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

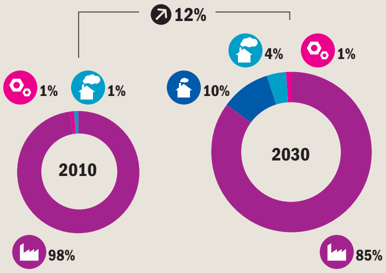
2010 EFFECT TODAY

USD **LOSS** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **25 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

SEVERITY ●●○○

AFFECTED

MDG EFFECT ○○○○○○●

- 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

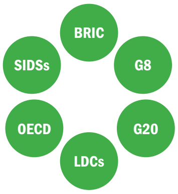
RELATIVE IMPACT

$$$$$$ 54	2010
$$$$$$$$$$ 100	2030

HOTSPOTS

2010	$	2030
7,250	**CANADA**	20,000
0	**NIGERIA**	1,500
0	**MADAGASCAR**	750
85	**INDONESIA**	600
50	**RUSSIA**	350

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

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).

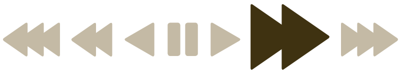
Current and prospective oil sand reserves outside Canada include those found in Angola, China, Congo, Indonesia, Italy, Madagascar, Nigeria, Russia, Trinidad and Tobago and the US. Indonesia, Russia and the US have already commenced small-scale levels of production.

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

N/A

SURGE



OCCURRENCE

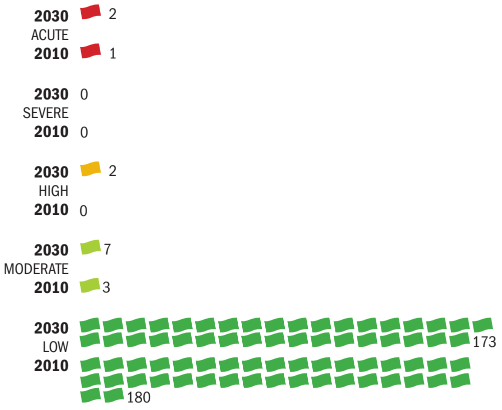
N/A

PEAK IMPACT

N/A

GENDER BIAS

VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: CAPP, 2011; CERES, 2010

BASE DATA: World Energy Council, 2010

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

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.

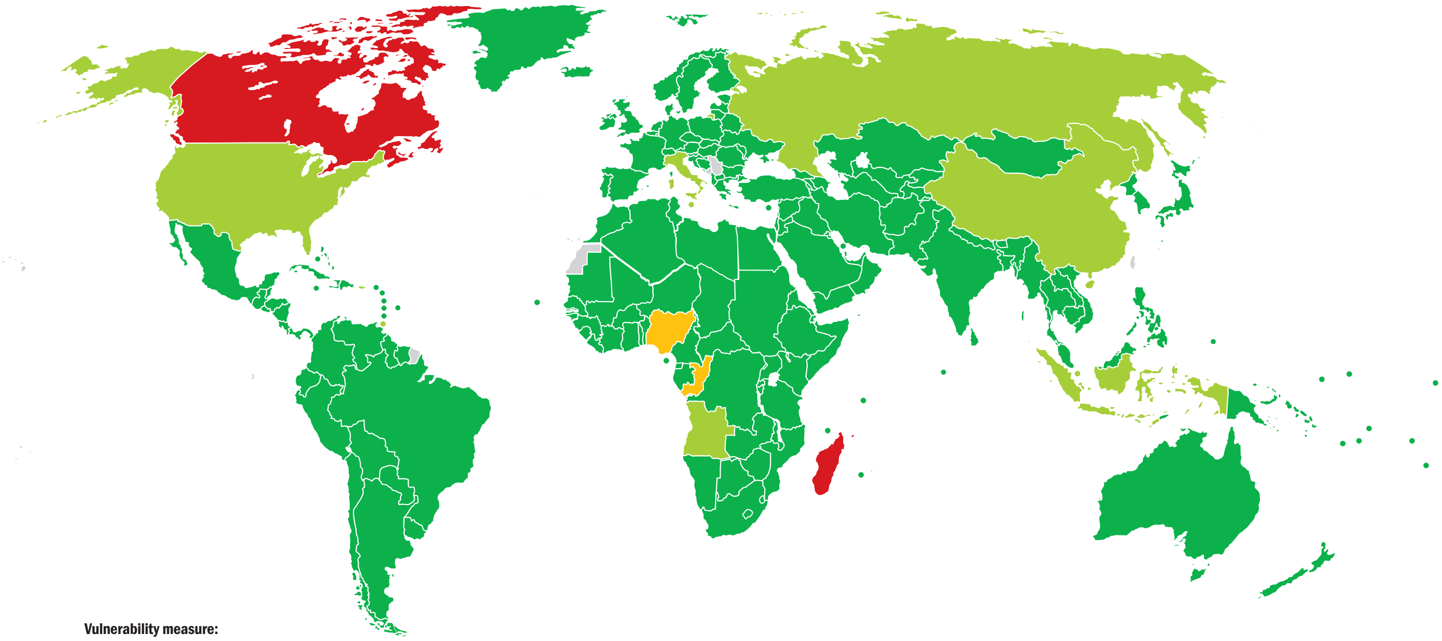
ESTIMATES COUNTRY-LEVEL IMPACT

	$		☢	
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				
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				
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				

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

	$		☢	
COUNTRY	2010	2030	2010	2030
Kuwait				
Kyrgyzstan				
Laos				
Latvia				
Lebanon				
Lesotho				
Liberia				
Libya				
Lithuania				
Luxembourg				
Macedonia				
Malawi				
Malaysia				
Maldives				
Mali				
Malta				
Marshall Islands				
Mauritania				
Mauritius				
Mexico				
Micronesia				
Moldova				
Mongolia				
Morocco				
Mozambique				
Myanmar				
Namibia				
Nepal				
Netherlands				
New Zealand				
Nicaragua				
Niger				

	$		☢	
COUNTRY	2010	2030	2010	2030
North Korea				
Norway				
Oman				
Pakistan				
Palau				
Panama				
Papua New Guinea				
Paraguay				
Peru				
Philippines				
Poland				
Portugal				
Qatar				
Romania				
Rwanda				
Saint Lucia				
Saint Vincent				
Samoa				
Sao Tome and Principe				
Saudi Arabia				
Senegal				
Seychelles				
Sierra Leone				
Singapore				
Slovakia				
Slovenia				
Solomon Islands				
Somalia				
South Africa				
South Korea				
Spain				
Sri Lanka				

	$		☢	
COUNTRY	2010	2030	2010	2030
Sudan/South Sudan				
Suriname				
Swaziland				
Sweden				
Switzerland				
Syria				
Tajikistan				
Tanzania				
Thailand				
Timor-Leste				
Togo				
Tonga				
Tunisia				
Turkey				
Turkmenistan				
Tuvalu				
Uganda				
Ukraine				
United Arab Emirates				
United Kingdom				
Uruguay				
Uzbekistan				
Vanuatu				
Venezuela				
Vietnam				
Yemen				
Zambia				
Zimbabwe				

☢ Tonnes of toxic waste (thousands) - yearly average

OIL SPILLS

ESTIMATES GLOBAL CARBON IMPACT

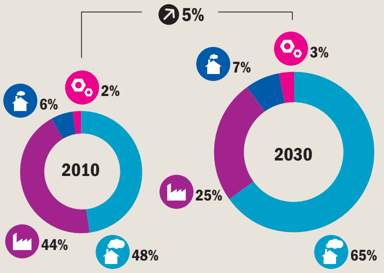
2010 EFFECT TODAY

USD **LOSS** PER YEAR **10 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **40 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

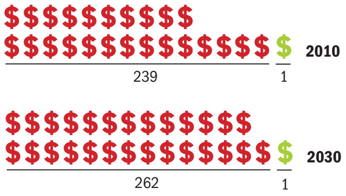
SEVERITY ⚠ ⚠ ⚠

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

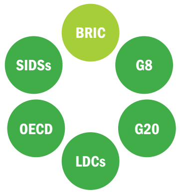
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
3,250	**KUWAIT**	15,000
2,000	**SAUDI ARABIA**	8,000
3,500	**UNITED STATES**	6,250
350	**ECUADOR**	1,500
300	**SINGAPORE**	1,250

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

Change in relation to overall global population and/or GDP

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

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

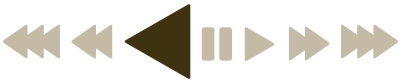
The global impact of oil spills on the world economy is estimated at 12 billion dollars a year today, and is expected to nearly triple to more than 30 billion dollars a year in 2030 but with losses remaining stable as a share of GDP.

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

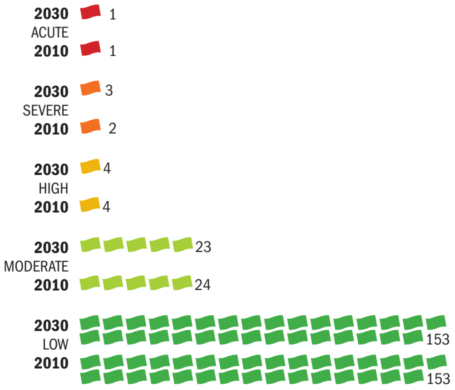
N/A

SURGE



OCCURRENCE

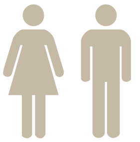
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Muehlenbachs et al., 2011; Schmidt, 2004; Westwood, 2010

BASE DATA: CEDRE, 2010; Tryse, 2010

● Acute ● Severe ● High ● Moderate ● Low

Number of major oil spills per decade (over 10,000 tones of oil spilled)

▬ = 5 countries (rounded)

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.

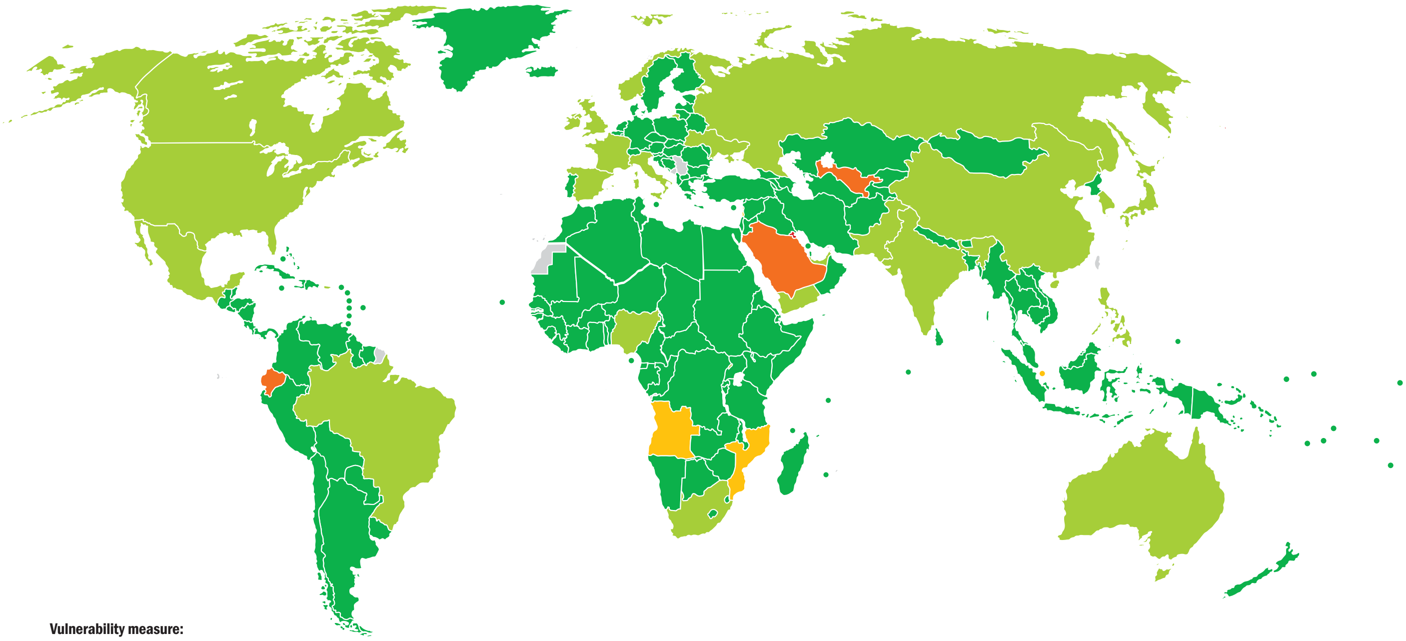
ESTIMATES COUNTRY-LEVEL IMPACT

	$		■	
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
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				
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				

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

	$		▮	
COUNTRY	2010	2030	2010	2030
Guinea				
Guinea-Bissau				
Guyana				
Haiti				
Honduras				
Hungary				
Iceland				
Indonesia				
Iran				
Iraq				
Israel				
Jamaica				
Jordan				
Kazakhstan				
Kenya				
Kiribati				
Kyrgyzstan				
Laos				
Latvia				
Lesotho				
Liberia				
Libya				
Lithuania				
Luxembourg				
Macedonia				
Madagascar				
Malawi				
Malaysia				
Maldives				
Mali				
Malta				
Marshall Islands				

