2016 REPORT

Environmental Performance Index

GLOBAL METRICS FOR THE ENVIRONMENT

The Environmental Performance Index ranks countries' performance on high-priority environmental issues.

www.epi.yale.edu

Yale Center for Environmental Law & Policy, Yale University

Yale Data Driven Environmental Group, Yale University, Yale-NUS College

Center for International Earth Science Information Network, Columbia University

In collaboration with the World Economic Forum

With support from Samuel Family Foundation, McCall MacBain Foundation

The 2016 Environmental Performance Index is a project lead by the Yale Center for Environmental Law & Policy (YCELP) and Yale Data-Driven Environmental Solutions Group at Yale University (Data-Driven Yale), the Center for International Earth Science Information Network (CIESIN) at Columbia University, in collaboration with the Samuel Family Foundation, McCall MacBain Foundation, and the World Economic Forum.

About YCELP

The Yale Center for Environmental Law & Policy, a joint research institute between the Yale School of Forestry & Environmental Studies and Yale Law School, seeks to incorporate fresh thinking, ethical awareness, and analytically rigorous decision making tools into environmental law and policy.

About Data-Driven Yale

The Yale Data-Driven Environmental Solutions Group seeks to address critical environmental challenges using cutting edge data analytics and other innovative methods. Launched in 2015, the research group is an interdisciplinary collaboration of policy experts, data scientists, visual designers, and interactive programmers at the Yale School of Forestry and Environmental Studies and Yale-NUS College, Singapore.

About CIESIN

The Center for International Earth Science Information Network's mission is to provide access to and enhance the use of information worldwide, advance the understanding of human interactions in the environment, and serve the needs of science and public and private decision making.

About the Samuel Family Foundation

The Samuel Family Foundation has a long history of supporting the arts, healthcare and education. In recent years, it has broadened its mandate internationally, to engage in such partnerships as the Clinton Global Initiative, and participate in programs aimed at global poverty alleviation, disability rights and human rights advocacy, environmental sustainability, education and youth programs.

About the McCall MacBain Foundation

The McCall MacBain Foundation is based in Geneva, Switzerland, and was founded by John and Marcy McCall MacBain. Its mission is to improve the welfare of humanity through focused grants in education, health and the environment. Believing that strong, dedicated and creative leadership are required in these areas to achieve positive outcomes, much of its funding is designed to identify and support individuals having such qualities.

About the World Economic Forum

The World Economic Forum is an independent international organization committed to improving the state of the world by engaging business, political, academic and other leaders of society to shape global, regional and industry agendas.

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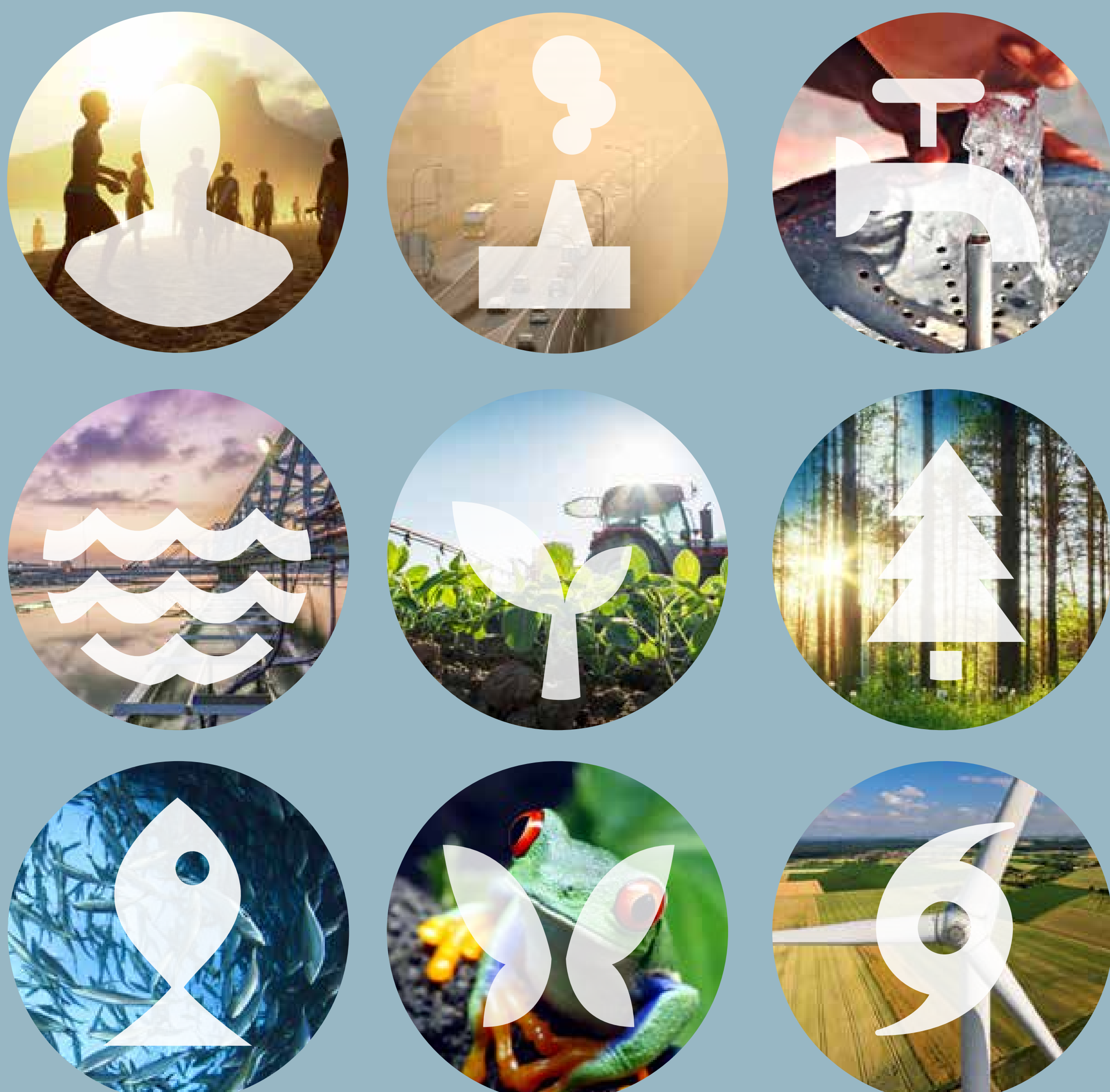
ABBREVIATIONS AND ACRONYMS

A	AQI	Air Quality Index
B	BOD	Biochemical Oxygen Demand
C	CAIT	Climate Analysis Indicators Tool
	CBD	Convention on Biological Diversity
	CDC	Center for Disease Control
	CIESIN	Center for International Earth Science Information Network
	CO_2	Carbon Dioxide
D	DALY	Disability-Adjusted Life Year
	DOPA	Digital Observer of Protected Areas
E	EPI	Environmental Performance Index
	EEA	European Environment Agency
	EEZ	Exclusive Economic Zone
	ERE	Environmental Risk Exposure
	EU	European Union
F	FAO	Food and Agriculture Organization
	FSC	Forest Stewardship Council
G	G-20	Group of Twenty
	GBD	Global Burden of Disease
	GDP	Gross Domestic Product
	GEMS	Global Environment Monitoring System
	GFW	Global Forest Watch
	GHGs	Greenhouse Gases
	GNI	Gross National Income
I	ICES	International Council for the Exploration of the Seas
	IEA	International Energy Agency
	IHME	Institute for Health Metrics and Evaluation
	INDC	Intended Nationally Determined Contribution
	IPCC	Intergovernmental Panel on Climate Change
	IUCN	International Union for Conservation of Nature
J	JMP	Joint Monitoring Programme
K	kWh	Kilowatt Hours
L	LDCs	Least Developed Countries
M	MDGs	Millennium Development Goals
	MSY	Maximum Sustainable Yield
N	N	Nitrogen
	NASA	National Aeronautics and Space Administration
	NBALANCE	Nitrogen Use Balance
	NO_2	Nitrogen Dioxide
	NOx	Nitrogen Oxides
	NUE	Nitrogen Use Efficiency
O	O_3	Ozone
	OECD	Organisation for Economic Co-operation and Development
	OHI	Ocean Health Index
	OPEC	Organization of the Petroleum Exporting Countries
P	PM	Particulate Matter
	POPs	Persistent Organic Pollutants
	PPP	Purchasing Power Parity
R	REDD	Reducing Emissions from Deforestation and Forest Degradation
S	SAU	Sea Around Us
	SIDS	Small Island Developing States
	SDGs	Sustainable Development Goals
T	TAC	Total Allowable Catch
	TMREL	Theoretical Minimum Risk Exposure Level
U	UN	United Nations
	UNICEF	United Nations Children's Fund
	UNEP	United Nations Environment Programme
	UNFCCC	United Nations Framework Convention on Climate Change
	UNStats	United Nations Statistical Division
V	VOCs	Volatile Organic Compounds
W	WCMC	World Conservation Monitoring Centre
	WDPA	World Database on Protected Areas
	WHO	World Health Organization
	WWF	World Wildlife Fund
Y	YCELP	Yale Center for Environmental Law & Policy

EXECUTIVE SUMMARY

2016



What is the EPI?

