HYDRO ENERGY

ESTIMATES GLOBAL CLIMATE IMPACT

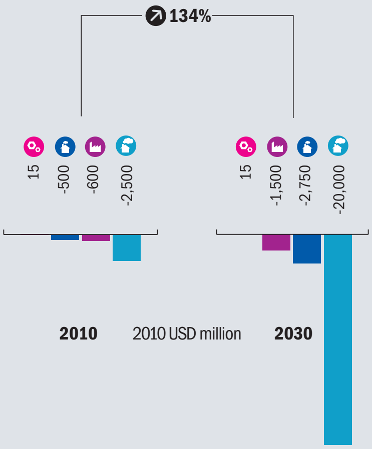
2010 EFFECT TODAY

USD **GAIN** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

USD **GAIN** PER YEAR **25 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

SEVERITY

AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

- The world will benefit from increasing hydro energy wealth as climate change brings more rain to many places
- Some regions will be heavily affected by localized reductions in rainfall and a corresponding loss of energy potential for existing hydropower installations
- Additional hydro energy capacity can already be foreseen in zones where there is high certainty of more useable rainfall, especially in high latitudes
- The negative effects of hydro energy can be offset by measures such as expanding reservoirs to increase water holding capacity in affected zones, and through a forward-looking diversification of energy supply

RELATIVE IMPACT

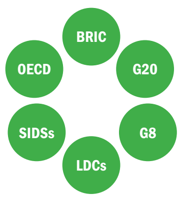
$$$$$$ $ 2010
54 2

$$$$$$$$ $ 2030
72 3

HOTSPOTS

2010		2030
150	**UKRAINE**	800
30	**ROMANIA**	250
85	**TURKEY**	250
25	**IRAN**	150
35	**ITALY**	100

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)

Vulnerability of hydropower to climate effects can be high: in Brazil in 2001, intense drought was a key contributor to a "virtual breakdown" of power generation from hydro sources, a dominant energy supply for the country (IPCC, 2012b). Such extreme hydrological events are becoming more common (IPCC, 2007; Hansen et al., 2012). According to the assessment made here, however, fewer than 20 countries would be negatively affected to any significant degree, and many more could benefit. This is because water availability is increasing in many areas of the world as a result of climate change (Bates et al., 2008).

New opportunities will arise over the next 30 years as precipitation increases global hydro energy capacity, and when access to this established clean energy technology will be most needed. Where reductions do occur, they may be severe: a study of nearly 6,000 European hydro stations concluded that 25% reductions in power generation could become a reality for the southern and Mediterranean areas (Lehner et al., 2005). Where the effects are likely to be negative, economies should plan for a diversification to other energy sources, and mitigate the effects of rainfall loss through measures such as reservoir expansion. The intrinsic uncertainty of rainfall will make planning for these large-scale and capital-intensive energy systems difficult (IPCC, 2012b).

CLIMATE MECHANISM

The hydro energy sector has recognized sensitivities to climate change. This is because climate change alters the water cycle of the planet, notably accelerating it and increasing the amount of available rainfall, water, and river flow (Huntington, 2006; Stromberg et al., 2010). However, many countries will not experience an improvement in water availability, but will see declines, as water replenishments fail to keep pace with rising heat (Chu et al., 2009). In the long term, melting glaciers may further increase water scarcity, but in the coming years it is likely to increase water flows (Olefs et al., 2009). All these factors can have an impact on the power generation capacity of hydro energy installations (Lehner et al., 2001; Pereira de Lucena et al., 2009; Hamududu and Killingtveit, 2012). Globally, major rivers are expected to increase in flow or decline depending on local and regional climate conditions—although these are uncertain for many areas (Nohara et al., 2006). Evidence tends to favour an increase in rainfall (or runoff) in the far north and south, and a decrease in tropical regions (Helm et al., 2010).

IMPACTS

Given the still relatively small scale of hydro power installations in the global energy mix—although it is still by far the largest source of renewable energy—the positive effect worldwide is small at around 4 billion dollars in 2010 (US EIA, 2011).