	$		▮	
COUNTRY	2010	2030	2010	2030
Mauritania				
Mauritius				
Micronesia				
Moldova				
Mongolia				
Morocco				
Myanmar				
Namibia				
Nepal				
Netherlands				
New Zealand				
Nicaragua				
Niger				
North Korea				
Oman				
Palau				
Panama				
Papua New Guinea				
Paraguay				
Peru				
Poland				
Portugal				
Qatar				
Romania				
Rwanda				
Saint Lucia				
Saint Vincent				
Samoa				
Sao Tome and Principe				
Senegal				
Seychelles				
Sierra Leone				

	$		▮	
COUNTRY	2010	2030	2010	2030
Slovakia				
Slovenia				
Solomon Islands				
Somalia				
Sri Lanka				
Sudan/South Sudan				
Suriname				
Swaziland				
Sweden				
Switzerland				
Syria				
Tajikistan				
Tanzania				
Thailand				
Timor-Leste				
Togo				
Tonga				
Trinidad and Tobago				
Tunisia				
Turkey				
Turkmenistan				
Tuvalu				
Uganda				
Uruguay				
Vanuatu				
Venezuela				
Vietnam				
Zambia				
Zimbabwe				

▮ Gallons of oil spilled (thousands) - yearly average

HABITAT CHANGE

BIODIVERSITY

CORROSION

WATER

$	300 BILLION LOSS 1,750 BILLION LOSS	2010 2030	⚠⚠⚠⚠ ▶▶▶
$	1 BILLION LOSS 5 BILLION LOSS	2010 2030	⚠⚠⚠⚠ ▶
$	5 BILLION LOSS 10 BILLION LOSS	2010 2030	⚠⚠⚠⚠ ◀

BIODIVERSITY

ESTIMATES GLOBAL CARBON IMPACT

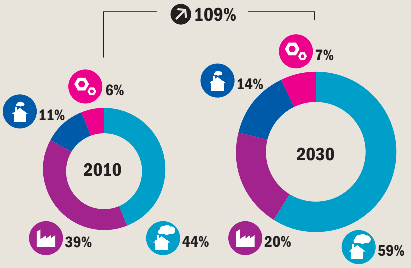
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **300 BILLION**

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **1,750 BILLION**

$ ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

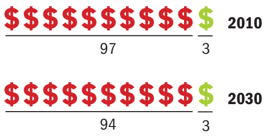
SEVERITY ⚠ ⚠ ⚠ ⚠

AFFECTED

MDG EFFECT

- 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

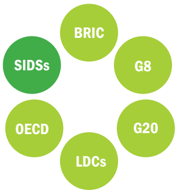
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
35,000	**BRAZIL**	300,000
80,000	**USA**	250,000
20,000	**CHINA**	200,000
15,000	**RUSSIA**	100,000
10,000	**INDONESIA**	90,000

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)
Developing Country Low Emitters
Developed
Developing Country High Emitters
Other Industrialized

$ = Losses per 1,000 USD of GDP

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.

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 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).

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.

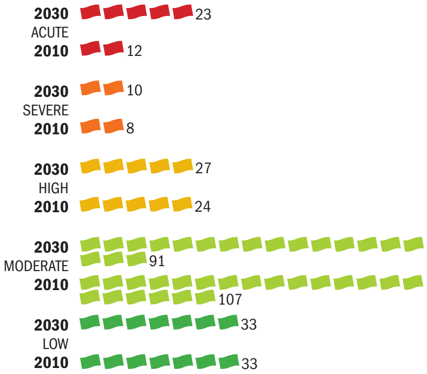
Around 20 countries are acutely vulnerable to these effects, all tropical developing countries with highly abundant ecosystems in Africa, Latin America and Southeast Asia. The impacts will undermine development, especially since lowest income groups are more dependent on ecosystem services, such as water 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.

BIGGER PICTURE

N/A

SURGE

VULNERABILITY SHIFT



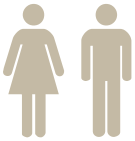
OCCURRENCE

N/A

PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Costanza, 2006; Hooper, 2012; Reilly, 2008

BASE DATA: OECD, 2012; Reilly, 2008

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

THE INDICATOR

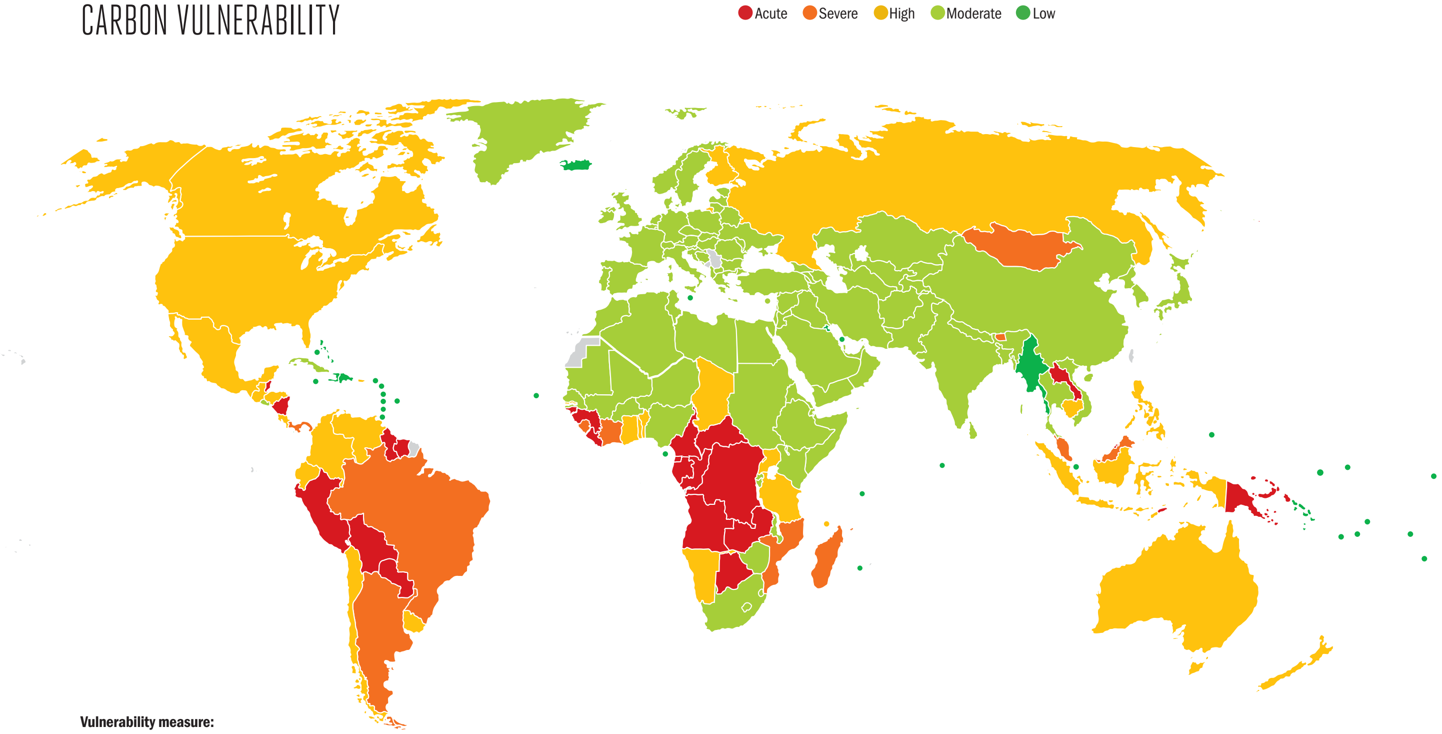
The indicator measures losses in biodiversity richness resulting from ground-level ozone toxicity and acid rain and their effect on net primary productivity (Reilly, 2007; Hooper et al., 2012). The change is mapped on the basis of vegetation distribution and translated into losses in ecosystem services 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
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
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

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY



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

COUNTRY	2010	2030
Iran	550	4,250
Iraq	10	85
Ireland	100	350
Israel	10	70
Italy	550	1,750
Japan	5,250	15,000
Jordan	1	5
Kazakhstan	350	2,250
Kenya	100	650
Kyrgyzstan	25	150
Latvia	40	300
Lebanon	10	70
Lesotho	5	25
Libya	15	150
Lithuania	65	450
Luxembourg	5	15
Macedonia	35	250
Malawi	35	250
Mali	30	200
Mauritania	10	55
Moldova	10	50
Morocco	35	250
Nepal	150	1,000
Netherlands	45	150
Niger	5	40
Nigeria	900	6,000
North Korea	15	150
Norway	450	1,250
Oman	10	70
Pakistan	100	800
Poland	400	2,750
Portugal	250	750
Romania	200	1,500
Rwanda	1	15
Saudi Arabia	35	250
Senegal	60	400
Slovakia	100	750
Slovenia	50	350
Somalia	10	50
South Africa	1,500	9,000
South Korea	350	2,750
Spain	1,250	3,500
Sri Lanka	300	2,250
Sudan/South Sudan	40	300
Swaziland	5	45
Sweden	1,000	3,250
Switzerland	85	250
Syria	5	50
Tajikistan	10	70
Thailand	1,750	15,000
Tunisia	20	150
Turkey	650	2,000
Turkmenistan	40	250
Ukraine	350	2,250
United Arab Emirates	5	30
United Kingdom	350	1,000
Uzbekistan	20	150
Vietnam	800	8,750
Yemen	15	100
Zimbabwe	30	200
LOW		
Antigua and Barbuda		
Bahamas		
Bahrain		
Barbados		
Cape Verde		
Dominica		
Dominican Republic		
Fiji		
Grenada		
Haiti		
Iceland		
Jamaica		
Kiribati		
Kuwait		
Maldives		
Malta		
Marshall Islands		
Mauritius		
Micronesia		
Myanmar		
Palau		
Qatar		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Seychelles		
Singapore		
Solomon Islands		
Tonga		
Trinidad and Tobago		
Tuvalu		
Vanuatu		

CORROSION

ESTIMATES GLOBAL CARBON IMPACT

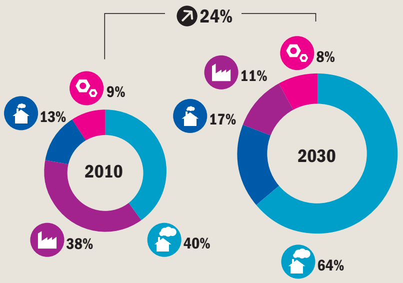
2010 EFFECT TODAY

USD **LOSS** PER YEAR **1 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **5 BILLION**

ECONOMIC IMPACT



CONFIDENCE
SPECULATIVE

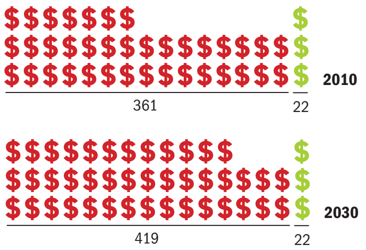
SEVERITY ⚠⚠

AFFECTED

MDG EFFECT

- 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

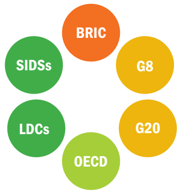
RELATIVE IMPACT



HOTSPOTS

	2010	2030
CHINA	400	2,250
INDIA	100	550
SOUTH KOREA	80	450
RUSSIA	60	250
UNITED STATES	200	200

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)
Developing Country Low Emitters
Developed
Developing Country High Emitters
Other Industrialized

$ = Losses per 10 million USD of GDP

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; Huifang 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.

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

N/A

SURGE

OCCURRENCE

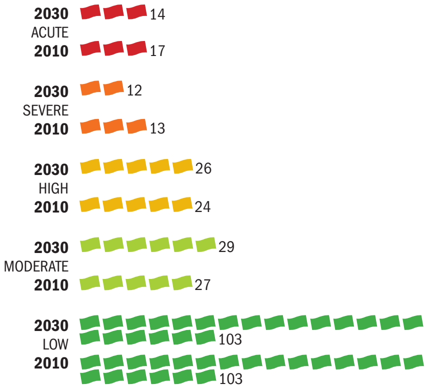
N/A

PEAK IMPACT

N/A

GENDER BIAS

VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: OECD, 2012

BASE DATA: World Bank, 2005b

▬ = 5 countries (rounded)

🔴 Acute 🟠 Severe 🟡 High 🟢 Moderate 🟢 Low

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.