The Environmental Performance Index (EPI) ranks countries' performance on high-priority environmental issues in two areas: protection of human health and protection of ecosystems. Within these two policy objectives the EPI scores national performance in nine issue areas comprised of more than 20 indicators (see EPI Framework). EPI indicators measure country proximity to meeting internationally established targets or, in the absence of agreed targets, how nations compare to one another.

Complete methods, data, and results are available online at www.epi.yale.edu.

Why the EPI?

Pioneering data-driven approaches to environmental policy in the last 15 years, the EPI has accelerated the global use of quantitative metrics to evaluate policy performance. The United Nations Sustainable Development Goals (SDGs), adopted in September 2015, have assimilated a parallel approach, defining 17 goals and 169 targets to guide the global development agenda. Aligning EPI's indicators with the SDGs provides a baseline for evaluating national performance and shows how far countries are from reaching global targets.

The EPI's value lies not only in the overall rankings, which are intended to drive productive competition, but also in the issue-by-issue metrics that provide a diagnostic tool for countries to look internally for areas of weakness and strength. A common framework and methodology allows countries to compare their performance with that of neighbors and peers, and, through the analysis of time series data, see how their own performance has changed over time.

This Index builds on previous EPIs, innovating in key areas including, for the first time, human health metrics that capture health risks across all ages and genders instead of using child mortality as a proxy. The 2016 EPI introduces novel measures of agricultural sustainability that form a foundation for a comprehensive suite of agriculture indicators to be developed. This EPI also includes new species protection indicators that speak to key conservation outcomes, shining a light on badly needed measures of biodiversity loss. The air quality category, moreover, has improved with the addition of an NO2 indicator, which describes pollutants that are especially toxic to humans.

Results and Conclusions

The 2016 EPI's innovations have shaken up the rankings since the Index's previous iteration. Finland has taken the top spot, followed by Iceland, Sweden, Denmark, and Slovenia. Finland's top ranking stems from its societal commitment to achieve a carbon-neutral society that does not exceed nature's carrying capacity by 2050, a vision replete with actionable goals and measurable indicators of sustainable development. Finland's goal of consuming 38 percent of their final energy from renewable sources by 2020 is legally binding, and they already produce nearly two-thirds of their electricity from renewable or nuclear power sources.

The 2016 EPI's poor performers are a familiar group to the Index's low end. Somalia again takes last place (180th) followed, in ascending order, by Eritrea, Madagascar, Niger, and Afghanistan. These African and South Asia nations all have broad governance problems with long, troubled legacies. The Index's bottom third, comprised mostly of African countries with a smattering of South and East Asian nations, is a list of troubled states whose problems extend beyond their inability to sustain environmental and human health. These nations show that environmental performance is an issue of governance – only well-functioning governments are able to manage the environment for the benefit of all.

Examining trends in environmental performance over the last decade, nearly every country has improved its EPI score. Countries already achieving high EPI scores, including those in Europe and North America, have the smallest gains in environmental performance, suggesting incremental improvements at high levels of achievement are difficult to make. Developing countries, particularly those in Sub-Saharan Africa, have seen the greatest gains in environmental performance over the last decade. Investments in clean water, sanitation, and energy infrastructure are the main contributors to improvements in these nations' scores.

In addition to these headline rankings, the 2016 EPI provides an overview of global environmental performance, identifying key trends and the status for high-priority issues. This year, we find:

1. More deaths globally occur due to poor air quality than water. In 2013, unsafe water was responsible for 2 percent of global deaths (~1.24 million), while poor air quality was responsible for 10 percent of all global deaths (~5.52 million). Economic development leads to improvement in some environmental areas, yet it is also associated with increased human health hazards. As nations become wealthier, their governments invest in sanitation infrastructure and fewer people are exposed to unsafe water, leading to fewer deaths from waterborne illnesses. But as countries develop, increased industrial production, urbanization, and motorized transport expose human populations to dangerous airborne compounds. Thus, deaths attributed to air pollution have risen steadily over the past decade in step with exposure.

2. More than 3.5 billion people - half of the world's population - live in nations with unsafe air quality. Dangerous air pollution is not confined to any one country or group of countries – it is a global issue. The World Health Organization considers air unsafe when average exposure to fine particulate matter exceeds 10 micrograms/m3. A third of people exposed to poor air quality (1.3 billion) live in the East Asia and Pacific region, where in China and South Korea more than 50 percent of their populations are exposed to unsafe levels of fine particulate matter. In India and Nepal, the percentage is nearly 75 percent.

3. The number of people lacking access to clean water has been nearly cut in half from 960 million in 2000 to 550 million today, around 8 percent of the world's population. 2.4 billion people lack access to sanitation.

4. 34 percent of global fish stocks are overexploited or collapsed. The stark decline of fish stocks shows that when measurement is poor or not aligned with proper management, environmental and human health suffer. Marine fisheries are poorly monitored, as many fleets misreport or fail to report catch data, and international policy targets are ad hoc and incomplete.

5. 15.4 percent of terrestrial habitats and 8.4 percent of marine habitats in 2014 were protected. Nations are less than 2 percent away from reaching global targets on biodiversity and habitat. But, there is roughly a 3 percent global gap between Terrestrial Habitat Protection and Species' Habitat Protection, suggesting that nationally-designated protected areas do not always align with species preservation. Protected areas are often established on marginal lands, rather than in high-value areas where wildlife is forced out by agricultural development and human settlements.

6. 2.52 million km2 for tree cover was lost in 2014 – an area roughly twice the size of Peru.

7. 23 percent of countries have no wastewater treatment. Sustainable Development Goal 6 – to ensure availability and sustainable management of water and sanitation for all – sets a target to halve the proportion of untreated wastewater by 2030. More than 80 percent of the world's discharged wastewater is untreated when it's released into the environment. Countries need to invest in wastewater treatment infrastructure to reach this goal.

8. Only 20 percent of countries are meeting targets for Nitrogen Use Efficiency. Nitrogen use efficiency directly enhances crop productivity while decreasing nitrogen runoff and associated environmental degradation. Excess nitrogen not taken up by crops enters the environment through nitrogen leaching, ammonia volatilization, and nitrous oxide emissions. This nitrogen pollution has negative impacts on air and water quality, leads to ozone layer depletion, and exacerbates climate change.

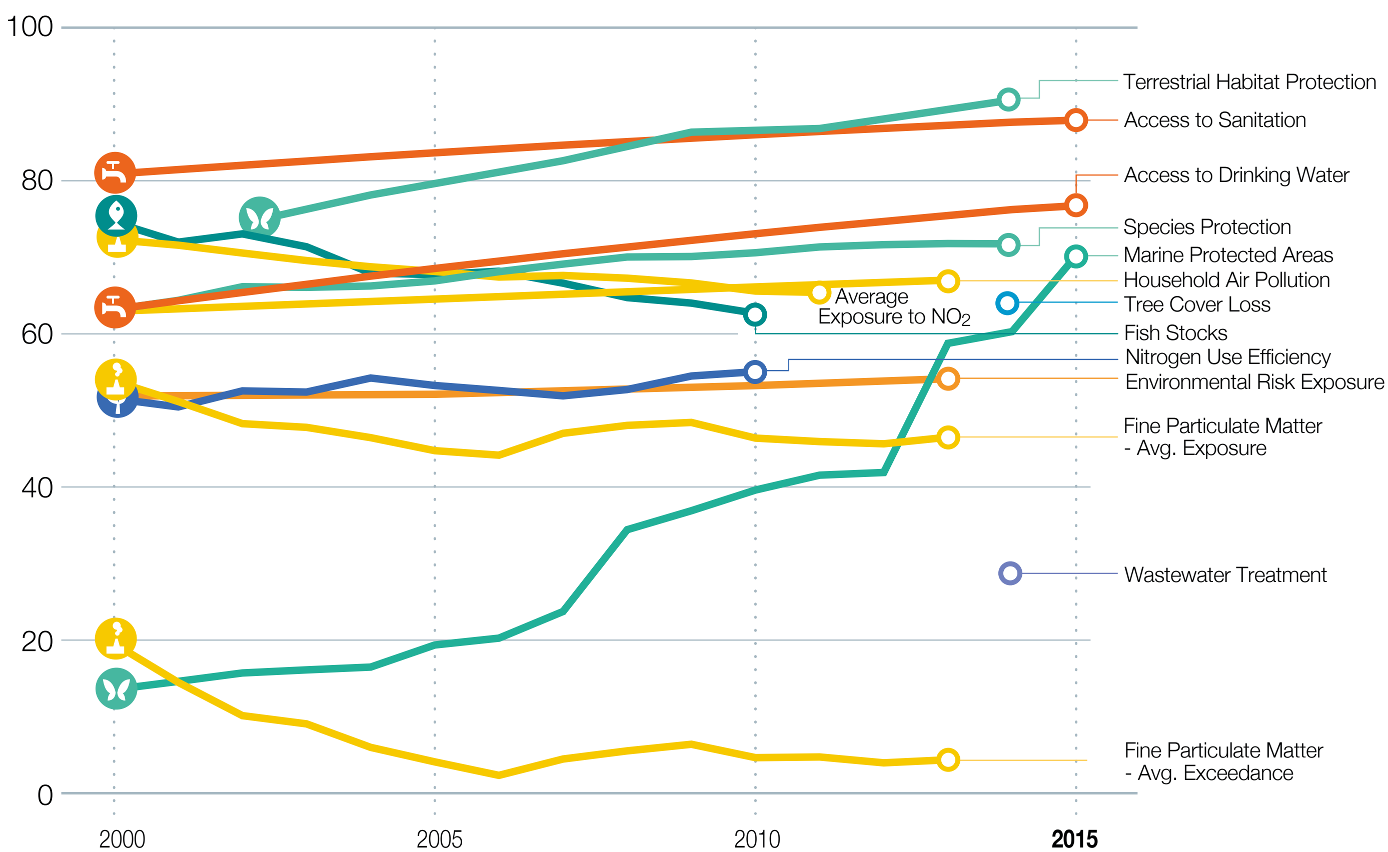
9. Around one-third of countries scored on Climate and Energy are reducing their carbon intensity. Globally, Trends in Carbon Intensity are starting to slightly decline. The 2015 Paris Climate Agreement specifies climate change action expected from all countries, yet solid metrics to evaluate performance remain elusive. Measuring climate change performance – that is, assessing which countries are implementing policies that result in measurable climate mitigation – is an extremely urgent challenge. The inextricable linkage between carbon and economic growth makes disentangling performance signals from emissions difficult. As a result, the 2016 EPI's Climate and Energy indicators primarily show how countries are decarbonizing economic growth rather than whether their climate policies are having a tangible effect.

