OECD).

- Acute
- Severe
- High
- Moderate
- Low

HOTSPOTS

Hotspots show countries estimated to experience the largest total impacts of any country irrespective of overall size of population or wealth/GDP. The overall impacts are given as yearly averages for 2010 and 2030 for the top five countries by total impact in 2030.

Countries with the largest total climate-related mortality by number of deaths. Additional deaths due to climate/carbon - yearly average

Countries with the largest total climate-related damage costs. Additional economic losses due to climate/carbon (2010 USD PPP) - yearly average

KEY COUNTRY GROUP DATA

Country Group	UNFCCC Classification	Number of Countries	Share of Global Population*		Share of Global GDP (PPP)**		Average Per Capita GDP (PPP)**	Share of Total GHG Emissions	Average Per Capita GHG Emissions
			2010	2030	2010	2030			
Year	2012	2010/2030	2010	2030	2010	2030	2010	2005	2005
Developed	Annex II	23	13%	12%	48%	25%	\$38,000	30%	13 tons CO ₂ e
Developing Country High Emitters	Non-Annex I	60	40%	38%	32%	50%	\$15,000	50%	14 tons CO ₂ e
Developing Country Low Emitters	Non-Annex I	85	42%	45%	13%	17%	\$5,000	12%	2 tons CO ₂ e
Other Industrialized	Non-Annex II Annex I	16	6%	5%	8%	8%	\$17,000	7%	7 tons CO ₂ e
World Total (World Average)		184	6.8 billion	8.1 billion	\$73 billion	\$210 billion	(\$19,000)	42 GtCO ₂ e	(8 tons CO ₂ e)

* Population data - source: UNSD, 2012 ** GDP data - sources: CIESIN, 2012; IMF WEO, 2012
 † GHG data includes all Kyoto gases and Land use, land-use change and forestry (LULUCF) - source: Climate Analytics, 2012

BIGGER PICTURE

Bigger Picture gives insight into the situation beyond Climate or Carbon effects. The Monitor only measures the share of impact estimated to result from climate change or the carbon economy. In many instances, Climate or Carbon are just one -sometimes small, sometimes large- causal factor in contributing to losses. Elsewhere, it is useful to know how impact relates to the overall issue analysed. Thus, the Bigger Picture provides an indication of the overall scale of a concern and the Climate or Carbon linked part of the issue under analysis.

ENVIRONMENTAL DISASTERS 10

Whether or not specific events can be identified as "caused" by climate change, all weather is more affected by a global climate system that is warmer, more active, and wetter (Trenberth, 2012). As a result, it is evident that storms are generally becoming more extreme, particularly in terms of wind speeds and quantity of rainfall. Moreover, there is a poleward shift to the north and south of cyclone storm tracks, as parts of the world adjacent to the tropics are experiencing more "typical" weather. Where vulnerabilities to more severe storms are accentuated by environmental and income-related factors -such as for high risk urban slums in low-lying coastal areas- the dangers of these changes are much higher (IPCC, 2012a). Corresponding measures will need to offset the additional risk by reducing community vulnerabilities and, where possible, limiting exposures to storm hazards (UNISDR, 2009 and 2011). Heightened emergency assistance should also be focused in the coming years and decades.

CLIMATE MECHANISM
Climate change increases air and sea temperatures, boosting the level of moisture in the atmosphere; this leads to acceleration of the planet's hydrological system, heavier precipitation, higher maximum winds and a general tendency to more extreme weather (IPCC, 2007). These hallmarks have been recognized in storms, including cyclones (IPCC, 2012a). Whether or not there has been a change in the frequency or overall number of cyclones in recent years can side-track the focus on other important factors, such as wind speed changes (Keenan et al. in Chan et al. (eds), 2010). Simply counting the change in the number of cyclones often leads to the conclusion that there is less cyclone activity, since there is generally understood to be a slight increase in the most extreme cyclones, such as categories 3 to 5, but an overall decrease in the total number of cyclones since the reduction in less severe storms is expected to be greater (Keenan et al., 2010). It is not surprising that an increase in the most extreme cyclones, as measured on the well-known Saffir-Simpson scale results in fewer cyclones overall, since the scale itself is static, measures overall power, and is a rough proxy for the size of storms (Dolan and Davis, 1992; Ingh et al., 2008). Larger more powerful storms absorb and dissipate considerable more energy than smaller ones, whose declining numbers have been attributed to an overall decline in cyclone frequency in recent times (IPCC, 2012a). Not is the ultimate number of storms as important as the intensity or size of those storms: in the US, 85% of all cyclone damage is caused by the most extreme storms (Rudestam and Gurev, 2007; Pielke et al., 2008). A large share of the damage caused by cyclones is the result of storm surge, or inundations from rainfall, high winds, and freak waves caused by major storms, which have been worsened by heavier rainfall and sea-level rise, both of which are fuelled by climate change (Gangopria et al., 2009).