Losses by comparison are estimated at around 0.5 billion dollars.

The worst affected zones are Southern Europe and Central America, while the largest total gains include China, Canada, and the US, subject of course to different degrees of uncertainty linked to rainfall projections to 2030.

Between 2010 and 2030 the estimated effect more than doubles as a proportion of GDP, with around 25 billion dollars in yearly gains by 2030.

The number of worst affected countries has more than doubled, and there is a significant increase in gains among the many countries that are projected to benefit.

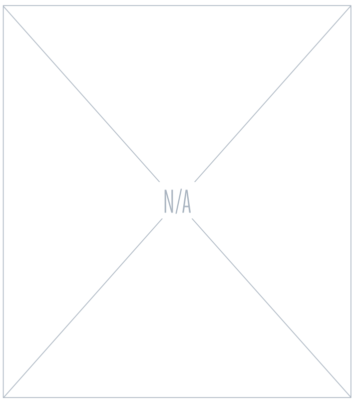
THE BROADER CONTEXT

The hydro energy sector has undergone continued expansion in recent decades—although not as rapidly as renewable energy technologies—and is expected to continue to grow as a source of power generation (US EIA, 2011; BP, 2012). Given the large-scale up-front capital investment involved and the long-term shelf life of installations, careful consideration should be given to new investments, particularly since several episodes of decline in water-fed energy supply have already been observed in different areas (IPCC, 2012b). Significant opportunities to support an expansion of hydro energy are emerging in some areas, especially high-latitude regions where there is much greater certainty of increasing rainfall over the next 20 years and beyond (Bates et al., 2008; Helm et al., 2010).

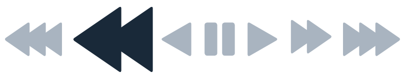
VULNERABILITIES AND WIDER OUTCOMES

Watershed or water catchment capacity in reservoirs is a key contributor to resilience of hydro power installations, since these can stock water during

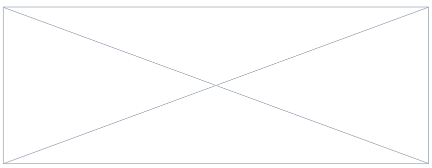
BIGGER PICTURE



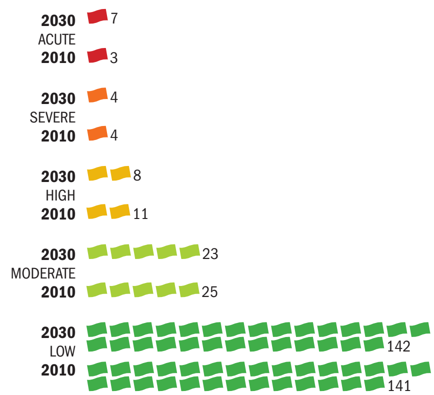
SURGE



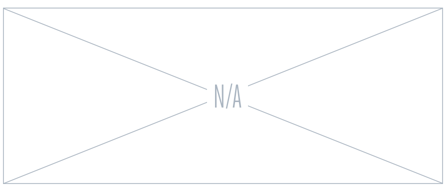
OCCURRENCE



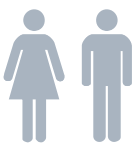
VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



INDICATOR INFORMATION

MODEL: Lehner, 2003; Nohara, 2006

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: IEA, 2011; Lehner, 2001

= 5 countries (rounded)

Acute Severe High Moderate Low

extended periods of drought, and retain water deposited at inconvenient times of the year and saved for later use (IPCC, 2012b). Hydro installations that are powered only by river flow and not through a reservoir are particularly exposed to diminished rainfall and water runoff, as was pointed out in the Vietnam country study in this report. Whether environmental management is poor or sound may also play a role: for example, Costa Rica, one of the countries worst hit, has begun to reverse its deforestation process, which is expected to result in improved watershed capacity, although only high altitude or mature forests are understood to add to surrounding water supplies (Morse et al., 2009; Postel and Thompson, 2005; Hamilton, 2008). Lower-income countries are relatively well shielded since investment in capital-intensive hydro power installations in these countries has so far been marginal (UNEP Risoe, 2012). Both the Ghana and Vietnam country studies in this report highlight the potential negative effects of hydro installations for coastal erosion, which can compound climate change-induced sea-level rise.