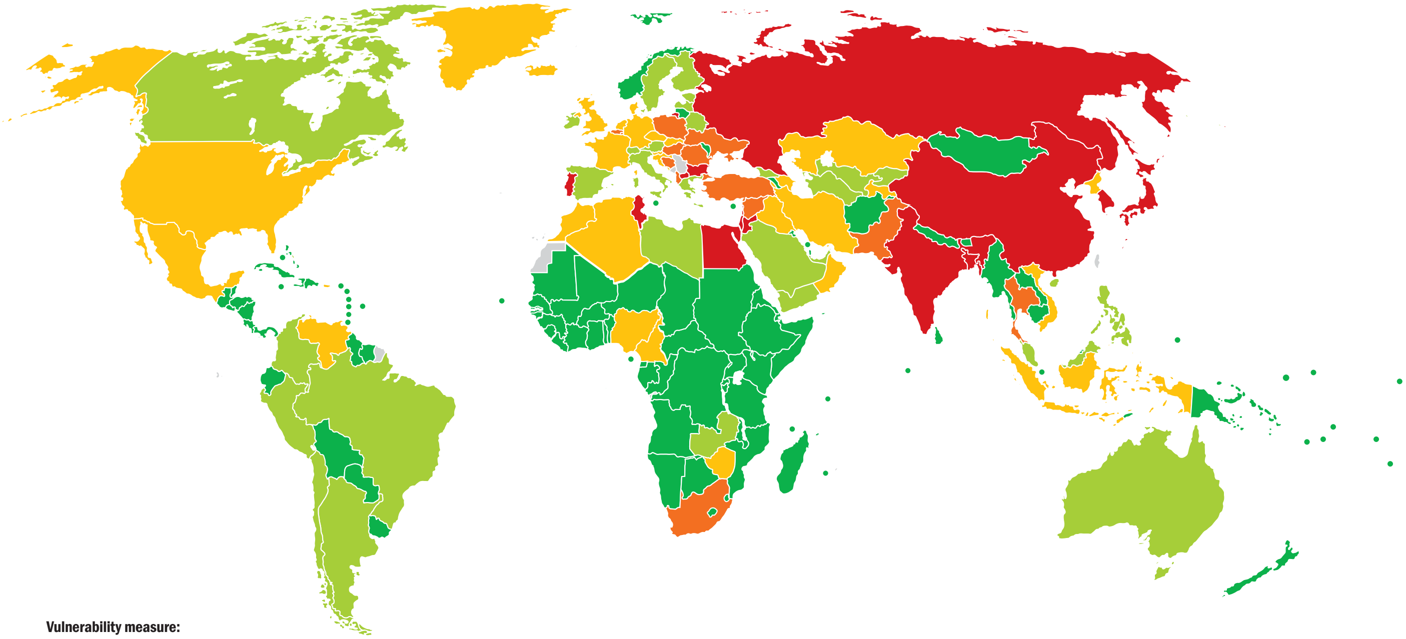
ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Bangladesh	5	25
Bulgaria	5	10
China	400	2,250
Egypt	15	80
India	100	550
Israel	15	35
Japan	150	150
Jordan	1	10
Lebanon	10	40
Macedonia	1	1
Portugal	15	15
Russia	60	250
South Korea	80	450
Tunisia	1	10
SEVERE		
Albania	1	1
Belgium	15	15
Bosnia and Herzegovina	1	1
Hungary	5	15
Pakistan	10	40
Poland	20	50
Romania	5	15
South Africa	10	35
Syria	1	10
Thailand	10	45
Turkey	10	20
Ukraine	5	20
HIGH		
Algeria	1	5
Azerbaijan	1	1
Cameroon	1	1
Croatia	1	1
Czech Republic	5	10
Denmark	1	1
France	20	20
Germany	40	40
Indonesia	5	30
Iran	10	40
Iraq	1	5
Kazakhstan	1	5
Mexico	15	35
Morocco	1	5
Netherlands	5	5
Nigeria	1	5
North Korea		1
Oman		1
Slovakia	1	5
Slovenia	1	1
Tajikistan		
United Kingdom	40	45
United States	200	200
Venezuela	1	10
Vietnam	1	20
Zimbabwe		
MODERATE		
Argentina		1
Australia	1	1
Austria	1	1
Belarus	1	1
Brazil	5	15
Canada	5	5
Chile	1	1
Colombia	1	1
Estonia		
Finland		
Georgia		
Greece	1	1
Ireland		
Italy	10	10
Kyrgyzstan		
Latvia		
Libya		1
Malaysia	1	5
Peru		
Philippines	1	5
Saudi Arabia	1	10
Spain	5	5
Sweden	1	1
Switzerland		
Turkmenistan		
United Arab Emirates		1
Uzbekistan	1	1
Yemen		1
Zambia		
LOW		
Afghanistan		
Angola		
Antigua and Barbuda		
Armenia		
Bahamas		
Bahrain		
Barbados		
Belize		
Benin		
Bhutan		

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

COUNTRY	2010	2030
Bolivia		
Botswana		
Brunei		
Burkina Faso		
Burundi		
Cambodia		
Cape Verde		
Central African Republic		
Chad		
Comoros		
Congo		
Costa Rica		
Cote d,Ivoire		
Cuba		
Cyprus		
Djibouti		
Dominica		
Dominican Republic		
DR Congo		
Ecuador		
El Salvador		
Equatorial Guinea		
Eritrea		
Ethiopia		
Fiji		
Gabon		
Gambia		
Ghana		
Grenada		
Guatemala		
Guinea		
Guinea-Bissau		

COUNTRY	2010	2030
Guyana		
Haiti		
Honduras		
Iceland		
Jamaica		
Kenya		
Kiribati		
Kuwait		
Laos		
Lesotho		
Liberia		
Lithuania		
Luxembourg		
Madagascar		
Malawi		
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Micronesia		
Moldova		
Mongolia		
Mozambique		
Myanmar		
Namibia		
Nepal		
New Zealand		
Nicaragua		
Niger		
Norway		

COUNTRY	2010	2030
Palau		
Panama		
Papua New Guinea		
Paraguay		
Qatar		
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Solomon Islands		
Somalia		
Sri Lanka		
Sudan/South Sudan		
Suriname		
Swaziland		
Tanzania		
Timor-Leste		
Togo		
Tonga		
Trinidad and Tobago		
Tuvalu		
Uganda		
Uruguay		
Vanuatu		

WATER

ESTIMATES GLOBAL CARBON IMPACT

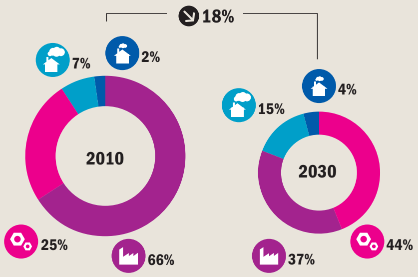
2010 EFFECT TODAY

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

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR 10 **BILLION**

ECONOMIC IMPACT



CONFIDENCE

INDICATIVE

SEVERITY

AFFECTED

MDG EFFECT

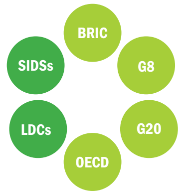
- Bodies of fresh water become acidic when continuously subjected to highly acidic rainfall as a result of air pollution from local or regional heavy industries
- Local vulnerabilities are higher where soils are more acidic and fail to reduce the acidity level of polluted rains
- Acidic water is toxic 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

2010	$	2030
1,500	**USA**	2,250
300	**BELARUS**	1,250
200	**POLAND**	650
100	**UKRAINE**	600
100	**RUSSIA**	500

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)
Developing Country Low Emitters
Developed
Developing Country High Emitters
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)

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 (Jeziorskietal 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 (Larssen 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

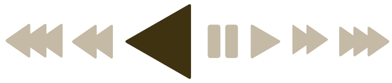
The global impact of acid rain due to industrial processes on water resources is estimated at a modest five billion dollars in 2010. It is assumed these effects will double by 2030 but remain stable as a share of GDP with losses of ten billion dollars a year.

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

N/A

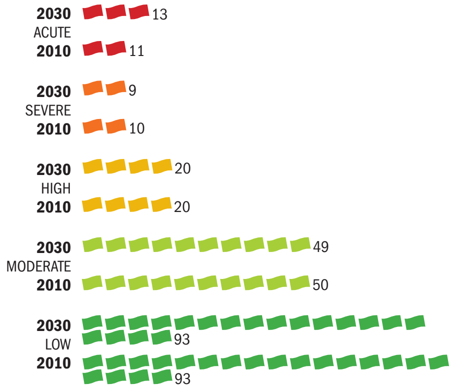
SURGE



OCCURRENCE

N/A

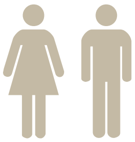
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: OECD, 2012

BASE DATA: Vorosmarty et al., 2010

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

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.

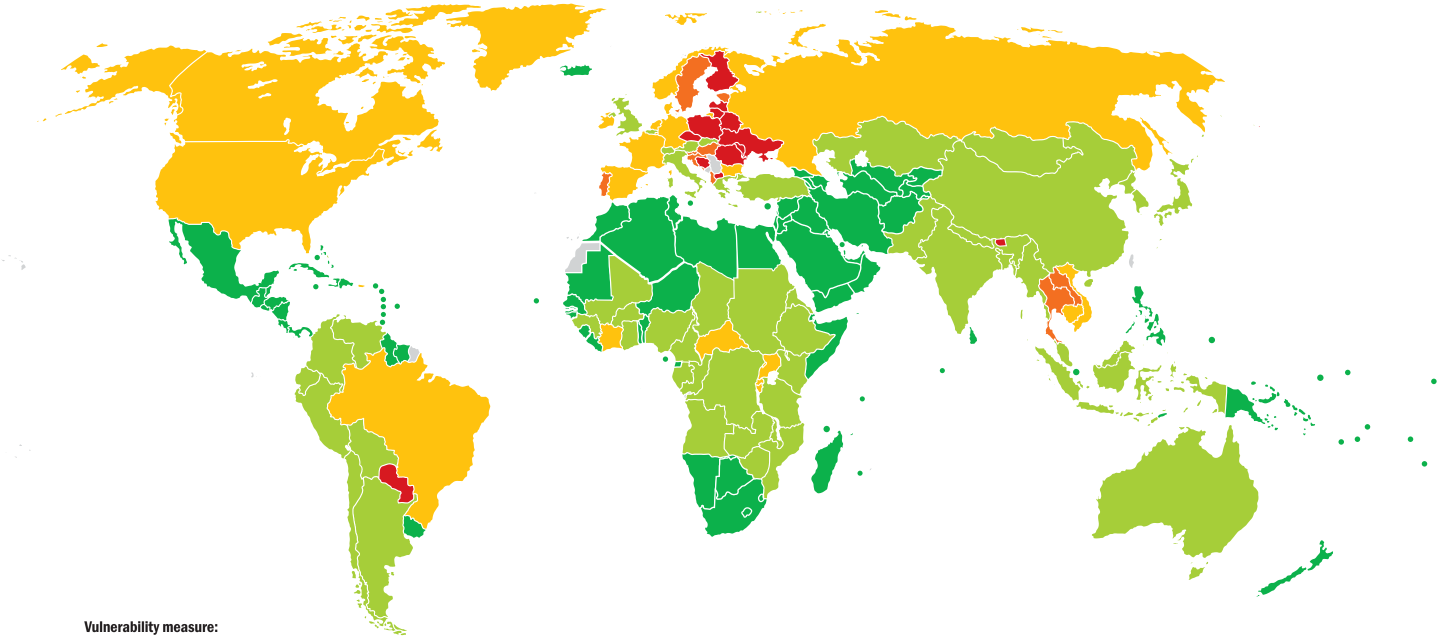
ESTIMATES COUNTRY-LEVEL IMPACT

	$		◎	
COUNTRY	2010	2030	2010	2030
ACUTE				
Belarus	300	1,250	7,500	10,000
Bhutan	1	5	45	60
Bosnia and Herzegovina	5	25	300	400
Czech Republic	90	250	2,250	2,000
Finland	50	65	1,750	1,500
Latvia	25	100	1,000	1,500
Lithuania	65	300	2,250	3,000
Macedonia	10	45	350	500
Moldova	10	40	1,250	1,750
Paraguay	5	30	500	700
Poland	200	650	6,500	5,750
Romania	75	350	3,500	5,000
Ukraine	100	600	7,250	10,000
SEVERE				
Albania	1	15	150	250
Croatia	10	60	450	650
Estonia	5	15	200	200
Hungary	35	100	1,250	1,000
Laos	1	15	250	350
Portugal	50	65	1750	1,500
Slovenia	10	25	250	200
Sweden	60	80	1,750	1,500
Thailand	85	450	4,750	6,750
HIGH				
Brazil	90	400	6,750	7,750
Bulgaria	5	20	150	200
Burundi		1	200	250
Cambodia	1	10	250	350
Canada	150	200	4,250	3,500
Central African Republic		1	150	200
Cote d'Ivoire	1	10	600	800
Denmark	30	35	1,000	900
France	150	200	4,750	4,250
Germany	350	450	10,000	8,750
Ireland	15	20	400	350
Luxembourg	5	5	65	55
Netherlands	40	50	950	850
Norway	15	20	450	400
Russia	100	500	4,500	5,250
Rwanda	1	1	200	250
Spain	90	100	2,750	2,500
Uganda	1	10	750	1,000
United States	1,500	2,250	30,000	25,000
Vietnam	20	150	2000	3000
MODERATE				
Angola	1	5	150	200
Argentina				1
Australia	10	10	250	200
Austria	15	15	300	250
Bangladesh	1	10	400	550
Belgium	10	10	250	200
Bolivia	1	5	55	75
Burkina Faso			5	10
Cameroon	1	5	200	300
Chad		1	30	40
Chile				
China	45	300	3,250	3,750
Colombia	1	5	70	100
Congo	1	1	80	100
DR Congo	1	5	1,000	1,500
Ecuador		1	10	15
Eritrea			10	15
Ethiopia		1	30	40
Gabon				1
Ghana	1	5	250	350
Greece	10	15	350	300
Guinea			25	35
India	30	150	3,250	3,750
Indonesia	1	5	250	250
Italy	1	1	80	70
Japan	10	10	300	250
Kazakhstan	1	5	55	75
Kenya			5	5
Malawi		1	80	100
Malaysia	1	15	95	150
Mali			5	5
Mongolia				
Mozambique			15	20
Myanmar	1	5	200	300
Nepal			10	15
Nigeria	1	1	90	100
North Korea		1	20	30
Pakistan	1	15	350	500
Peru	1	10	80	100
Slovakia	5	15	150	100
South Korea	30	150	650	850
Sudan/South Sudan	1	1	100	150
Switzerland	1	1	30	25
Tanzania	1	5	350	450
Turkey	5	5	150	250
United Kingdom	95	100	2,500	2,000
Venezuela	5	35	400	550
Zambia			20	30
Zimbabwe			10	10