Key Findings of the 2016 Environmental Performance Index

1 The world is making progress addressing some environmental issues while others have worsened considerably. A "global scorecard' (Figure 1) illustrates this progress and deterioration, showing promising trends in Health Impacts, Access to Drinking Water, and Access to Sanitation. Air Quality (NO2) and Fisheries, however, exhibit troubling declines. Comparing relative performance across issues, the world performs poorly on Wastewater Treatment and Air Quality (PM2.5) as well as in Carbon Intensity Trend indicators. Trends suggest improvement in many areas, yet progress remains slow, and some trends are overshadowed by other, more troubling findings. The world's nations protect more marine habitat than ever, for instance, yet fish stocks are declining. Performance among areas is linked and trends sometimes conflict, exhibiting the complexity of global environmental measurement.

2 Economic development leads to improvement in some environmental areas, yet development is also associated with increased prevalence of environmental hazards. Air and Water indicators clearly exhibit these conflicting signals. As nations have become wealthier, particularly in Asia, their governments invest in sanitation infrastructure and fewer people are exposed to unsafe water, leading to fewer deaths from waterborne illnesses. But as countries develop, increased industrial production, shipping, and automotive transportation foul the air, exposing human populations to dangerous airborne compounds. Thus, deaths attributed to air pollution have risen steadily in the past decade in step with exposure.

Figure 1: Global indicators for most of the policy issues assessed by the EPI. Note: Some indicators, such as Tree Cover Loss, are expressed as trends that already encompass a time series. These indicators are exhibited by a dot instead of a line.
Data Source: 2016 EPI.



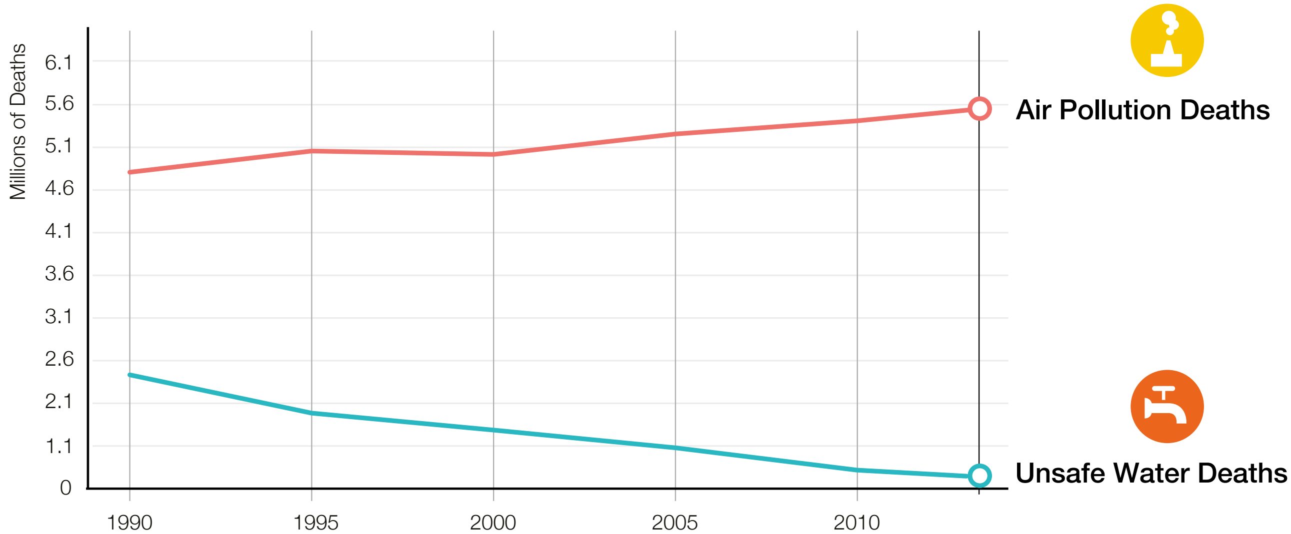
Air pollution is a growing global problem; worse in rapidly developing economies, like China and India, than in wealthy or very poor nations. Yet dangerous air pollution is not confined to any one country or group of countries – it is a global issue. More than 3.5 billion people, or half of the world's population, live in nations where average exposure to fine particulate matter exceeds levels the World Health Organization (WHO) considers safe (10 micrograms/m3). One-third (1.3 billion) of these people live in the East Asia and Pacific region, where in China and South Korea more than 50 percent of their populations are exposed to unsafe levels of fine particulate matter. In India and Nepal, the percentage is nearly 75 percent. In contrast, drinking water metrics have improved steadily, The number of people lacking access to clean water has been cut nearly in half from 960 million in the year 2000 to 550 million, or around 8 percent of the world's population, today.

3 When measurement is poor or not aligned with proper management, environmental and human health suffer. EPI shows that sectors with weak measurement are also areas exhibiting decline. Marine fisheries are poorly monitored, for instance, as many fleets misreport or fail to report catch data, and international policy targets are ad hoc and incomplete. It is no surprise that fish stocks around the world are in stark decline. The 2016 EPI, in collaboration with Sea Around Us – a fisheries research initiative based at the University of British Columbia – takes into account the quality of fisheries data by penalizing countries whose data are incomplete or unreliable.

4 Developing policy relevant indicators based in science is essential to appropriate measurement and management. Indicators and policy targets are too often framed by political aims rather than science. Two new EPI indicators – Species Protection and Drinking Water Quality – show how policy targets are frequently defined according to political expediency. The 2016 EPI Species Protection indicator, which relies on the Map of Life – a global database of species – measures the gap between terrestrial protected areas and actual species habitats. This gap (Figure 4) suggests that nationally designated protected areas do not always align with species preservation. Protected areas are often established on marginal lands, rather than in high-value areas where wildlife is forced out by agricultural development and human settlements.

Millennium Development Goal-7 includes an indicator that assesses Access to Drinking Water, yet this MDG metric is not optimally suited to its goal, which is for countries to increase access to "safe drinking water." The indicator used to measure the goal's progress is framed in terms of access

Figure 2: The number of global deaths due to unsafe drinking water has declined over the last two decades, but the deaths from poor air quality have increased. *Data source: GBD, 2013.*



to "improved" or "unimproved" sources, as determined by a piped (as opposed to open) water source. This metric does not say whether the water from improved sources is actually treated and safe to drink. Data from the Institute for Health Metrics and Evaluation (IHME) – a research organization that produces the Global Burden of Disease, a measure of death attributable to certain risk factors – reveals a radically different picture of unsafe water quality exposure than the one that MDG-7's indicators paint (Figure 5). In many countries and regions, a significant portion of 'improved' drinking water

Figure 3: The percentage of global fish stocks that are overexploited or collapsed has increased over the last several decades, reaching its current peak at 34 percent. *Data source: Sea Around Us, 2015.*