RESPONSES

Where energy potential is set to decline, there are two main response areas: first, undertaking or intensifying measures aimed at improving the supply of water through enhanced watershed catchment and upstream water resource conservation. Increasing forest area and certain types of nature reserves can help build up the water capacity under certain conditions (Postel and Thompson, 2005). Depending on the type of installation, expanding the size of drawing reservoirs to stock more water may also provide a buffer against declining rainfall. In more arid regions, managing upstream water consumption, such as irrigation, may also yield positive results by lessening water withdrawals (Kang et al., 2004). Second, ensure diversification of future energy investments away from hydro power. At the same time, there is a danger that affected economies compensate for lost production in the hydro energy sector through an increase in carbon intensive modes of energy supply. In some major economies, experts have recently been recommending further investment in oil and gas energy generation as a least-cost adaptation option for hydro energy and other renewable energy sources that may be affected by climate change (Pereira de Lucena et al., 2010). Conversely, certain experts have argued that the promotion of hydropower has caused serious environmental damage and should be reconsidered (Haya, 2007).

THE INDICATOR

The indicator maps changes in river discharge in relation to estimated effects of climate change and the corresponding effect on the global hydro-energy potential of existing installations, and draws on International Energy Agency data (Lehner et al., 2001; IEA, 2012b). Key limitations relate to the scale of the information and uncertainty in the direction and magnitude of rainfall changes. The main model is geographically limited to Europe, and effects are extrapolated using river flow information (Nohara et al., 2006). Differences in anticipated changes in rainfall patterns could mean very different outcomes in river discharge and energy potential for those areas where there is less agreement and certainty around the direction of the change (Bates et al., 2008; Hamududu and Killingtveit, 2012).

ESTIMATES COUNTRY-LEVEL IMPACT

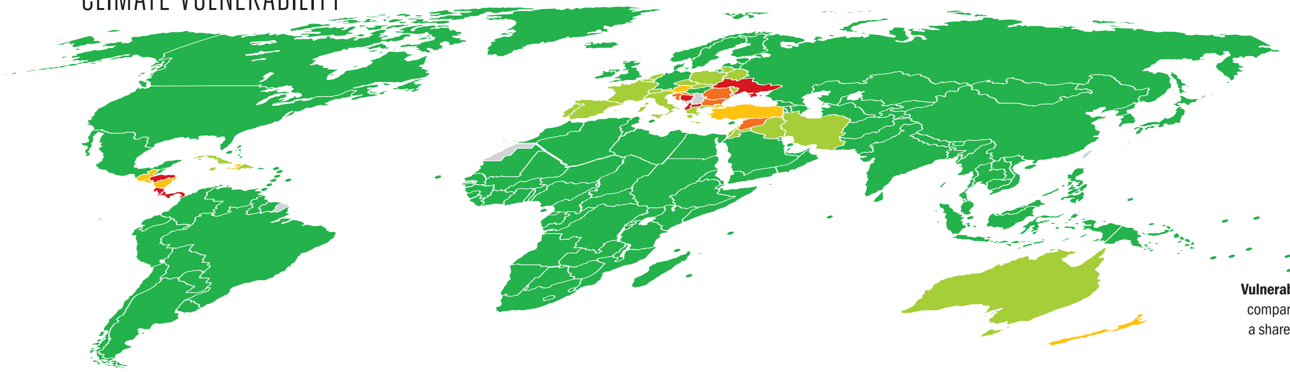
COUNTRY	$ 2010	2030
ACUTE		
Albania	10	100
Bosnia and Herzegovina	15	100
Costa Rica	15	100
Honduras	10	70
Macedonia	5	30
Panama	10	80
Ukraine	150	800
SEVERE		
Bulgaria	5	95
Croatia	10	75
Romania	30	250
Syria	20	100
HIGH		
Austria	10	50
El Salvador	5	35
Guatemala	10	55
Haiti	1	5
New Zealand	10	25
Nicaragua	1	10
Slovenia	5	40
Turkey	85	250
MODERATE		
Australia	5	15
Belarus		
Belgium		
Cuba		1
Czech Republic		5
Dominican Republic	1	20
France	25	100
Greece	1	20
Iran	25	150