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

	$		◎	
COUNTRY	2010	2030	2010	2030
LOW				
Afghanistan				
Algeria				
Antigua and Barbuda				
Armenia				
Azerbaijan				
Bahamas				
Bahrain				
Barbados				
Belize				
Benin				
Botswana				
Brunei				
Cape Verde				
Comoros				
Costa Rica				
Cuba				
Cyprus				
Djibouti				
Dominica				
Dominican Republic				
Egypt				
El Salvador				
Equatorial Guinea				
Fiji				
Gambia				
Georgia				
Grenada				
Guatemala				
Guinea-Bissau				
Guyana				
Haiti				
Honduras				
Iceland				
Iran				
Iraq				
Israel				
Jamaica				
Jordan				
Kiribati				
Kuwait				
Kyrgyzstan				
Lebanon				
Lesotho				
Liberia				
Libya				
Madagascar				
Maldives				
Malta				
Marshall Islands				
Mauritania				
Mauritius				
Mexico				
Micronesia				
Morocco				
Namibia				
New Zealand				
Nicaragua				
Niger				
Oman				
Palau				
Panama				
Papua New Guinea				
Philippines				
Qatar				
Saint Lucia				
Saint Vincent				
Samoa				
Sao Tome and Principe				
Saudi Arabia				
Senegal				
Seychelles				
Sierra Leone				
Singapore				
Solomon Islands				
Somalia				
South Africa				
Sri Lanka				
Suriname				
Swaziland				
Syria				
Tajikistan				
Timor-Leste				
Togo				
Tonga				
Trinidad and Tobago				
Tunisia				
Turkmenistan				
Tuvalu				
United Arab Emirates				
Uruguay				
Uzbekistan				
Vanuatu				
Yemen				

◎ Volume of water to treat (millions m^3) - yearly average

HEALTH IMPACT

COSTS
2010
172 BILLION
2030
630 BILLION

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

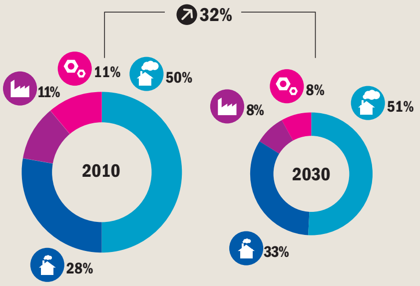
2010 EFFECT TODAY

DEATHS PER YEAR **1.4 MILLION**

2030 EFFECT TOMORROW

DEATHS PER YEAR **2.1 MILLION**

MORTALITY IMPACT



CONFIDENCE
ROBUST

SEVERITY ⚠ ⚠ ⚠ ⚠

AFFECTED

MDG EFFECT

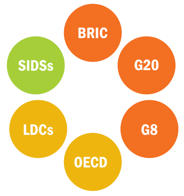
- Cities are home to over half the world's population and growing, all concentrated on only 2% of its surface area, producing 80% of all GHG emissions
- Where there are no strict emission controls, air contaminants from industry and transportation may become toxic and lethal
- Air pollution is a leading 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

RELATIVE IMPACT

HOTSPOTS

2010		2030
500	CHINA	800
200	INDIA	350
45	PAKISTAN	100
55	UNITED STATES	75
65	RUSSIA	70

GEOPOLITICAL VULNERABILITY



Deaths
Developing Country Low Emitters
Developing Country High Emitters
Developed
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 (PM2.5) per cubic meter of ambient air, or a 1–2% increase in mortality rates for several major diseases per 10μg/m3 more particulates (Pope et al., 2009; Zanobetti and Schwartz, 2009). Currently, the global average of fine particle pollution is 20μg/m3 (PM2.5). China's major industrial zones have the world's highest concentrations, at over 100μg (PM2.5). More than half the population of East Asia currently exceeds the World Health Organization's 35μg (PM2.5) uppermost safety limit (WHO, 2006). By comparison, recommended levels are below 10μg, 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).

BIGGER PICTURE

N/A

SURGE

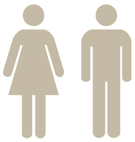
OCCURRENCE

N/A

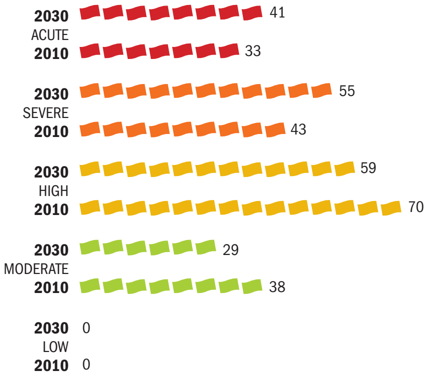
PEAK IMPACT

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Bell et al., 2007; OECD, 2012; Sheffield et al., 2011

BASE DATA: McMichael et al., 2004; WHO, 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).

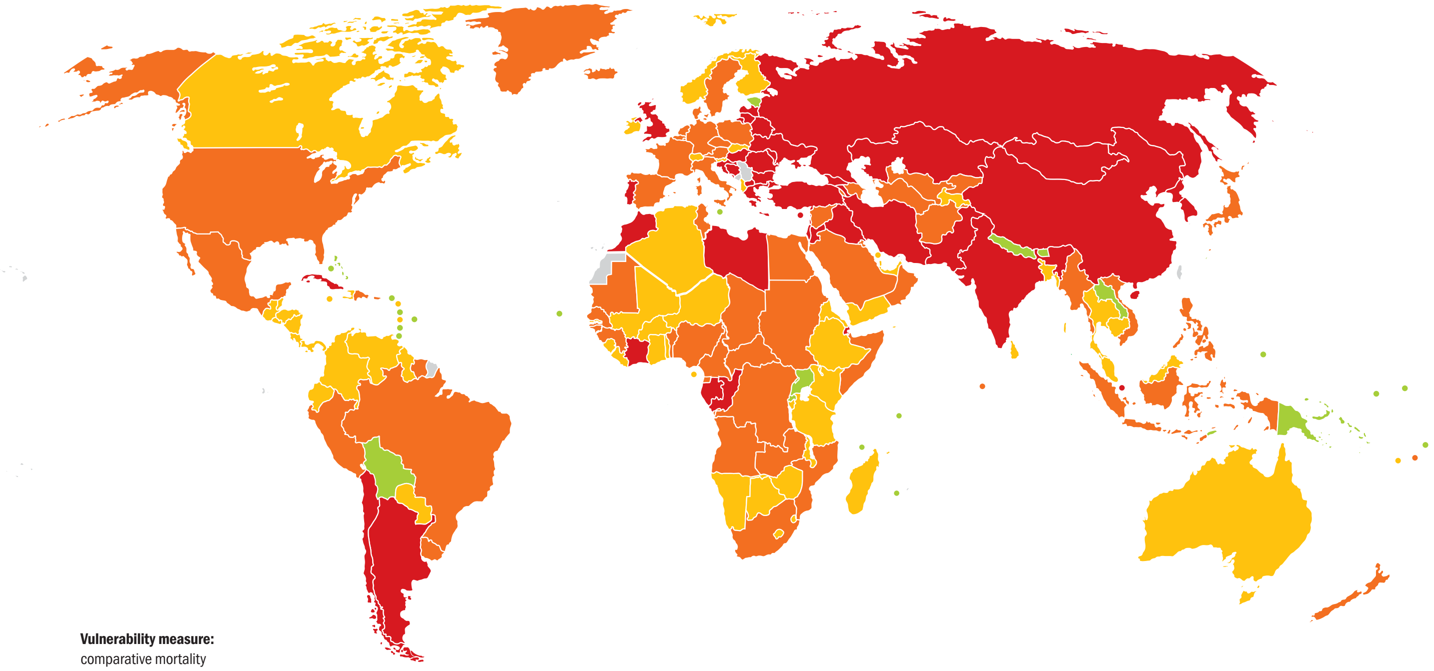
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Argentina	9,500	10,000	100,000	150,000
Armenia	2,000	2,000	20,000	30,000
Belarus	3,500	3,500	60,000	100,000
Bosnia and Herzegovina	2,000	2,000	20,000	30,000
Bulgaria	4,000	4,000	35,000	35,000
Chile	3,500	4,500	35,000	55,000
China	500,000	800,000	4,500,000	8,000,000
Congo	1,000	2,000	15,000	40,000
Cote d'Ivoire	3,500	5,500	60,000	150,000
Croatia	1,000	1,500	15,000	15,000
Cuba	3,000	3,500	30,000	45,000
Cyprus	300	350	5,000	8,500
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
North Korea	6,000	7,000	85,000	150,000
Pakistan	45,000	100,000	400,000	1,000,000
Portugal	3,000	3,000	40,000	50,000
Romania	7,500	8,000	70,000	80,000
Russia	65,000	70,000	900,000	1,000,000
Singapore	1,500	2,500	20,000	45,000
South Korea	10,000	15,000	300,000	600,000
Turkey	25,000	35,000	300,000	450,000
Ukraine	30,000	30,000	300,000	350,000
United Kingdom	15,000	15,000	200,000	350,000
SEVERE				
Afghanistan				

☠ Additional mortality - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

COUNTRY	☠ 2010	☠ 2030	🚹 2010	🚹 2030
HIGH				
Albania	250	350	9,500	20,000
Algeria	2,000	3,000	65,000	200,000
Australia	1,500	2,000	45,000	95,000
Bahrain	75	100	1,500	3,000
Bangladesh	9,500	20,000	200,000	700,000
Belize	15	15	200	400
Botswana	150	250	5,000	15,000
Brunei	15	35	500	1,500
Burkina Faso	1,000	2,000	20,000	60,000
Burundi	350	700	15,000	60,000
Cambodia	650	1,500	25,000	100,000
Canada	2,500	3,000	45,000	80,000
Colombia	5,000	7,000	55,000	90,000
Costa Rica	250	300	3,000	5,000
Dominica	5	10	150	350
Ecuador	850	1,000	9,500	15,000
El Salvador	450	600	8,500	20,000
Eritrea	250	500	7,000	25,000
Ethiopia	3,500	6,500	100,000	400,000
Finland	600	700	15,000	20,000
Gambia	150	250	3,500	10,000
Ghana	2,000	3,500	40,000	100,000
Guatemala	600	900	10,000	25,000
Guyana	85	80	1,500	2,000
Haiti	900	1,000	10,000	25,000
Honduras	600	900	15,000	30,000
Ireland	200	250	5,500	10,000
Jamaica	300	400	4,000	7,500
Kenya	2,000	3,000	40,000	100,000
Lesotho	150	200	5,500	20,000
Liberia	350	750	8,000	25,000
Madagascar	1,000	2,000	20,000	65,000
Malawi	1,000	2,000	20,000	60,000
Malaysia	2,000	4,500	35,000	100,000
Mali	800	1,500	15,000	45,000
Namibia	150	250	5,500	20,000
Nicaragua	300	450	4,000	10,000
Niger	650	1,500	10,000	35,000
Norway	500	600	15,000	25,000
Panama	200	250	3,000	5,000
Paraguay	300	500	4,500	9,000
Qatar	100	150	1,500	2,000
Saint Vincent	10	10	100	200
Sao Tome and Principe	15	30	350	1,000
Sierra Leone	550	950	8,500	25,000
Slovakia	500	550	6,000	7,500
Slovenia	200	250	3,000	4,000
Sri Lanka	900	2,000	65,000	250,000
Swaziland	50	80	5,000	20,000
Switzerland	850	950	15,000	25,000
Tajikistan	300	450	4,000	10,000
Tanzania	3,500	6,000	60,000	150,000
Thailand	4,500	8,000	75,000	250,000
Togo	450	800	15,000	45,000
United Arab Emirates	600	800	8,000	10,000
Vanuatu	10	15	250	700
Venezuela	3,000	4,500	35,000	55,000
Yemen	1,500	4,000	20,000	50,000
Zimbabwe	1,500	2,000	15,000	45,000
MODERATE				
Antigua and Barbuda				

🚹 Additional persons affected - yearly average

INDOOR SMOKE

ESTIMATES GLOBAL CARBON IMPACT

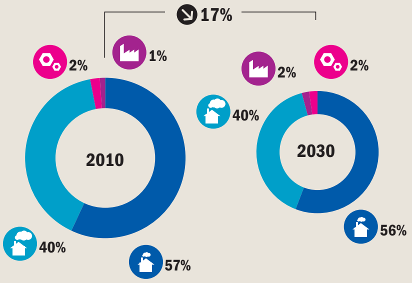
2010 EFFECT TODAY

DEATHS PER YEAR **3.1 MILLION**

2030 EFFECT TOMORROW

DEATHS PER YEAR **3.1 MILLION**

MORTALITY IMPACT



CONFIDENCE

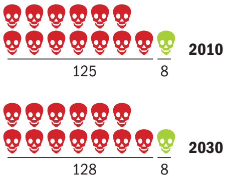
ROBUST

SEVERITY ⚠ ⚠ ⚠ ⚠

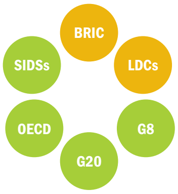
AFFECTED

MDG EFFECT

RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



- ➔ 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

HOTSPOTS

2010		2030
850,000	**CHINA**	850,000
750,000	**INDIA**	700,000
95,000	**INDONESIA**	150,000
100,000	**PAKISTAN**	150,000
150,000	**NIGERIA**	100,000

Deaths

Developing Country Low Emitters

Developing Country High Emitters

Developed

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.