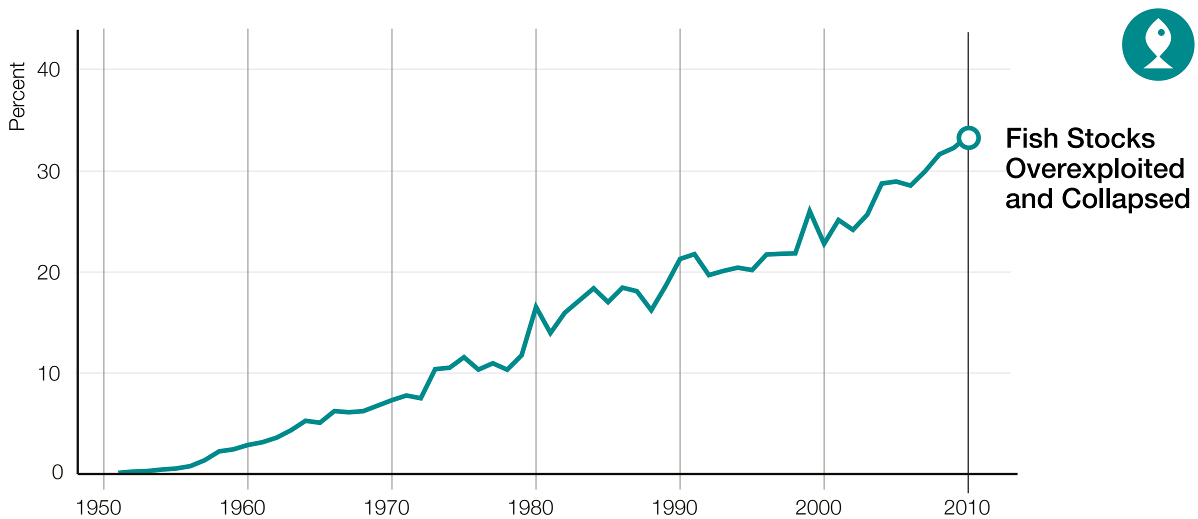
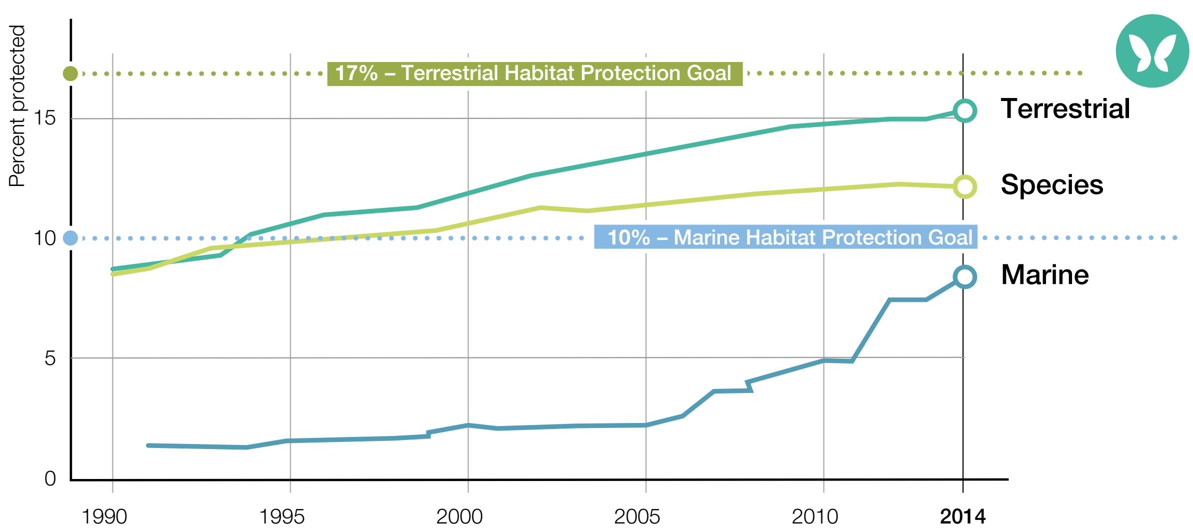


Figure 4: Time series of biodiversity and habitat protection indicators show improvement over time, but a gap between terrestrial habitats and species' habitats. *Source: Terrestrial/Marine Protected Areas data: IUCN and UNEP-WCMC. 2014; Species Protection data: 2016 EPI, Map of Life.*



sources are untreated. These results show policy targets that are politically expedient – it is easier, after all, to measure access to "improved" and "unimproved" water than to measure water quality – but not wholly relevant to science or human health.

5 The 2015 Paris Climate Agreement specifies climate change action expected from all countries, yet solid metrics to evaluate performance remain elusive. Measuring climate change performance – that is, assessing which countries are implementing policies that result in measurable climate mitigation – is one of the most urgent challenges facing society today. The inextricable linkage between carbon and economic growth makes disentangling performance signals from emissions difficult. As a result, the 2016 EPI's Climate and Energy indicators primarily signal how countries are decarbonizing economic growth rather than whether their climate policies are having a tangible effect. These indicators cannot point to underlying drivers of decarbonization, whether they are due to economic decline or through concerted policy effort. Denmark, for instance, has made strong commitments to reduce emissions through increasing efficiency and renewable energy production. Singapore, as a result of its high urban density, has been able to lower its carbon intensity relative to economic peers over the last decade. Other countries, such as Russia, are likely overachieving compared to economic peers due to recession rather than ambitious climate efforts.

Other Conclusions

1) Data from new sources including from cutting-edge technologies help improve global monitoring of progress towards international goals, such as the SDGs, yet these innovations do not represent a policy silver bullet. The EPI uses advances in satellite technology and remote sensing, which contribute to globally comparable datasets where national governments fail to monitor or report environmental data. Satellite data is used to generate air quality and forestry metrics that are more readily comparable and comprehensive than what has emerged from previous models and national reports. These new data sources,

Figure 5: Proportions of unimproved and improved drinking water sources that are untreated, filtered, and chlorinated provide a different picture of water quality than MDG-7 metrics that only show improved and unimproved categories.
Data source: IHME, 2015.

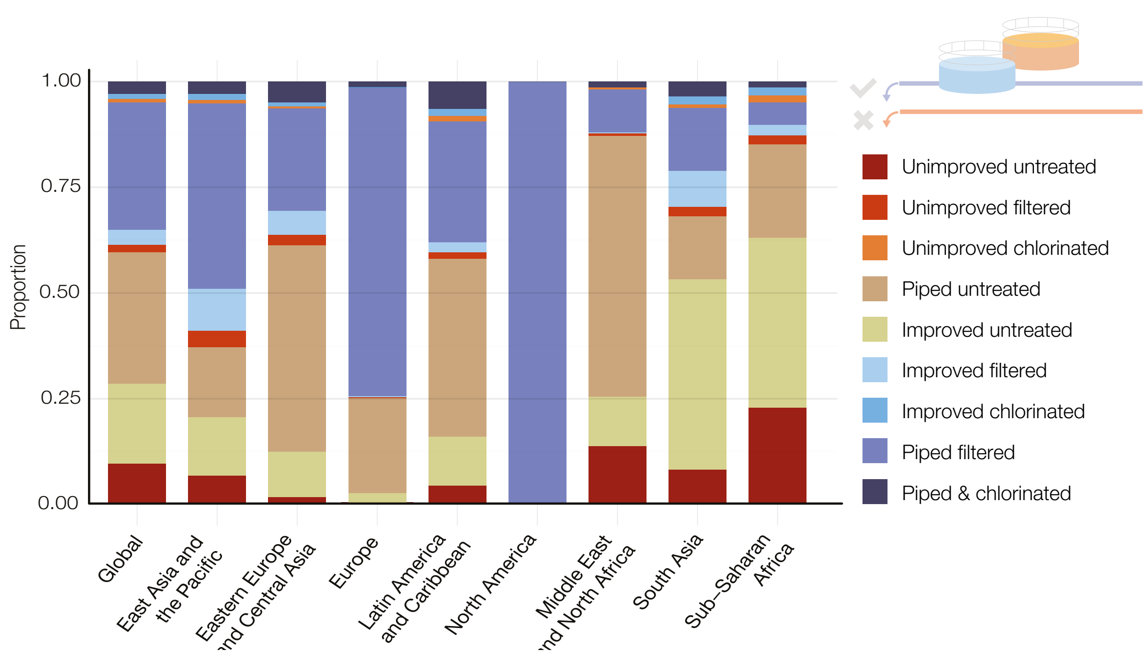
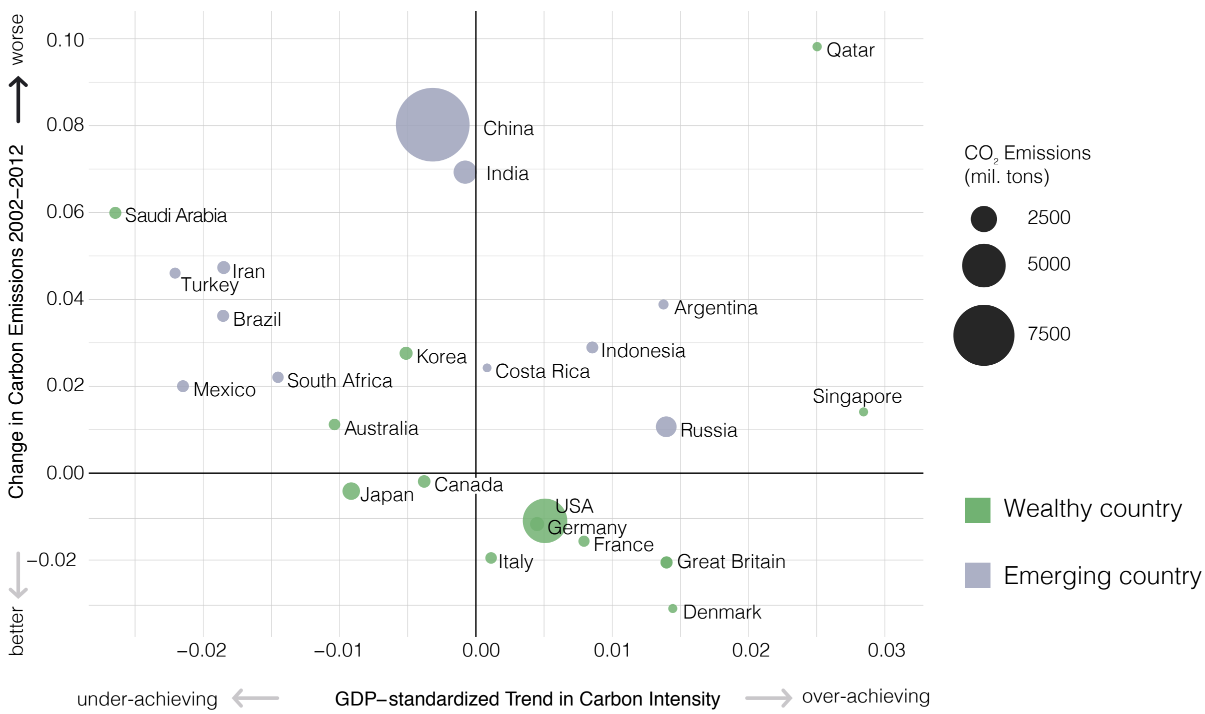


Figure 6: Climate change performance in the 2016 EPI for selected top carbon-emitting countries, gauged according to the GDP-standardized Trend in Carbon Intensity and Trend in Carbon Emissions. *Source: 2016 EPI.*



however, are not perfect. Satellite-derived tree cover data, for instance, uses a global definition of forest cover that counts plantations and natural forest equally. Because satellites have set orbits and a limited time series, forests with slower growth and regeneration cycles may be incorrectly registered as "loss" depending on the duration of measurement. Long-term, three-year rolling averages of air quality data also result in lower exposure values than data produced by ground-based monitors.

