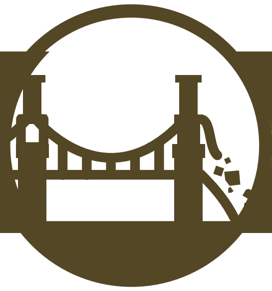
CORROSION



ESTIMATES GLOBAL CARBON IMPACT

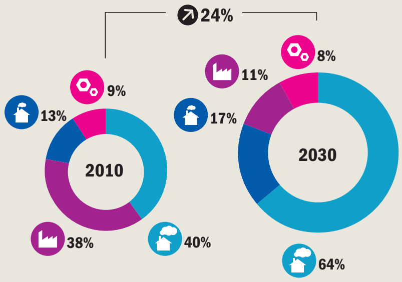
2010 EFFECT TODAY

USD LOSS PER YEAR **1 BILLION**

2030 EFFECT TOMORROW

USD LOSS PER YEAR **5 BILLION**

ECONOMIC IMPACT



CONFIDENCE
SPECULATIVE

SEVERITY

AFFECTED

MDG EFFECT

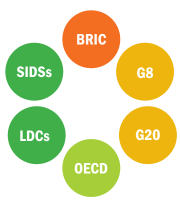
- Air pollution from industrial, residential and transport emissions causes costly damage to infrastructure, vehicles and other materials
- The corrosion effect is most severe where industrialized or newly-industrializing countries lack controls on harmful emissions such as sulphur dioxide and that rely 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
400	CHINA	2,250
100	INDIA	550
80	SOUTH KOREA	450
60	RUSSIA	250
200	UNITED STATES	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).

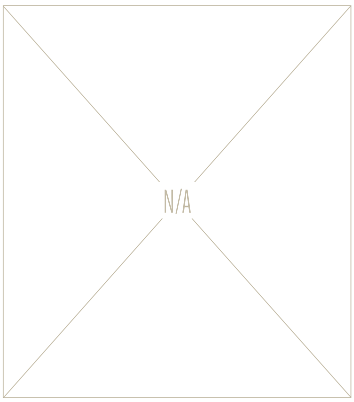
HAZARD MECHANISM

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).

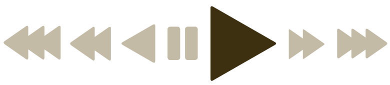
IMPACTS

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.

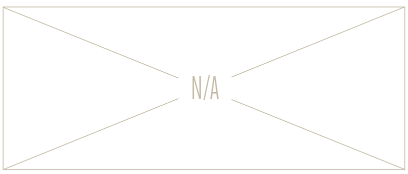
BIGGER PICTURE



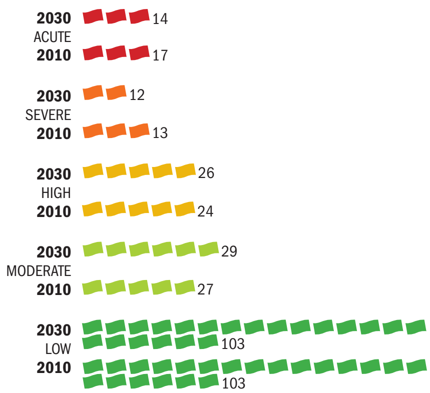
SURGE



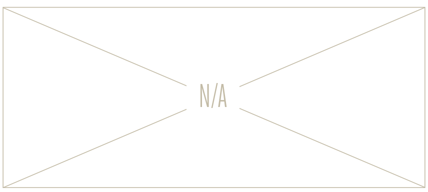
OCCURRENCE



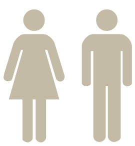
VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS



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.

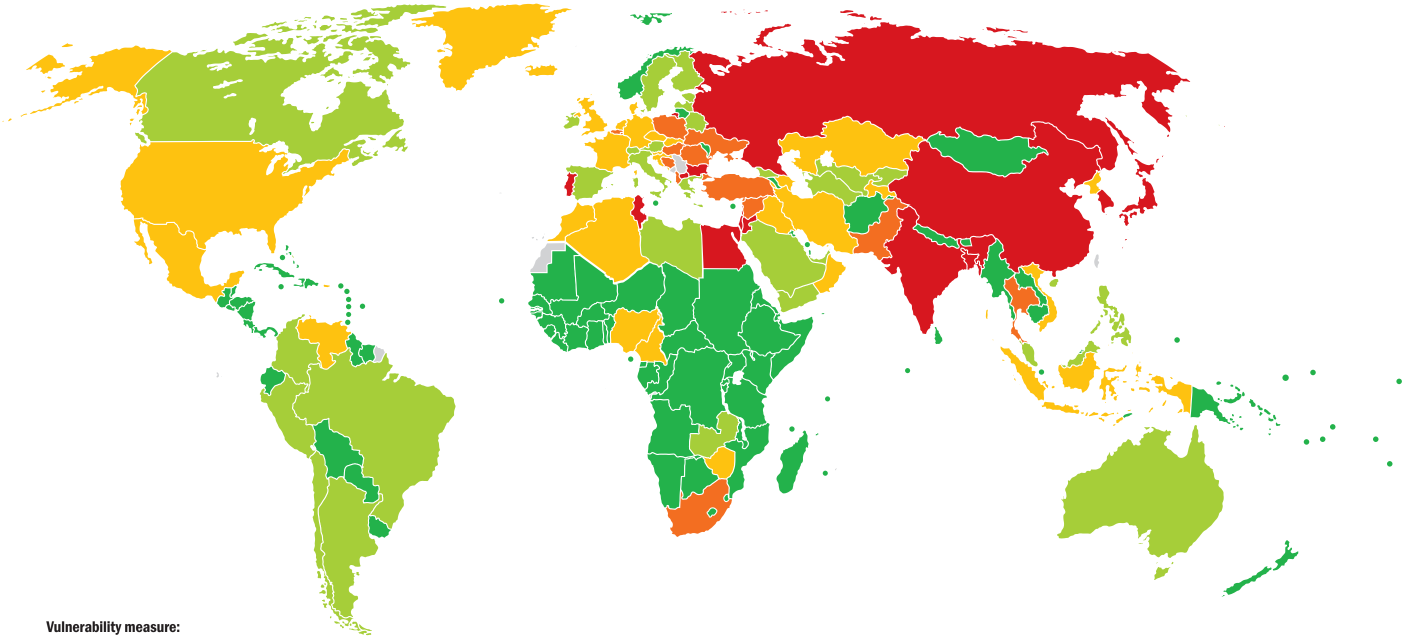
ESTIMATES COUNTRY-LEVEL IMPACT

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		