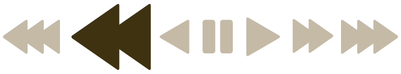
BIGGER PICTURE

N/A

PEAK IMPACT

N/A

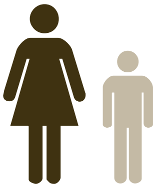
SURGE



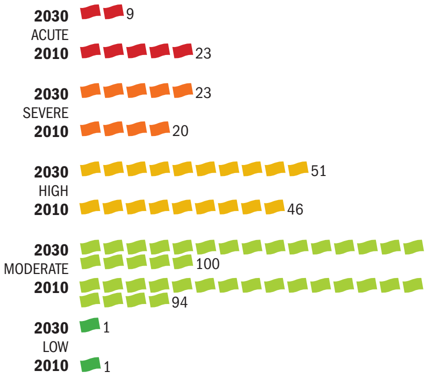
OCCURRENCE

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: OECD, 2012

BASE DATA: Fullerton et al., 2008; Mishra 1999; McMichael et al., 2004; WHO, 2009

▬ = 5 countries (rounded)

THE INDICATOR

The indicator measures the human health impact of smoke inhalation from the incomplete combustion of wood, coal and other biomass fuels burned for cooking or heating within buildings, above all in developing countries. The indicator estimates the direct effect this practice has on chronic respiratory disease (chronic obstructive pulmonary disease), lower respiratory illnesses, lung cancer, cardiovascular disease and tuberculosis (WHO, 2004; Fullerton et al., 2008; Mishra et al., 1999a). It also measures the indirect effect of increased mortality due to injuries from partial or complete visual impairment (blindness) resulting from extended smoke exposure (Mishra et al., 1999b; Lee et al., 2003). The indicator relies on the World Health Organization's latest update of the global disease burden database (WHO BDD, 2011) and relies on the Organization for Economic Co-operation and Development's analysis to estimate how indoor smoking mortality is likely to evolve through to 2030 (OECD, 2012).

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	80,000	100,000	4,500,000	6,000,000
Angola	35,000	35,000	3,000,000	3,000,000
Burundi	15,000	10,000	700,000	550,000
Cambodia	15,000	15,000	450,000	500,000
Mali	25,000	20,000	1,000,000	1,000,000
Niger	30,000	30,000	2,000,000	2,000,000
Rwanda	15,000	15,000	850,000	700,000
Sierra Leone	15,000	15,000	750,000	650,000
Somalia	15,000	15,000	750,000	750,000
SEVERE				
Bangladesh				

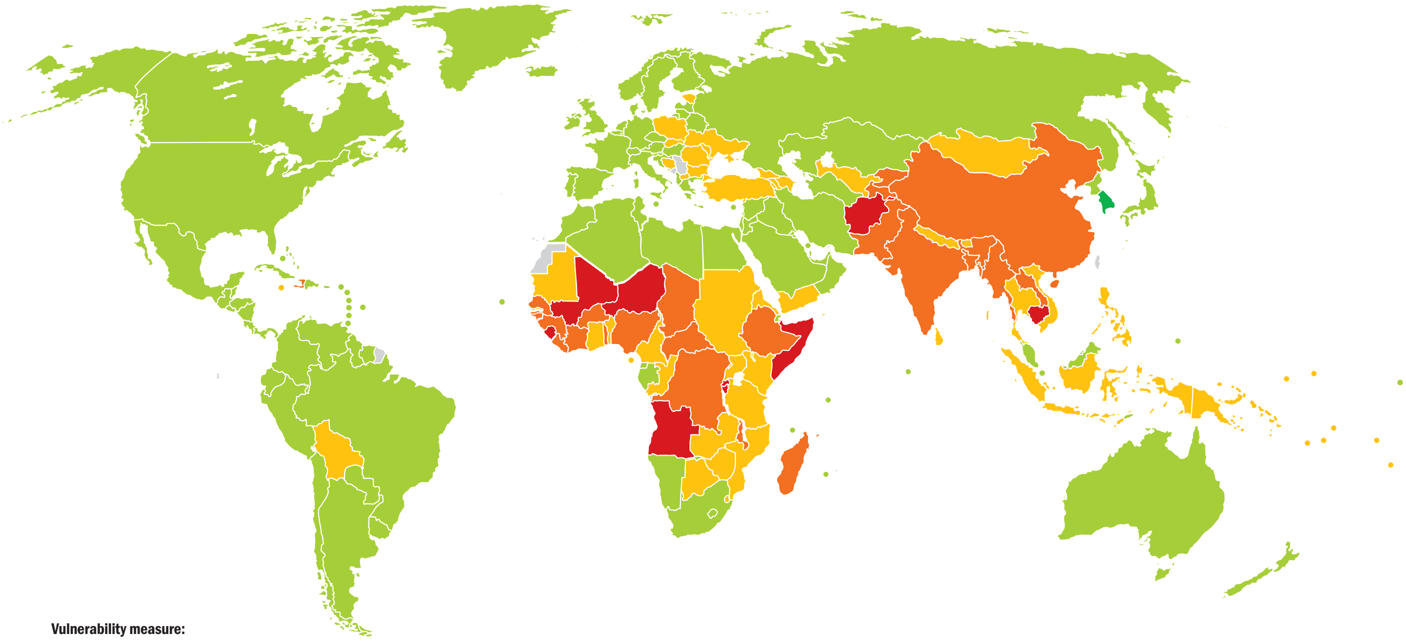
	☠		🧍	
COUNTRY	2010	2030	2010	2030
HIGH				
Armenia				

	☠		🧍	
COUNTRY	2010	2030	2010	2030

☠ Additional mortality - yearly average

CARBON VULNERABILITY

🟥 Acute 🟧 Severe 🟨 High 🟩 Moderate 🟩 Low



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

COUNTRY	2010	2030	2010	2030	COUNTRY	2010	2030	2010	2030	COUNTRY	2010	2030	2010	2030
MODERATE														
Albania														

Additional persons affected - yearly average

OCCUPATIONAL HAZARDS

ESTIMATES GLOBAL CARBON IMPACT

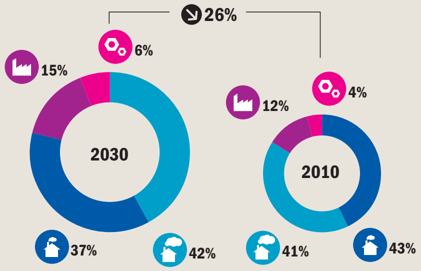
2010 EFFECT TODAY

DEATHS PER YEAR **55,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **80,000**

MORTALITY IMPACT



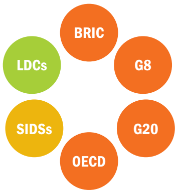
- A world economy relying on carbon-intensive forms of energy for 90% of its needs puts the health of millions of exposed workers at risk
- Hazardous professions range from coal miners facing elevated risks of stomach cancer to thermal power plant workers or truck drivers disproportionately exposed to 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

RELATIVE IMPACT

HOTSPOTS

2010	Deaths	2030
15,000	**INDIA**	25,000
15,000	**CHINA**	25,000
3,250	**UNITED STATES**	4,000
1,750	**INDONESIA**	3,250
1,000	**BANGLADESH**	2,000

GEOPOLITICAL VULNERABILITY



- Deaths
- Developing Country Low Emitters
- Developing Country High Emitters
- Developed
- 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 (Swean 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.

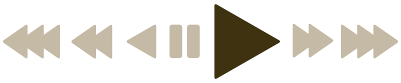
Effects are widespread globally in line with the comprehensive breadth of a carbon-intensive economy in all but the lowest-income low-emissions developing countries. Industrialized countries figure among those worst affected.

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

N/A

SURGE



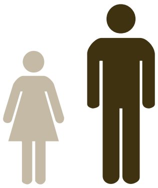
OCCURRENCE

N/A

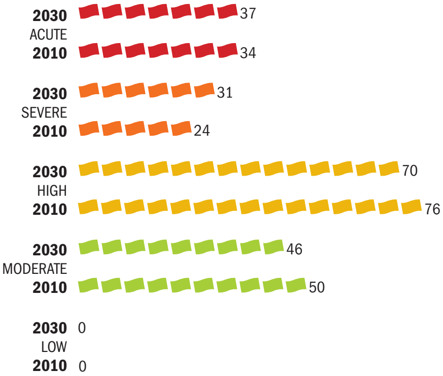
PEAK IMPACT

N/A

GENDER BIAS



VULNERABILITY SHIFT



▬ = 5 countries (rounded)

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.

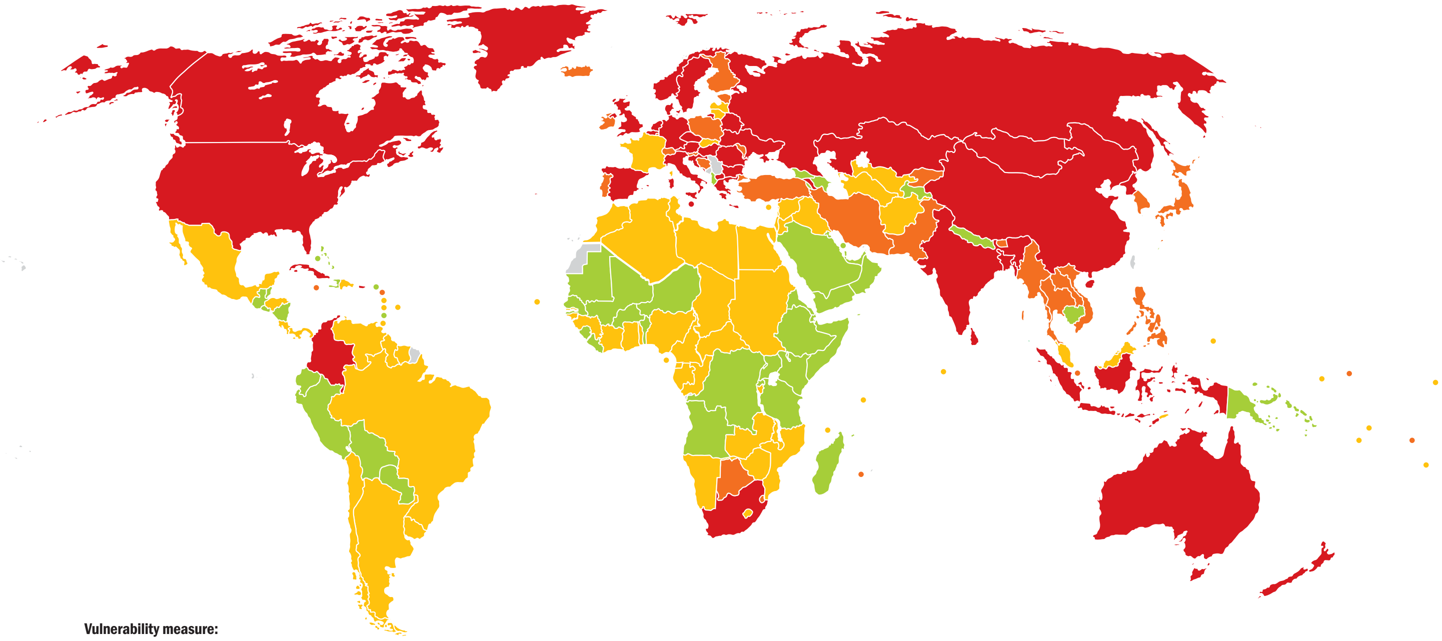
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🚹	
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
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
SEVERE				
Bhutan				
HIGH				
Afghanistan				

☠ Additional mortality - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

COUNTRY	☠ 2010	☠ 2030	🚹 2010	🚹 2030

COUNTRY	☠ 2010	☠ 2030	🚹 2010	🚹 2030
MODERATE				
Albania				

COUNTRY	☠ 2010	☠ 2030	🚹 2010	🚹 2030

🚹 Additional persons affected - yearly average

SKIN CANCER

ESTIMATES GLOBAL CARBON IMPACT

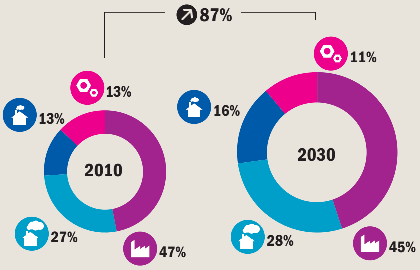
2010 EFFECT TODAY

DEATHS PER YEAR **20,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **45,000**

MORTALITY IMPACT

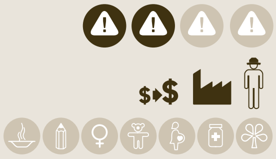


CONFIDENCE
ROBUST

SEVERITY

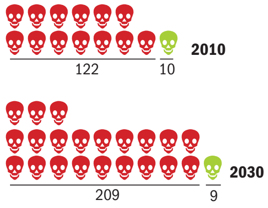
AFFECTED

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

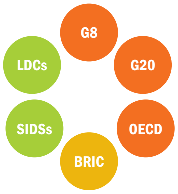
RELATIVE IMPACT



HOTSPOTS

2010		2030
3,500	**USA**	8,000
2,000	**CHINA**	4,250
850	**GERMANY**	1,750
800	**UNITED KINGDOM**	1,750
850	**RUSSIA**	1,500

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

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).