2) Sub-national indicators often illustrate more accurate and actionable data than national level metrics. Environmental issues are rarely confined to national borders. And many environmental issues, when measured at the national level, lose local relevance. How can a single measure of air or water quality define an entire country, particularly when it is as large and diverse as the United States or Russia? The EPI's selection of the nation-state as the unit of measure is not always the best level of analysis for a particular environmental concern. In the case of Nitrogen Balance, for example, a country can exhibit areas of both excess nitrogen and nitrogen deficiency, due to soil and climatic differences. A national measure of Nitrogen Balance obscures these nuances.

3) Better environmental measurement and indicator systems are needed. Every EPI underscores this conclusion. While there has been progress in some areas of measurement, particularly with technological advances and innovations like satellite data, many environmental concerns lack comparable data to monitor extent or progress. Freshwater quality, species loss, climate adaptation, and waste management are some issues that remain absent from the EPI's evaluation because of insufficient data. Without this information, environmental management will suffer and natural systems and human health will decline. As the EPI shows, progress occurs only when measurement and management align.

EPI 2016 Rankings

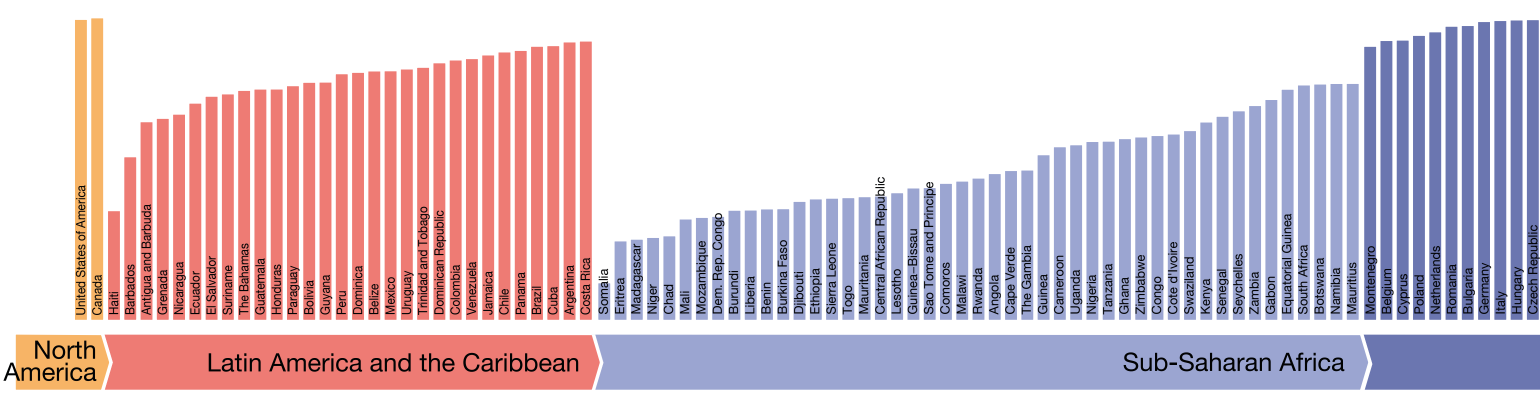
Rank	Country	Score	Peer Comp.*
1	Finland	**90.68**	↑
2	Iceland	**90.51**	↑
3	Sweden	**90.43**	↑
4	Denmark	**89.21**	↑
5	Slovenia	**88.98**	↑
6	Spain	**88.91**	↑
7	Portugal	**88.63**	↑
8	Estonia	**88.59**	↑
9	Malta	**88.48**	↑
10	France	**88.2**	↑
11	New Zealand	**88**	↑
12	United Kingdom	**87.38**	↑
13	Australia	**87.22**	↑
14	Singapore	**87.04**	↑
15	Croatia	**86.98**	↑
16	Switzerland	**86.93**	↑
17	Norway	**86.9**	↑
18	Austria	**86.64**	↑
19	Ireland	**86.6**	↑
20	Luxembourg	**86.58**	↑
21	Greece	**85.81**	↓
22	Latvia	**85.71**	↓
23	Lithuania	**85.49**	↓
24	Slovakia	**85.42**	↓
25	Canada	**85.06**	↑
26	United States of America	**84.72**	↓
27	Czech Republic	**84.67**	↓
28	Hungary	**84.6**	↓
29	Italy	**84.48**	↓
30	Germany	**84.26**	↓

Rank	Country	Score	Peer Comp.*
31	Azerbaijan	**83.78**	↑
32	Russia	**83.52**	↑
33	Bulgaria	**83.4**	↓
34	Romania	**83.24**	↓
35	Belarus	**82.3**	↑
36	Netherlands	**82.03**	↓
37	Armenia	**81.6**	↑
38	Poland	**81.26**	↓
39	Japan	**80.59**	↑
40	Cyprus	**80.24**	↓
41	Belgium	**80.15**	↓
42	Costa Rica	**80.03**	↑
43	Argentina	**79.84**	↑
44	Ukraine	**79.69**	↑
45	Cuba	**79.04**	↑
46	Brazil	**78.9**	↑
47	Montenegro	**78.89**	↓
48	Serbia	**78.67**	↑
49	Israel	**78.14**	↑
50	Macedonia	**78.02**	↑
51	Panama	**78**	↑
52	Chile	**77.67**	↑
53	Tunisia	**77.28**	↑
54	Jamaica	**77.02**	↑
55	Moldova	**76.69**	↑
56	Venezuela	**76.23**	↑
57	Colombia	**75.93**	↑
58	Dominican Republic	**75.32**	↑
59	Fiji	**75.29**	↑
60	Taiwan	**74.88**	↑

Rank	Country	Score	Peer Comp.*
61	Albania	**74.38**	↓
62	Trinidad and Tobago	**74.34**	↑
63	Malaysia	**74.23**	↑
64	Morocco	**74.18**	↑
65	Uruguay	**73.98**	↑
66	Philippines	**73.7**	↑
67	Mexico	**73.59**	↑
68	Belize	**73.55**	↑
69	Kazakhstan	**73.29**	↓
70	Dominica	**73.25**	↑
71	Kyrgyz Republic	**73.13**	↓
72	Tajikistan	**73.05**	↓
73	Peru	**72.95**	↑
74	Jordan	**72.24**	↑
75	Guyana	**71.14**	↑
76	Bolivia	**71.09**	↑
77	Mauritius	**70.85**	↑
78	Namibia	**70.84**	↑
79	Botswana	**70.72**	↑
80	South Korea	**70.61**	↑
81	South Africa	**70.52**	↑
82	Paraguay	**70.36**	↓
83	Algeria	**70.28**	↑
84	Turkmenistan	**70.24**	↓
85	Samoa	**70.2**	↑
86	Bahrain	**70.07**	↑
87	Qatar	**69.94**	↑
88	Honduras	**69.64**	↓
89	Guatemala	**69.64**	↓
90	Equatorial Guinea	**69.59**	↑

* The Peer Comparison column identifies whether a country performs better or worse than countries in its region.