IMPACTS
The impact of climate change on both tropical cyclones and major storms outside of the tropics (extra-tropical cyclones) is estimated to already cost 15 billion dollars and to be responsible for an average of almost 2,500 deaths each year, with around 1.5 million people affected and in need of emergency assistance. In global terms, the number of countries experiencing extreme effects is limited, particularly since the great majority of losses relate to tropical cyclones, which are a serious concern for only 30 to 40 countries in the world's cyclone belts. A dozen countries in Asia, Africa, the Pacific, and the Caribbean are estimated to suffer Acute or Severe vulnerability to climate change-aggravated storm effects. The countries most vulnerable cut across the socio-economic spectrum from Japan to major emerging economies, such as China, least developed countries such as Madagascar, or small island developing states, such as Haiti. Bangladesh is currently estimated to suffer the greatest human impact of these effects, with over 1,000 additional casualties due to climate change on an average yearly basis -major storms do not occur annually, but since in every 5 to 20 years. Myanmar and India are estimated to suffer the next greatest share of additional casualties. In overall economic terms, China, Japan, the US, North Korea, and South Korea experience the greatest estimated losses, incurring between 2 and 5 billion dollars a year in damages. A number of small island countries, such as Antigua and Barbuda, Dominica, Grenada, and Vanuatu are identified as experiencing the most severe economic and human loss

ENVIRONMENTAL DISASTERS 11

CLIMATE VULNERABILITY

CLIMATE UNCERTAINTY

Vulnerability measure: comparative mortality risk as a result of population (national) and losses as a share of GDP in USD (national) with same full weighting to each

Legend: Limited Partial Considerable

COUNTRY	2010	2010	2010	2010	2010	2010	2010	2010	2010
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1

BIGGER PICTURE

MONITOR

PEAK IMPACT

2008 MYANMAR 138,366 2008 UNITED STATES 19,230
 2007 BANGLADESH 4,270 2004 JAPAN 6,144
 2004 HAITI 2,297 2000 INDONESIA 7,850
 2000 UNITED STATES 1,862 2000 CHINA 7,469
 2004 PHILIPPINES 1,861 2000 NORTH KOREA 6,400

● Acute ● Severe ● High ● Moderate ● Low

● 5 countries (total)

VULNERABILITY SHIFT

GENDER BIAS

INDICATOR INFORMATION

MODEL: Chan et al. 2014; Mendelsohn et al. 2011
 EMERGENCY SCENARIO: SRES A3B (IPCC, 2000)
 BASE DATA: Population: WorldPop; Mortality: UNISDR; GDP: WorldPop; Storms: OCHA/UNISDR 2012; March by NADCE 2010 (unavailable)

MAIN TEXT

Main Text provides a descriptive overview of the indicator. It is a summarized explanation of the particular effect or effect area under assessment for each of the Monitor's 34 indicators.

CLIMATE/CARBON VULNERABILITY

The map shows the 2030 vulnerability level for every country (all 184) for each indicator.

STORMS

ENVIRONMENTAL DISASTERS 11

CLIMATE VULNERABILITY

CLIMATE UNCERTAINTY

Vulnerability measure: comparative mortality risk as a result of population (national) and losses as a share of GDP in USD (national) with same full weighting to each

Legend: Limited Partial Considerable

COUNTRY	2010	2010	2010	2010	2010	2010	2010	2010	2010
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1
Algeria	1	1	1	1	1	1	1	1	1

INDICATOR INFORMATION

MODEL: Chan et al. 2014; Mendelsohn et al. 2011
 EMERGENCY SCENARIO: SRES A3B (IPCC, 2000)
 BASE DATA: Population: WorldPop; Mortality: UNISDR; GDP: WorldPop; Storms: OCHA/UNISDR 2012; March by NADCE 2010 (unavailable)

● Acute ● Severe ● High ● Moderate ● Low

● 5 countries (total)

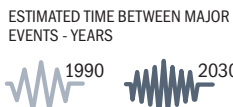
SURGE

Surge shows how fast or slowly impacts are accelerating relative to other indicators. The rate of change in impacts as a share of population (for mortality) or wealth/GDP (for economic) may be increasing rapidly or slowly, or may be decreasing or be stable over time. One of seven possible values spanning this spectrum are assigned on a statistical basis independently for the Climate and Carbon sections of the Monitor and only in relation to the other indicators of those sections.



OCCURRENCE

Occurrence shows how extreme events will become more frequent over time. It indicates the expected change in the occurrence of a major event over time as the frequency of events is evolving. For example, a major flood or landslide that occurred in 1990 once every 20 years, would occur in 2030 once every 15 years.



GENDER BIAS

Gender Bias indicates the degree to which a particular effect is understood to have a pronounced negative impact either for women or men. In certain cases, there may be independent reasons for heightened exposure in both men and women, in which case a double bias is emphasized.

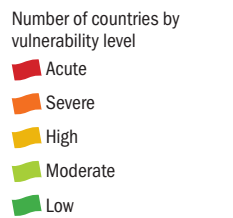


INDICATOR INFORMATION

Indicator Information provides essential source information. It gives references for the model or models used to calculate either climate or carbon effects, the reference emission scenario relied upon, and sources of socio-economic or environmental base data.

VULNERABILITY SHIFT

Vulnerability Shift illustrates the degree to which a particular effect is understood to have a pronounced negative impact either for women or men. In certain cases, there may be independent reasons for heightened exposure in both men and women, in which case a double bias is emphasized. Typically, more countries register in the Acute or Severe levels of vulnerability in 2030 versus 2010, as countries experiencing milder levels of impact begin, with accelerated climate change, to share similar intensities to those felt by only few front-line countries today.



CLIMATE UNCERTAINTY

(Only applies to Climate section)

The map indicates regional uncertainties of key climate factors. It shows the level of disagreement among groups of climate models on the direction of change of a given indicator's key climate variable(s), e.g. whether rainfall will increase or decrease as the planet warms. Information is provided for each of the Monitor's 21 sub-regions. Regions have "Limited" uncertainty when less than 10% of models disagree on the direction of change for that zone. Uncertainty is "Considerable" when less than two thirds of models agree, and "Partial" when more than two thirds agree, but not as many as 90% or more.