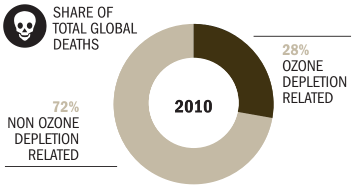
IMPACTS

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.

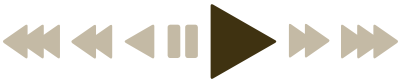
BIGGER PICTURE



PEAK IMPACT

N/A

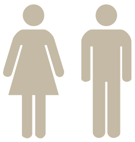
SURGE



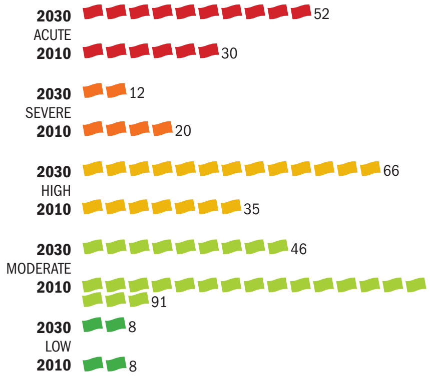
OCCURRENCE

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Martens, 1998; WHO IARC, 2005

BASE DATA: WHO, 2009

▬ = 5 countries (rounded)

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.

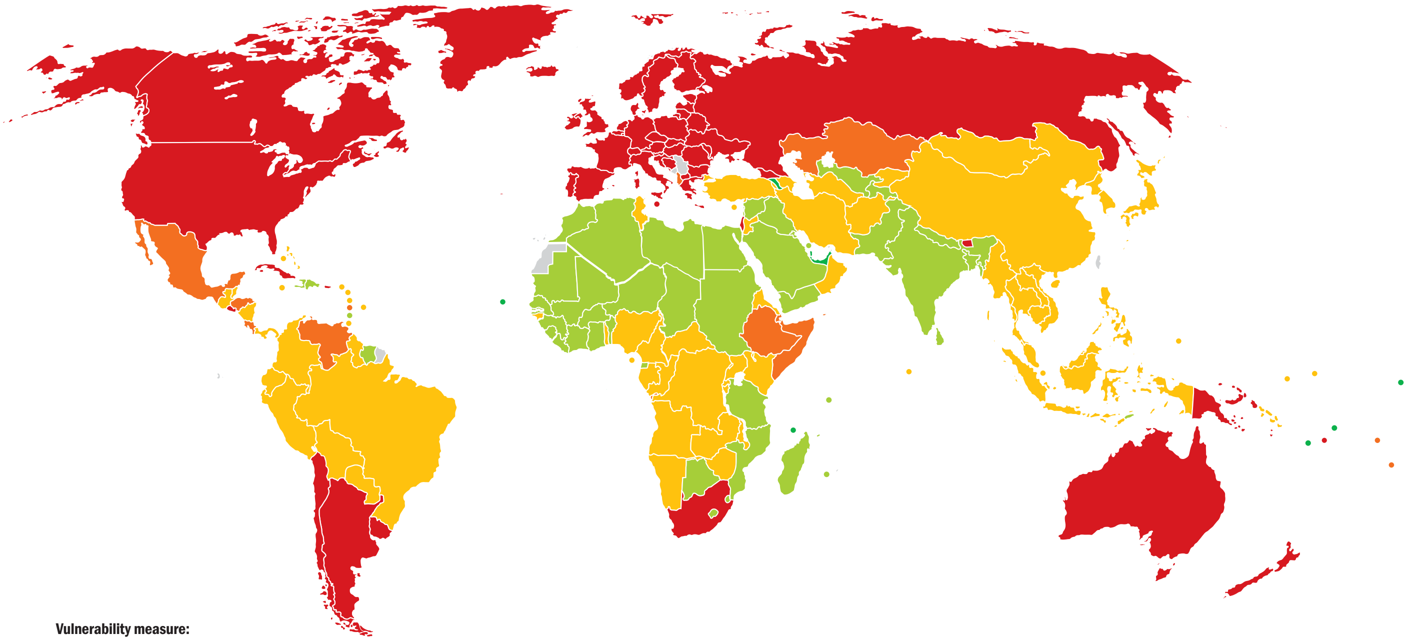
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Argentina	250	600	450	1,000
Australia	500	1,250	2,500	6,000
Austria	100	250	550	1,000
Belarus	70	150	100	250
Belgium	100	200	500	1,000
Bhutan	5	20	10	30
Bosnia and Herzegovina	30	60	50	100
Bulgaria	95	150	150	300
Canada	300	700	1,500	3,500
Chile	95	200	150	400
Croatia	70	150	150	250
Cuba	100	200	200	350
Czech Republic	150	250	250	500
Denmark	80	150	400	800
El Salvador	40	100	70	200
Estonia	20	35	35	60
Fiji	5	15	10	25
Finland	60	150	300	600
France	750	1,500	3,500	7,500
Georgia	30	50	50	90
Germany	850	1,750	4,250	8,250
Greece	100	200	500	1,000
Hungary	150	250	250	500
Iceland	5	10	15	40
Ireland	55	150	250	650
Israel	85	200	400	1,000
Italy	650	1,250	3,000	5,750
Latvia	35	65	60	100
Lebanon	50	100	90	200
Lithuania	30	65	60	100
Luxembourg	5	10	20	50
Macedonia	35	70	60	100
Malta	1	5	15	25
Moldova	35	70	55	100
Netherlands	250	500	1,000	2,250
New Zealand	100	250	550	1,250
Norway	100	200	450	1,000
Papua New Guinea	75	200	100	350
Poland	500	1,000	900	1,750
Portugal	100	250	550	1,000
Romania	200	400	350	700
Russia	850	1,500	1,500	3,000
Slovakia	55	100	100	200
Slovenia	35	70	150	350
South Africa	350	650	650	1,250
Spain	400	750	2,000	3,750
Sweden	150	350	800	1,500
Switzerland	100	200	550	1,000
Ukraine	300	600	550	1,000
United Kingdom	800	1,750	3,750	8,000
United States	3,500	8,000	15,000	40,000
Uruguay	25	60	50	100
SEVERE				
Albania				
HIGH				
Afghanistan				

☠ Additional mortality - yearly average

CARBON VULNERABILITY

🟥 Acute 🟧 Severe 🟨 High 🟩 Moderate 🟩 Low



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

COUNTRY	2010	2030	2010	2030

COUNTRY	2010	2030	2010	2030
MODERATE				
Algeria				

COUNTRY	2010	2030	2010	2030
LOW				
Armenia				

Additional persons affected - yearly average

INDUSTRY STRESS

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

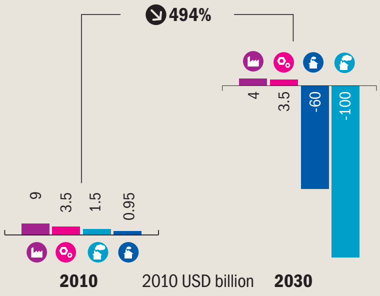
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **15 BILLION**

2030 EFFECT TOMORROW

$ USD **GAIN** PER YEAR **150 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

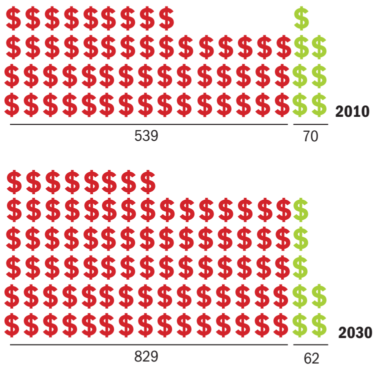
SEVERITY ⚠ ⚠

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

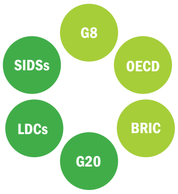
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
6,750	**USA**	8,000
1,500	**RUSSIA**	4,750
350	**SYRIA**	2,500
200	**IRAN**	1,250
650	**CANADA**	1,250

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)

Developing Country Low Emitters

Developed

Developing Country High Emitters

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)

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, instance, acid rain, formed in particular from sulphur and nitrogen emissions, increases the acidity of soils with limited natural capacity to neutralize acidity loads; it is also toxic for plants, impairing productivity (World Bank, 2005; Wang et al., 2009; Ping et al., 2011). Third, 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).

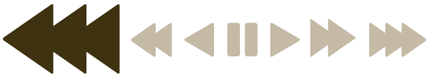
IMPACTS

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

N/A

SURGE



OCCURRENCE

N/A

VULNERABILITY SHIFT

PEAK IMPACT

N/A

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

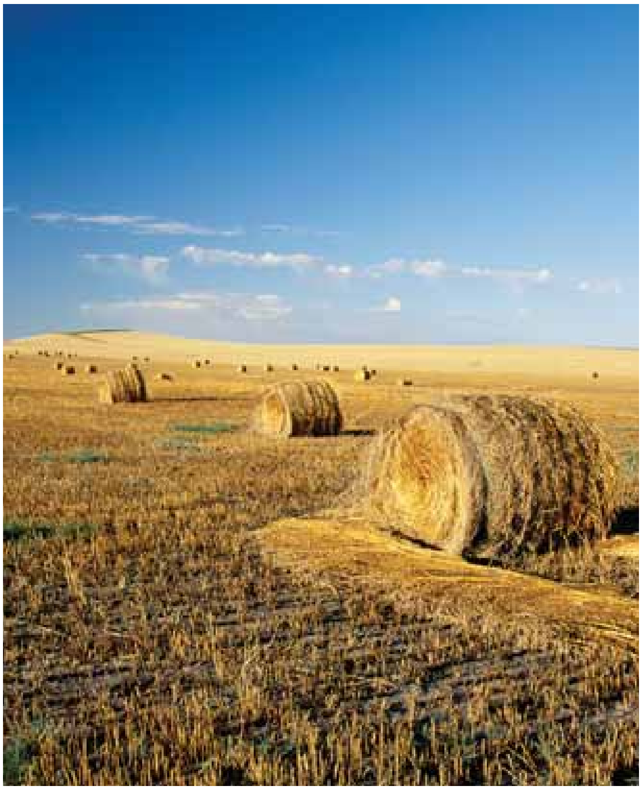
▬ = 5 countries (rounded)

🔴 Acute 🟠 Severe 🟡 High 🟢 Moderate 🟢 Low 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 CO^2 fertilization than presented here (Ainsworth et al., 2008; Leaky et al., 2009).