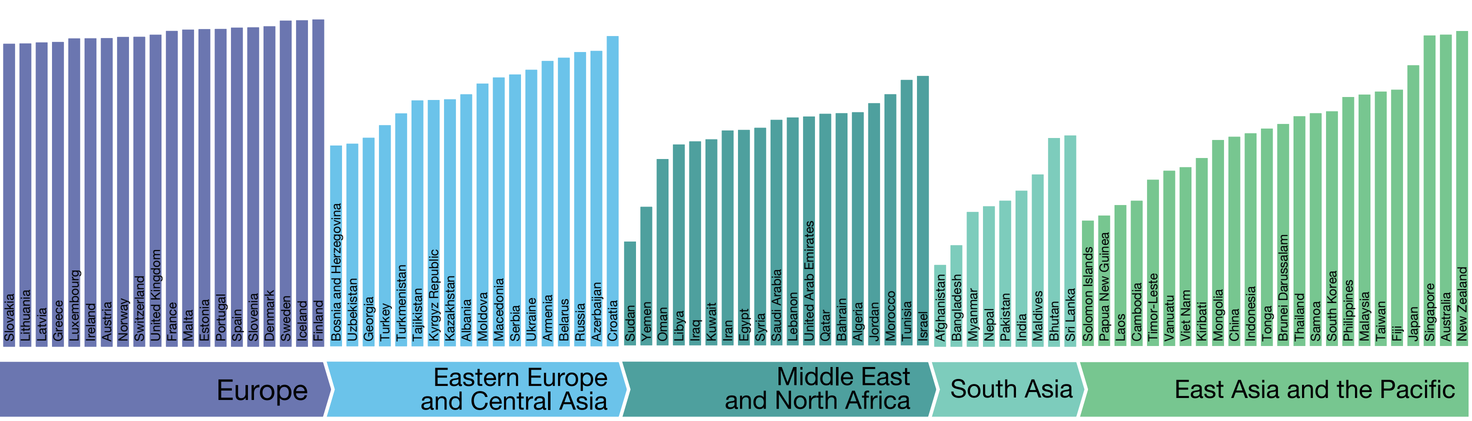
Regional Rankings



Rank	Country	Score	Peer Comp.*
91	Thailand	**69.54**	↑
92	United Arab Emirates	**69.35**	↑
93	The Bahamas	**69.34**	↓
94	Lebanon	**69.14**	↑
95	Saudi Arabia	**68.63**	↑
96	Suriname	**68.58**	↓
97	El Salvador	**68.07**	↓
98	Brunei Darussalam	**67.86**	↑
99	Turkey	**67.68**	↓
100	Gabon	**67.37**	↑
101	Syria	**66.91**	↑
102	Tonga	**66.86**	↓
103	Ecuador	**66.58**	↓
104	Egypt	**66.45**	↓
105	Iran	**66.32**	↓
106	Zambia	**66.06**	↑
107	Indonesia	**65.85**	↓
108	Sri Lanka	**65.55**	↑
109	China	**65.1**	↓
110	Bhutan	**64.99**	↑
111	Georgia	**64.96**	↓
112	Seychelles	**64.92**	↑
113	Kuwait	**64.41**	↓
114	Mongolia	**64.39**	↓
115	Nicaragua	**64.19**	↓
116	Iraq	**63.97**	↓
117	Senegal	**63.73**	↑
118	Uzbekistan	**63.67**	↓
119	Libya	**63.29**	↓
120	Grenada	**63.28**	↓

Rank	Country	Score	Peer Comp.
121	Bosnia and Herzegovina	**63.28**	↓
122	Antigua and Barbuda	**62.55**	↓
123	Kenya	**62.49**	↑
124	Swaziland	**60.63**	↑
125	Kiribati	**60.48**	↓
126	Oman	**60.13**	↓
127	Cote d'Ivoire	**59.89**	↑
128	Congo	**59.56**	↑
129	Zimbabwe	**59.25**	↑
130	Ghana	**58.89**	↑
131	Viet Nam	**58.5**	↓
132	Tanzania	**58.34**	↑
133	Nigeria	**58.27**	↑
134	Vanuatu	**57.74**	↓
135	Uganda	**57.56**	↑
136	Cameroon	**57.13**	↑
137	Maldives	**57.1**	↑
138	Timor-Leste	**55.79**	↓
139	Guinea	**55.4**	↑
140	Barbados	**54.96**	↓
141	India	**53.58**	↑
142	The Gambia	**52.09**	↓
143	Cape Verde	**51.98**	↓
144	Pakistan	**51.42**	↓
145	Angola	**51.32**	↓
146	Cambodia	**51.24**	↓
147	Rwanda	**50.34**	↓
148	Laos	**50.29**	↓
149	Nepal	**50.21**	↓
150	Yemen	**49.79**	↓

Rank	Country	Score	Peer Comp.
151	Malawi	**49.69**	↓
152	Comoros	**49.2**	↓
153	Myanmar	**48.98**	↓
154	Sao Tome and Principe	**48.28**	↓
155	Guinea-Bissau	**48.2**	↓
156	Papua New Guinea	**48.02**	↓
157	Lesotho	**47.17**	↓
158	Solomon Islands	**46.92**	↓
159	Central African Republic	**46.46**	↓
160	Mauritania	**46.31**	↓
161	Togo	**46.1**	↓
162	Sierra Leone	**45.98**	↓
163	Ethiopia	**45.83**	↓
164	Djibouti	**45.29**	↓
165	Burkina Faso	**43.71**	↓
166	Benin	**43.66**	↓
167	Liberia	**43.42**	↓
168	Burundi	**43.37**	↓
169	Haiti	**43.28**	↓
170	Sudan	**42.25**	↓
171	Dem. Rep. Congo	**42.05**	↓
172	Mozambique	**41.82**	↓
173	Bangladesh	**41.77**	↓
174	Mali	**41.48**	↓
175	Chad	**37.83**	↓
176	Afghanistan	**37.5**	↓
177	Niger	**37.48**	↓
178	Madagascar	**37.1**	↓
179	Eritrea	**36.73**	↓
180	Somalia	**27.66**	↓



INTRODUCTION

Today's environmental crises upend yesterday's assumptions, establishing a new paradigm captured in the 2016 Environmental Performance Index (EPI). A nation's environment is not its own but is shared with its neighbors and the rest of the world. Pollution is not one country's problem – everyone bears its burden. Local actions lead to global environmental change and national policies have effects beyond state borders. Short-term decisions often produce permanent results. Environmental health is not merely a consideration for some people, but is central to human well-being. The 2016 EPI indicators depict these realities, reflecting global synergies among environmental issues as well as areas where the world's nations show little improvement or, worse, are regressing.

As nations become wealthier, their governments invest in infrastructure that generally lead to improved public health. And yet we also witness a phase of development that coincides with environmental degradation and destruction. Global environmental statistics reflect this tension. More people today have access to clean drinking water than ever before, meaning fewer people get sick and die from waterborne illnesses such as dysentery. Meanwhile we see the opposite trend for air quality; rapid industrialization and urbanization has resulted, in much of the world, in badly polluted air. Human health metrics confirm the toxic air's pernicious effects; in China, for instance, one in five deaths are attributed to air pollution.[1]

Expanding economies and urbanization have also produced conflicting signals in biodiversity and habitat loss. The world's nations have designated more and larger areas of protected land and sea than ever, yet wildlife populations are declining at an alarming rate. The causes are complex and poorly understood. Climate change and human exploitation of animals contribute to biodiversity decline, yet the task of measuring these dynamic agents and their cumulative effect is largely unmet.

A dearth of data confounds efforts to assess environmental quality in other domains, like the world's fisheries, for which reliable information is often unavailable. Illegal fishing, under-reported catches, and data irregularities make it difficult to measure the status of marine fish stocks. Fisheries science, however, has improved steadily, outpacing political responses for marine protection, and the science paints a grim picture of fish population decline in all the world's oceans. While insufficient and unreliable data undermine fisheries policy, agricultural sustainability lacks an agreed-upon foundational concept, an essential requirement of evaluation. Agriculture is a vast and diverse sector, impossible to capture in a single metric, and best agricultural practices vary widely according to geographical context. Despite these obstacles to assessment, there are promising signs that the world's governing bodies have awoken to the importance of measurement in developing equitable and sustainable societies.

Global Policy Developments Warrant New Measurement

Effective environmental solutions are global endeavors, commensurate with the problems they address. This year marks a new era of cooperation and partnership for international environmental policy. The Sustainable Development Goals (SDGs) and Paris Climate Change Agreement establish new models of action for tackling global environmental degradation and climate change. These policy frameworks recognize that all countries are part of the solution and national governments are one group – but not the only – who must lead the way.

Building on the expired Millennium Development Goals (MDGs), which aimed to eradicate extreme poverty, the SDGs articulate 17 goals that apply to all countries. One hundred indicators are now under consideration to measure social, economic, and environmental dimensions of sustainable development across the goals. The Paris Climate Change Agreement, negotiated in December 2015, sets an ambitious plan to reduce global greenhouse gas emissions. 196 countries have signed onto the new agreement, and all have agreed to take action on climate change in line with respective capacities.

Measuring and monitoring progress towards the SDGs and Paris Agreement pledges will be critical to maintaining

1 Forouzanfar M. H., Alexander L., Anderson H. R., Bachman V. F., Biryukov S., Brauer M…(2015). Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 386, 2287-2323.

international cooperation to address global environmental challenges. With 10 comprehensive reports and 15 years experience, the EPI provides a baseline analysis to inform national-level metrics that gauge progress towards global environmental goals, providing snapshots of environmental quality at global and national scales.

The EPI continuously adapts to global events, emerging technologies, and political developments to stay relevant in a changing international policy landscape. Incorporating the latest research and data, the 2016 Index includes new metrics to better capture environmental performance at the country level. Non-state actors, including cities, businesses, states, and regions, are vital yet undervalued entities for solving environmental challenges. For the next generation of environmental policy monitoring, metrics that capture environmental policy performance on priority issues at many levels of governance will be critical.

What is the EPI?

The Environmental Performance Index (EPI) ranks countries' performance on high-priority environmental issues in two areas: protection of human health and protection of ecosystems. Within these two policy objectives the EPI scores country performance in nine issue areas comprised of 20 indicators (see EPI Framework). Indicators in the EPI assess countries' proximity to internationally established targets or, in the absence of agreed-upon targets, how individual nations compare relative to the best performing countries.