COUNTRY	$ 2010	2030
Iraq	1	15
Israel		1
Italy	35	100
Jamaica	1	1
Jordan		1
Lebanon	1	15
Lithuania		
Moldova		1
Netherlands		
Poland	5	20
Portugal	-1	20
Slovakia	5	35
Spain	10	95
Switzerland	1	30
LOW		
Afghanistan		
Algeria		
Angola	-1	-5
Antigua and Barbuda		
Argentina	-20	-150
Armenia	-1	-15
Azerbaijan	-5	-20
Bahamas		
Bahrain		
Bangladesh	-1	-20
Barbados		
Belize		
Benin		
Bhutan		
Bolivia	-1	-10
Botswana		
Brazil	-150	-750

COUNTRY	$ 2010	2030
Brunei		
Burkina Faso		
Burundi		
Cambodia		
Cameroon	-5	-20
Canada	-350	-800
Cape Verde		
Central African Republic		
Chad		
Chile	-10	-60
China	-2,250	-20,000
Colombia	-20	-100
Comoros		
Congo		-1
Cote d,Ivoire	-1	-5
Cyprus		
Denmark		
Djibouti		
Dominica		
DR Congo	-5	-30
Ecuador	-5	-40
Egypt	-15	-95
Equatorial Guinea		
Eritrea		
Estonia		
Ethiopia	-1	-10
Fiji		
Finland	-10	-30
Gabon	-1	-5
Gambia		
Georgia	-15	-75
Germany	-10	-10

$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY

COUNTRY	2010	2030
Ghana	-5	-35
Grenada		
Guinea		
Guinea-Bissau		
Guyana		
Hungary		-1
Iceland	5	-1
India	-250	-1,500
Indonesia	-10	-75
Ireland	-1	-1
Japan	-80	-150
Kazakhstan	-10	-70
Kenya	-1	-5
Kiribati		
Kuwait		
Kyrgyzstan	-40	-250
Laos		
Latvia	-1	-15
Lesotho		
Liberia		
Libya		
Luxembourg		
Madagascar		
Malawi		
Malaysia	-10	-65
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Mexico	-60	-350

COUNTRY	2010	2030
Micronesia		
Mongolia		
Morocco	-1	-5
Mozambique	-10	-55
Myanmar	-1	-15
Namibia	-1	-5
Nepal	-5	-30
Niger		
Nigeria	-5	-30
North Korea	-25	-200
Norway	35	-150
Oman		
Pakistan	-55	-350
Palau		
Papua New Guinea		
Paraguay	-40	-250
Peru	-10	-75
Philippines	-10	-75
Qatar		
Russia	-300	-1,500
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Solomon Islands		
Somalia		

COUNTRY	2010	2030
South Africa	-1	-5
South Korea	-5	-40
Sri Lanka	-10	-55
Sudan/South Sudan	-1	-5
Suriname		
Swaziland		
Sweden	40	-60
Tajikistan	-45	-250
Tanzania	-1	-15
Thailand	-10	-60
Timor-Leste		
Togo		-1
Tonga		
Trinidad and Tobago		
Tunisia		-1
Turkmenistan		
Tuvalu		
Uganda		
United Arab Emirates		
United Kingdom	-5	-5
United States	-300	-700
Uruguay	-5	-20
Uzbekistan	-15	-90
Vanuatu		
Venezuela	-30	-200
Vietnam	-30	-300
Yemen		
Zambia	-5	-25
Zimbabwe	-1	-15