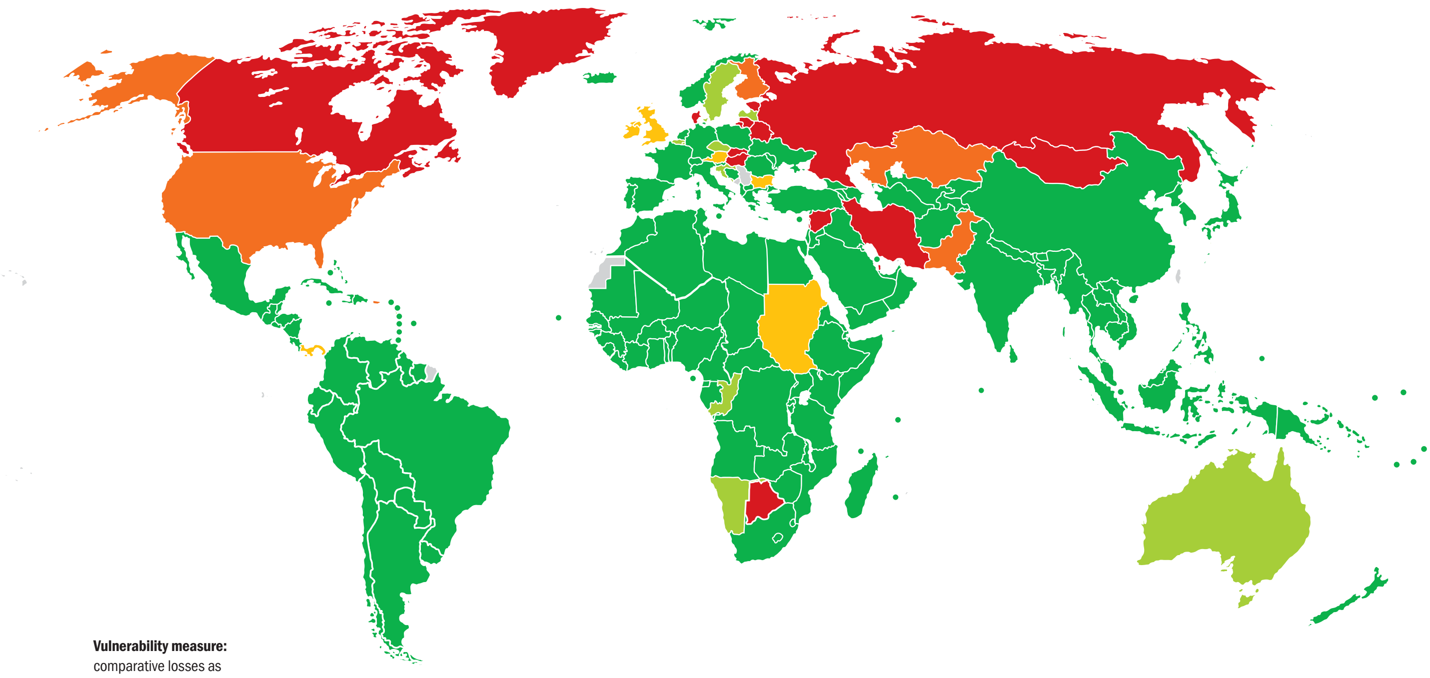
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030
ACUTE		
Belarus	200	750
Botswana	15	90
Canada	650	1,000
Denmark	150	250
Estonia	40	250
Hungary	300	1,000
Iran	200	1,500
Lithuania	15	100
Mongolia	5	60
Qatar	40	300
Russia	1,500	5,000
Slovakia	95	400
Syria	350	2,500
SEVERE		
Finland	45	80
Kazakhstan	150	300
Pakistan	250	700
United States	6,500	8,000
HIGH		
Austria	75	100
Bulgaria	150	90
Ireland	25	30
Panama	10	20
Sudan/South Sudan	5	40
United Kingdom	450	850
MODERATE		
Australia	80	85
Belgium	100	40
Congo	1	1
Croatia	40	1
Czech Republic	100	65
Latvia	10	5
Namibia	1	
Sweden	35	30
LOW		
Afghanistan	-10	-350
Albania	15	-100
Algeria	-1	-750
Angola	-25	-750
Antigua and Barbuda	-1	-20
Argentina	-25	-4,500
Armenia	-1	-90
Azerbaijan	20	-90
Bahamas	-1	-85
Bahrain	-1	-75
Bangladesh	-85	-3,500
Barbados		
Belize		-15
Benin	-10	-250
Bhutan	-1	-55
Bolivia	1	-150
Bosnia and Herzegovina	10	-95
Brazil	250	-3,000
Brunei	-5	-250
Burkina Faso	-10	-250
Burundi	-5	-100
Cambodia	-10	-700
Cameroon	-40	-1,000
Cape Verde	-1	-15
Central African Republic	-1	-35
Chad	-5	-200
Chile	10	-400
China	1,500	-80,000
Colombia	-1	-700
Comoros		-1
Costa Rica	-10	-400
Cote d'Ivoire	-35	-800
Cuba	-10	-650
Cyprus		
Djibouti	-1	-55
Dominica		-10
Dominican Republic	-5	-250
DR Congo	-20	-450
Ecuador	-10	-550
Egypt	150	-2,000
El Salvador	-5	-200
Equatorial Guinea		-5
Eritrea	-1	-20
Ethiopia	-40	-1,500
Fiji	-1	
France	250	-950
Gabon	-5	-250
Gambia	-1	-40
Georgia	1	-75
Germany	250	-100
Ghana	-65	-1,500
Greece	-55	-400
Grenada	-1	-10
Guatemala	-10	-350
Guinea	-10	-250
Guinea-Bissau	-1	-50
Guyana	1	-10
Haiti	-1	-80
Honduras	-5	-300
Iceland		-1

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

$

COUNTRY	2010	2030
India	1,500	-20,000
Indonesia	-200	-7,000
Iraq		-150
Israel	40	-150
Italy	150	-900
Jamaica	-10	-200
Japan	-200	-3,000
Jordan		-55
Kenya	-45	-1,000
Kiribati		-10
Kuwait	-10	-300
Kyrgyzstan	-5	-250
Laos	-10	-550
Lebanon	10	-40
Lesotho		-15
Liberia	-1	-40
Libya	-5	-500
Luxembourg		-1
Macedonia	30	-55
Madagascar	-15	-400
Malawi	-20	-450
Malaysia	-35	-2,000
Maldives	-1	-10
Mali	-15	-400
Malta	-1	-5
Marshall Islands		-5
Mauritania	-5	-100
Mauritius	-5	-50
Mexico	75	-2,000
Micronesia		-15
Moldova	-5	-150
Morocco	-15	-900

$

COUNTRY	2010	2030
Mozambique	-15	-450
Myanmar	-10	-550
Nepal	-30	-900
Netherlands	65	-60
New Zealand	-5	-85
Nicaragua	-1	-100
Niger	-5	-150
Nigeria	-400	-10,000
North Korea	5	-55
Norway	1	-20
Oman	-5	-200
Palau		-5
Papua New Guinea	-5	-200
Paraguay	5	-200
Peru		-500
Philippines	-30	-2,000
Poland	400	-150
Portugal	55	-50
Romania	50	-1,000
Rwanda	-10	-250
Saint Lucia	-1	-15
Saint Vincent		-10
Samoa	-1	-15
Sao Tome and Principe		-5
Saudi Arabia	-10	-450
Senegal	-10	-400
Seychelles	-1	-5
Sierra Leone	-5	-80
Singapore	-20	-550
Slovenia	5	-15
Solomon Islands	-1	-30
Somalia	-5	-200

$

COUNTRY	2010	2030
South Africa	40	-300
South Korea	-95	-5,000
Spain	250	-1,000
Sri Lanka	-15	-550
Suriname		-15
Swaziland		-20
Switzerland	10	-50
Tajikistan	-1	-250
Tanzania	-40	-1,500
Thailand	-15	-4,500
Timor-Leste		-35
Togo	-5	-150
Tonga	-1	-10
Trinidad and Tobago	-5	-200
Tunisia	25	-250
Turkey	550	-1,000
Turkmenistan	-45	-1,000
Tuvalu		-1
Uganda	-25	-850
Ukraine	250	-1,500
United Arab Emirates	-15	-600
Uruguay	10	-20
Uzbekistan	-45	-1,500
Vanuatu	-1	-25
Venezuela	-10	-600
Vietnam	-100	-5,000
Yemen	-10	-350
Zambia	-5	-200
Zimbabwe	1	-25

FISHERIES

ESTIMATES GLOBAL CARBON IMPACT

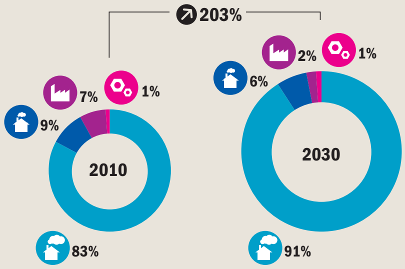
2010 EFFECT TODAY

USD **LOSS** PER YEAR **10 BILLION**

2030 EFFECT TOMORROW

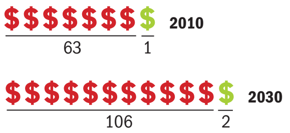
USD **LOSS** PER YEAR **75 BILLION**

ECONOMIC IMPACT



- 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

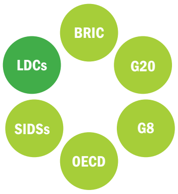
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
6,500	**CHINA**	65,000
500	**VIETNAM**	3,250
250	**SOUTH KOREA**	2,000
200	**THAILAND**	1,000
200	**INDONESIA**	800

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

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

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

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.

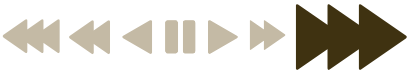
IMPACTS

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

N/A

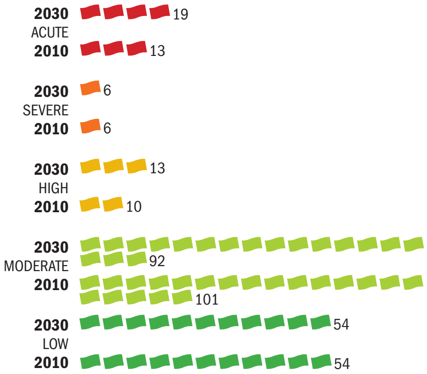
SURGE



OCCURRENCE

N/A

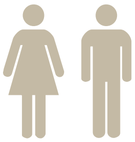
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: IGBP-DIS SoilData(V.0), 2008; OECD,2012

BASE DATA: FAO FISHSTAT (2012); FAOSTAT (2012); Rubin et al., 1992

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

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.

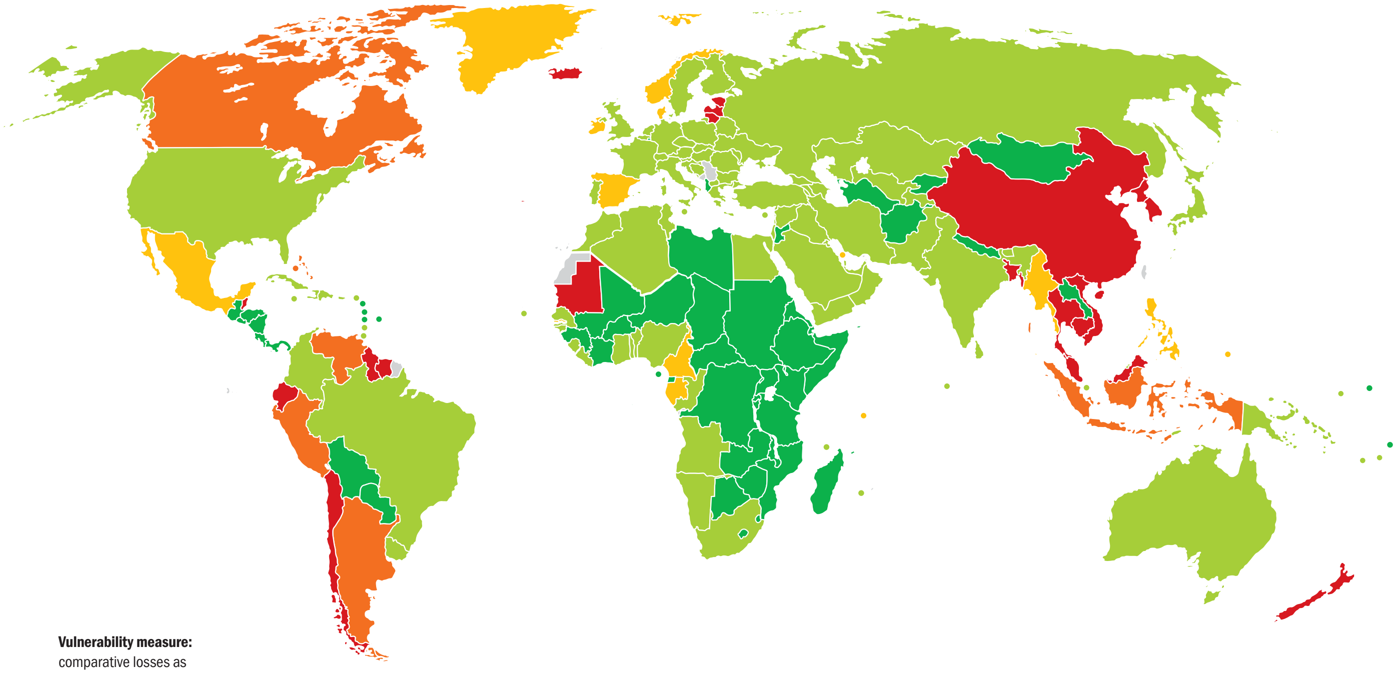
ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Bangladesh	65	300
Belize		1
Cambodia	10	50
Chile	80	600
China	6,500	65,000
Ecuador	45	350
Estonia	35	250
Guyana	5	45
Iceland	1	10
Latvia	5	35
Lithuania	10	75
Malaysia	80	500
Mauritania	1	15
New Zealand	20	60
North Korea	10	100
South Korea	250	2,000
Suriname	1	15
Thailand	200	1,000
Vietnam	500	3,250
SEVERE		
Argentina	60	450
Bahamas	1	5
Canada	150	400
Indonesia	200	800
Peru	20	150
Venezuela	25	200
HIGH		
Bahrain	1	10
Cameroon	1	10
Denmark	10	25
Gabon	1	5
Gambia		1
Ireland	10	30
Mexico	45	350
Myanmar	1	15
Norway	15	40
Palau		
Philippines	40	150
Seychelles		1
Spain	35	100
MODERATE		
Algeria		1
Angola	1	1
Antigua and Barbuda		
Armenia		
Australia	10	30
Austria		
Azerbaijan		
Belarus		
Belgium		1
Benin		1
Bhutan		
Bosnia and Herzegovina		
Brazil	5	30
Brunei		1
Bulgaria	1	10
Cape Verde		
Colombia		1
Comoros		
Congo		1
Croatia	1	5
Cuba	1	5
Cyprus		
Czech Republic		
Dominican Republic		1
Egypt	1	5
Fiji		
Finland		
France	35	100
Georgia		
Germany	5	15
Ghana		1
Greece	5	15
Grenada		
Guinea-Bissau		
Haiti		
Hungary	1	1
India	150	550
Iran	5	15
Iraq		
Israel		1
Italy	20	60
Jamaica		
Japan	65	200
Kazakhstan		
Kuwait	1	5
Lebanon		
Liberia		
Macedonia		
Maldives		
Malta		
Mauritius		
Micronesia		
Moldova		
Morocco	1	5