The EPI gives decision makers access to environmental data organized in ways that are easy to understand and relevant to policy, with the intention of encouraging nations to compete over advancing policies for the public good. The Index allows countries to compare their performance to neighbors and peers and, through the analysis of time series data, see how their own performance has changed over time.

Demand for robust, authoritative indicators of environmental performance is extremely high, and comes from all quarters of government, research, and activism.

This demand is driven by:

- a widespread recognition of the benefits of data-driven decision making;
- ongoing pressure on governments to invest limited resources as wisely as possible;
- growing concern over the dangers posed by poorly managed environmental risks;
- widespread commitment to making sustainability a central operating principle of the international development agenda; and
- rapid diffusion of sustainability strategies in the corporate sector.

17 Sustainable Development Goals (Source: globalgoals.org)

New Developments

The 2016 EPI introduces a host of innovations and improvements:

A Suite of Environmental Health Risk Measures. In partnership with the Institute for Health Metrics and Evaluation (IHME), we introduce a set of indicators that assess the environmental health risks associated with exposure to poor air and water quality. This measure replaces the Child Mortality indicator used in earlier EPIs, which is a proxy for assessing environmental pollution's impacts on human health. Child mortality is often tied to malnutrition and health care infrastructure - two factors distinct from, yet not entirely unrelated, to environmental pressures (see Box 1: Shifting from Child Mortality to a Broader Environmental Health Measure).

Agriculture. Following a year-long research endeavor, the 2016 EPI introduces new indicators that measure the efficiency and environmental impact of countries' agricultural practices. In step with SDG-2's emphasis on promoting sustainable agriculture, the 2016 EPI agriculture indicators assess the efficiency of fertilizer application and excesses that create environmental hazards, including soil contamination and water pollution. This change improves on earlier proxy measures for environmental pressures attributable to agricultural subsidies and for national legislation regarding the use of Persistent Organic Pollutants (POPs) chemicals defined by the Stockholm Convention.

Air Quality. Partnering with Dalhousie University, the 2016 EPI includes a new air quality indicator for nitrogen dioxide (NO_2). NO_2 emissions from fossil fuel combustion is hazardous to human health because of the compound's propensity to react with other chemicals, including Volatile Organic Compounds (VOCs), and produce ozone, fine particulate matter (PM2.5), and smog. Ground-level ozone and smog cause a range of insidious human health effects, including respiratory illnesses and heart and lung disease. Some governments directly monitor NO_2, but measurement is not universal. Satellite data fill the gaps, providing critical insight into ground-level exposures to NO_2.

Biodiversity and Habitat. Collaborating with the Map of Life - a global biodiversity database based at Yale University - the 2016 EPI introduces new Species Protection indicators that assess whether protected areas align with species' actual habitats. The new species protection indicators, paired with our Terrestrial and Marine Protected Areas indicators, provide a deeper understanding of nations' effectiveness in conserving habitats and protecting species.

Fisheries. Incomplete and poor quality data regarding international and nationally-reported fisheries led Sea Around Us – a fisheries research institute based at the University of British Columbia – to reconstruct and correct country fish catch datasets. This multi-year process has led to improved fish catch data from 1950 to 2010, although data validation is still ongoing. These reconstructed datasets hold the promise of more accurate fish catch data, yet the 2016 EPI incorporates a penalty based on expert-evaluated data quality that takes into consideration underreported data.

Forests. Using the latest Global Forest Watch data, the 2016 EPI measures tree cover loss over the last 15 years. The use of satellite data allows for global comparability to determine which countries are preventing tree cover loss, which has serious impacts on biodiversity and habitat preservation, climate change, and water cycles.

Box 1. SHIFTING FROM CHILD MORTALITY TO A BROADER ENVIRONMENTAL HEALTH MEASURE

Thirty-one to 40 percent of the disease burden for children under the age of five is attributable to environmental risk factors – mainly poor air quality and insufficient sanitation leading to unsafe drinking water.[2] Because the environment is such a large contributor to child mortality, the probability of a child dying between his or her first and fifth birthday is a strong indicator of a nation's environmental health pressures. The connection between child mortality and environmental vectors in part spurred Millennium Development Goal 4 (MDG-4), which set a target to reduce the under-five mortality rate by two-thirds from 1990 to 2015. The global under-five mortality rate declined in this period by more than half. Harnessing this momentum, the Sustainable Development Goals (SDGs) continued MDG-4, setting a target to end all preventable deaths of newborns and children under five by 2030.[3]

SDG-3 promotes human health and also introduces a goal to, by 2030, "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination." This new goal is one impetus for the 2016 EPI's introduction of a new indicator to measure environmental health: an Environmental Risk Exposure (ERE) variable that summarizes the health risk that poor air and water quality pose to populations, weighted by how much the particular risk factor contributes to a country's overall burden of disease (i.e., Disability-Adjusted Life Year or DALY). Summarized across all sexes and ages, this new ERE measure captures a holistic impact of environmental health pressures to a country's entire population. See Health Issue Profile for more information.

Why Measurement Matters?

The EPI was born out of recognition that environmental policymaking often lacks scientific, quantitative rigor. Millennium Development Goal 7 – to ensure environmental sustainability – brought attention to the linkages between sustainable development and poverty eradication, yet the goal lacked relevant or specific metrics.[4]

To address this gap, the Environmental Performance Index (EPI) was created with the aim to shape data-driven environmental policymaking. Effective environmental policy is burdened by two related hurdles, both of which are made less onerous through better measurement. First, environmental policy debates elicit deep divisions over the best way forward. Second, uncertainty about the nature and cause of environmental problems makes strong action and allocation of resources difficult to justify. Good environmental measurement injects objectivity into environmental policy debates, reducing disagreement about the scope and seriousness of problems and focusing attention on solutions.

Robust measurement also gives policymakers a foundation from which to promote environmental policy. When decision makers use data to reduce uncertainty, they can advance policy objectives with more than educated guesses or hunches. The trend of using data, and increasingly "big data," has become a common business and government practice.

Businesses have long understood that data can make the invisible visible, and firms use metrics ubiquitously to improve performance. Environmental indicators have been proven as useful tools in helping policymakers more efficiently allocate scarce resources. As the time-tested axiom goes, "You can't manage what you don't measure."

2 Prüss-Üstün, A. (2006). Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease. World Health Organization: Geneva.

3 United Nations. (2015). Goal 4: Reduce Child Mortality. Available: http://www.un.org/millenniumgoals/childhealth.shtml.

4 World Economic Forum (WEF) Global Leaders for Tomorrow Environment Task Force, Yale Center for Environmental Law and Policy (YCELP)/Yale University, and Center for International Earth Science Information Network (CIESIN)/ Columbia University, (2000). 2000 Pilot Environmental Sustainability Index (ESI). NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY. Available: http:// sedac.ciesin.columbia.edu/data/set/esi-pilotenvironmental-sustainability-index-2000.

Measurement provides what we need to know and highlights gaps in collective knowledge. The EPI was founded to correct the global scarcity of data describing environmental problems. At the local, national, and international levels, decision makers require detailed, accurate information. Indices, like the EPI, direct attention to data gaps, which can help generate efforts to achieve better information and spur novel data-gathering methods.

Why Rank?

Rankings, which are both loved and loathed, create interest and provoke action. They are a vehicle to motivate policy change and, at the very least, they spark conversation about an index's meaning. How a number is derived, its strengths and its limitations, opens discussion about what we should value and why. Rankings are sensitive to minute methodological changes, and thus have inherent subjective characteristics, but EPI users can pare the Index down to peer groups that afford salient, meaningful comparisons.

The EPI's primary value is its potential to illuminate avenues for change. More valuable than the rankings in and of themselves are the metrics and data that underpin the index.

A single number is attention-grabbing, but it is the subsequent inquiry and substantive conversation that are the project's most useful products. The transparency with which the EPI is constructed and the openness of its underlying data allow countries to use the EPI as a starting point for taking environmental action. These steps ideally would include:

→ development of better measurement and monitoring systems to improve environmental data collection;

→ creation of policies to address particularly weak areas;

→ communication and reporting of national-level data and statistics to international agencies such as the United Nations; and

→ delineation of sub-national metrics and targets for improved environmental performance.

Organization of this Report

This report aims to provide a narrative to help everyone grasp the environmental challenges that all countries face, regardless of the nation's level of economic development, geography, land area, or population. The report intends to make sense of environmental data's complexities and nuances and to enable readers to delve into the results presented by the EPI.

The report contains enough detail to provide a working knowledge of the EPI and its methods, yet it is not comprehensive. Specific information about the EPI's data, indicator calculations, and statistical methods is included in separate materials both on the 2016 EPI website (www.epi.yale.edu) and in forthcoming academic literature. All EPI data and infographics are available for free download and use under a creative commons license. By separating the technical from the illustrative, this report provides a qualitative look into the critical environmental issues that the EPI examines.

The 2016 EPI report is organized as follows:

- A Methods section provides an overview of how the EPI is calculated, how weightings are applied and take into consideration relevant issues for countries (e.g., what we refer to as "Material Thresholds"), and gaps in existing data;
- Nine issue profiles frame each environmental problem included in the 2016 EPI, examining the complexities involved in measuring national performance and distilling relevant policy signals from science and available data. These profiles draw attention to obstacles and opportunities posed by comparing disparate countries and the lack of comprehensive, timely and accurate data to develop indicators.
- The Regional Results and Trends section provides analysis of regional trends and results within relevant economic and political country groups.
- The report's Conclusion points to future areas of research.