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

🟥 Acute 🟧 Severe 🟨 High 🟩 Moderate 🟩 Low



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

COUNTRY	2010	2030
Namibia		1
Netherlands	10	35
Nigeria	5	20
Oman		1
Pakistan	1	1
Papua New Guinea		
Poland	1	10
Portugal	1	5
Qatar		1
Romania		
Russia		
Saudi Arabia	5	45
Senegal		1
Sierra Leone		1
Singapore	1	10
Slovakia		
Slovenia		1
Solomon Islands		
South Africa		1
Sri Lanka	1	10
Sweden	1	1
Switzerland		
Syria	1	5
Tajikistan		
Timor-Leste		
Togo		
Tonga		
Trinidad and Tobago		1
Tunisia	1	5
Turkey	5	15
Ukraine	1	10
United Arab Emirates		1

COUNTRY	2010	2030
United Kingdom	25	75
United States	250	700
Uruguay	1	10
Uzbekistan		
Vanuatu		
Yemen		
LOW		
Afghanistan		
Albania		
Barbados		
Bolivia		
Botswana		
Burkina Faso		
Burundi		
Central African Republic		
Chad		
Costa Rica		
Cote d,Ivoire		
Djibouti		
Dominica		
DR Congo		
El Salvador		
Equatorial Guinea		
Eritrea		
Ethiopia		
Guatemala		
Guinea		
Honduras		
Jordan		
Kenya		
Kiribati		
Kyrgyzstan		

COUNTRY	2010	2030
Laos		
Lesotho		
Libya		
Luxembourg		
Madagascar		
Malawi		
Mali		
Marshall Islands		
Mongolia		
Mozambique		
Nepal		
Nicaragua		
Niger		
Panama		
Paraguay		
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Somalia		
Sudan/South Sudan		
Swaziland		
Tanzania		
Turkmenistan		
Tuvalu		
Uganda		
Zambia		
Zimbabwe		

FORESTRY

ESTIMATES GLOBAL CARBON IMPACT

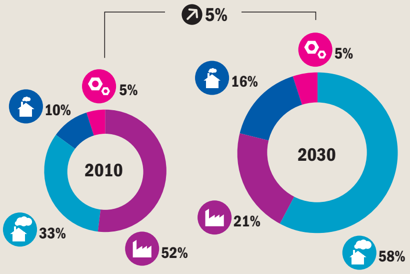
2010 EFFECT TODAY

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

2030 EFFECT TOMORROW

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

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

SEVERITY ⚠ ⚠ ⚠ ⚠

AFFECTED

MDG EFFECT

- 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

RELATIVE IMPACT

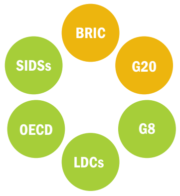
$$$$$$$$$$$$$ $ **2010**
127 6

$$$$$$$
$$$$$$$$$$$$$ $ **2030**
193 6

HOTSPOTS

2010	$	2030
3,500	**CHINA**	20,000
10,000	**USA**	15,000
900	**MALAYSIA**	5,000
1,500	**MEXICO**	4,750
1,000	**INDIA**	4,500

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 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 O_3 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 CO_2 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

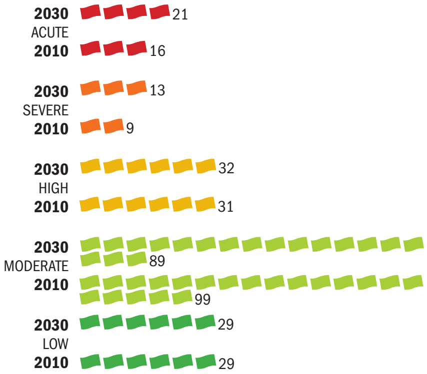
N/A

SURGE

OCCURRENCE

N/A

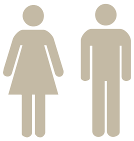
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Costanza et al., 1997; OECD, 2012; Reilly, 2008; Wentzel, 1982

BASE DATA: FAOSTAT (2012); Reilly, 2008

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

THE INDICATOR

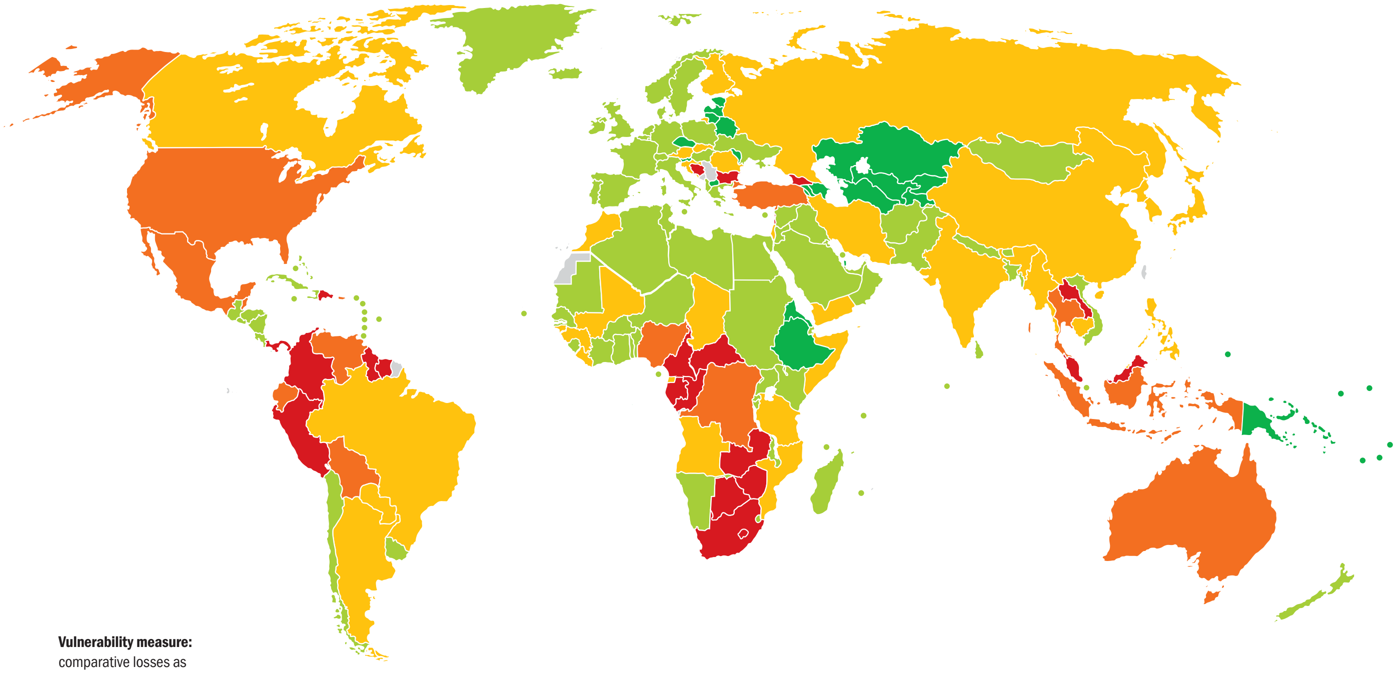
The indicator measures the impact of air pollution on the forestry sector focusing in particular on the extent to which ground-level ozone (O3) and acid rain affect forest productivity. It relies on an ecosystem valuation approach to translate losses into GDP (Reilly et al., 2007; Wentzel, 1982; Costanza 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	2010	2030
ACUTE		
Bosnia and Herzegovina	45	100
Botswana	90	400
Bulgaria	150	450
Cameroon	50	250
Central African Republic	1	10
Colombia	450	2,500
Congo	70	300
Dominican Republic	150	750
Gabon	30	200
Georgia	45	100
Guyana	5	35
Laos	10	100
Lebanon	70	350
Lesotho	5	20
Malaysia	900	5,000
Panama	200	1,000
Peru	250	1,250
South Africa	500	2,000
Suriname	5	25
Zambia	50	250
Zimbabwe	10	45
SEVERE		
Australia	750	800
Belize	1	5
Bolivia	15	100
DR Congo	5	40
Ecuador	55	300
Indonesia	550	2,750
Mexico	1,500	4,750
Nigeria	150	750
Thailand	350	2,000
Timor-Leste	1	10
Turkey	500	1,000
United States	10,000	15,000
Venezuela	200	1,000
HIGH		
Angola	25	150
Argentina	250	1,250
Austria	150	200
Brazil	650	3,250
Brunei	5	25
Cambodia	5	70
Canada	350	500
Chad	1	15
China	3,500	20,000
Croatia	35	95
Equatorial Guinea	5	35
Finland	35	70
Guinea	1	5
Guinea-Bissau		1
India	1,000	4,500
Iran	200	1,000
Israel	70	200
Japan	950	1,000
Liberia		1
Mali	1	10
Morocco	30	150
Mozambique	5	35
Myanmar	10	75
Paraguay	5	25
Philippines	65	350
Romania	60	150
Russia	450	1,750
Slovakia	45	100
Somalia	1	5
South Korea	200	1,000
Tanzania	10	50
Yemen	10	50
MODERATE		
Afghanistan		
Albania		1
Algeria	20	100
Antigua and Barbuda		
Bahamas	1	5
Bahrain		
Bangladesh	10	55
Barbados		
Belgium		1
Benin	1	5
Bhutan		1
Burkina Faso	1	5
Burundi		
Cape Verde		
Chile	5	40
Comoros		
Costa Rica	1	10
Cote d,Ivoire	1	10
Cuba	1	10
Cyprus		
Denmark		1
Djibouti		
Dominica		1
Egypt		
El Salvador		1
France	250	300

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY



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

$

COUNTRY	2010	2030
Gambia		1
Germany	550	650
Ghana	1	15
Greece	35	40
Grenada		
Guatemala	1	10
Haiti		
Honduras	1	20
Hungary	1	5
Iceland		
Iraq	10	40
Ireland		1
Italy	200	250
Jamaica		1
Jordan		
Kenya	1	5
Kuwait		
Libya		
Luxembourg		1
Madagascar	1	10
Malawi	1	1
Maldives		
Malta		
Mauritania		1
Mauritius		
Mongolia	1	5
Namibia		1
Nepal		1
Netherlands	60	70
New Zealand	1	5
Nicaragua	1	10
Niger		1

$

COUNTRY	2010	2030
North Korea		1
Norway	10	25
Oman		
Pakistan	10	65
Poland	150	350
Portugal	1	5
Rwanda		
Saint Lucia		
Saint Vincent		
Sao Tome and Principe		
Saudi Arabia		1
Senegal	1	10
Seychelles		1
Sierra Leone		1
Singapore		
Spain	250	300
Sri Lanka		1
Sudan/South Sudan	1	10
Swaziland		
Sweden	40	90
Switzerland	40	50
Syria		
Togo		1
Trinidad and Tobago		1
Tunisia		1
Uganda	1	5
Ukraine	45	100
United Arab Emirates		
United Kingdom	1	5
Uruguay		1
Vietnam	25	200

$

COUNTRY	2010	2030
LOW		
Armenia		
Azerbaijan		
Belarus		
Czech Republic		
Eritrea		
Estonia		
Ethiopia		
Fiji		
Kazakhstan		
Kiribati		
Kyrgyzstan		
Latvia		
Lithuania		
Macedonia		
Marshall Islands		
Micronesia		
Moldova		
Palau		
Papua New Guinea		
Qatar		
Samoa		
Slovenia		
Solomon Islands		
Tajikistan		
Tonga		
Turkmenistan		
Tuvalu		
Uzbekistan		
Vanuatu		