METHODS

The EPI Framework

The Environmental Performance Index (EPI) is constructed through the calculation and aggregation of more than 20 indicators reflecting national-level environmental data. These indicators are combined into nine issue categories, each of which fit under one of two overarching objectives. This section provides an overview of how the EPI is calculated. Complete methodological details and indicator-level metadata are available at **www.epi.yale.edu**.

Figure 7: The 2016 EPI Framework includes 9 issues and more than 20 indicators.
Access to Electricity is not included in the figure because it is not used to calculate country scores.

Box 2. SELECTION CRITERIA FOR DATA IN THE EPI

- **Relevance:** The indicator tracks the environmental issue in a manner applicable to countries under a wide range of circumstances.
- **Performance orientation**: The indicator provides empirical data on ambient conditions or on-the-ground results for the issue of concern, or it is a “best available data” proxy for the outcome measures.
- **Established scientific methodology:** The indicator is based on peer reviewed scientific data, data from the United Nations or other institutions charged with data collection.
- **Data quality:** The data represent the best available measure. All potential datasets are reviewed for quality and verifiability. Those that do not meet baseline quality standards are discarded.
- **Time series availability:** The data have been consistently measured across time, and efforts are made to continue consistent measurement.
- **Completeness**: The dataset must have adequate global and temporal coverage to be considered.

Calculating the EPI

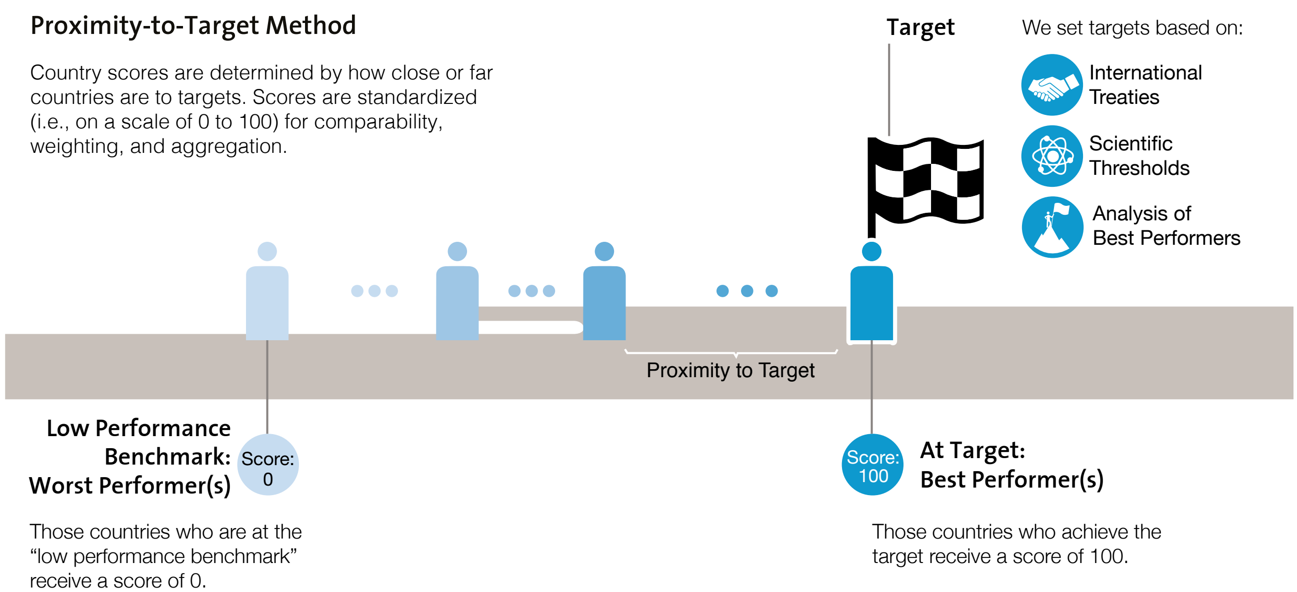
To create the EPI we transform raw datasets into comparable performance indicators, which requires standardizing raw values according to population, land area, gross domestic product, and other common units of measurement. We then perform statistical transformations to normalize data distributions and ensure weights assigned in the aggregation phase affect data as intended and are not influenced by skewed numbers. For more details on the EPI’s calculation methods, see www.epi.yale.edu.

The transformed data are used to calculate performance indicators. We develop EPI indicators using a “proximity-to-target” methodology, which assesses how close each country is to an identified policy target. The targets are high performance benchmarks defined primarily by international or national policy goals or established scientific thresholds. The benchmarks for protected areas, for example, are based on international policy targets established by the Convention on Biological Diversity (CBD). With 168 signatory countries and 196 Parties to the Convention, these benchmarks are widely accepted.

A high-performance benchmark can be determined through an analysis of the best-performing countries. Some of our indicators set benchmarks, for example, at the 95th percentile of the range of data. In some cases, the target is defined by established scientific consensus, as with the World Health Organization’s (WHO) recommended average exposure to fine particulate matter (PM2.5). Scores are then converted to a scale of 0 to 100 by simple arithmetic calculation, with 0 being the farthest from the target and 100 being the closest (Figure 8). In this way, scores convey analogous meaning across indicators, policy issues, and throughout the EPI.

Each indicator is weighted within the issue categories to create a single issue category score. These weightings are generally set according to the quality of the underlying data, as well as an indicator’s relevance or fit for assessing a given policy issue. If the underlying data for a particular indicator is less reliable or relevant than others in the same issue category, the indicator will be weighted less. Policy issues are weighted approximately equally within their objective (i.e., Environmental Health or Ecosystem Vitality). Contingent on the data strength in each category, slight adjustments to this weighting can be made. Because the Fisheries indicator’s

Figure 8: A proximity-to-target methodology is used to benchmark country's performance against targets.



data has not been fully vetted (see Fisheries Issue Profile for more information), this category affects only 5 percent of a country's score in Ecosystem Vitality.

Countries only receive scores for issues that are "material" or relevant to their environmental performance (see Material Thresholds below). The exclusion of certain issues for some countries proportionally increases the weight on other indicators within a policy issue and objective. A landlocked country's four Biodiversity and Habitat indicators (e.g., Terrestrial Protected Areas and Species Protection), for instance, receive 25 percent equal weight instead of 20 percent because the nation will not be assigned a Marine Protected Areas score.

The two objectives, Environmental Health and Ecosystem Vitality, are weighted equally to achieve a single value, the EPI score, for each country. For a more detailed explanation of the methods used for the 2016 EPI, see www.epi.yale.edu and *Measuring Progress: A Practical Guide from the Developers of the EPI.*[5] The EPI methodology has been replicated and adapted at the sub-national and provincial to evaluate environmental performance in several countries, including China, Malaysia, and Viet Nam (see Box 3: Smart-Scaling the EPI).

5 Hsu, A., Johnson, L., & Lloyd, A. (2013) Measuring Progress: A Practical Guide from the Developers of the Environmental Performance Index. Yale Center for Environmental Law and Policy: New Haven, CT. Available: http://epi.yale.edu.

Box 3. SELECTION CRITERIA FOR DATA IN THE EPI

A growing number of countries and regions have replicated or adapted the EPI's methodology and framework to assess environmental performance at the sub-regional or provincial level.[6] In addition to demonstrating the EPI's reach, these indices reflect the range of priorities driving a nation's environmental efforts, from China's concerns about economic sustainability to the Basque Country's drive to document its independent environmental efforts.

- Over a two-year period, **China** adapted the EPI framework by adding a third category on economic sustainability, reflecting the country's green growth priorities.[7]
- The **Basque Country** (Spain) EPI shows how a politically contested region used environmental performance as a way to compare itself to other European countries.[8] The index, released in 2013, marked the first index to compare sub-national governments to national ones.
- **India** launched an Environmental Sustainability Index at the state level, with a focus on critical in-country issues such as population pressures, waste management, and environmental budgets.
- Acknowledging the key role of cities in sustainability, **Malaysia** integrated new indicators on urban environmental performance and governance[9] into the second version of its state-level EPI,[10] launched in 2014.[11] Their website offers a close look into their methodology and results.[12]
- **Viet Nam** completed an EPI feasibility study at the provincial scale.[13] Provincial pilot studies pairing on-the-ground and satellite data on air quality and forest cover are now underway.
- In 2009, the **Abu Dhabi Emirate** (UAE) completed an EPI assessment, which took a deep look at key local issues including water and air quality.[14]

These cases demonstrate how smart-scaling the EPI framework to local contexts and scales can help countries prioritize key environmental issues. While the global EPI provides an overall picture to compare countries, the flexibility of the framework allows for wide and varied applications to capture key environmental metrics.

6 Yale Environmental Performance Index. Urban and Sub-National Applications. (n.d.). Available: http://epi.yale.edu/urban-and-sub-national-applications.

7 Hsu, A. and W. Miao. (2014, April 3). China's performance on the 2014 Environmental Performance Index: What are the key takeaways? Yale Environmental Performance Index, *The Metric.* Available: http://epi.yale.edu/the-metric/chinas-performance-2014-environmental-performance-index-what-are-key-takeaways.

8 Yale Environmental Performance Index, *Indicators in Practice.* (2015, February 20). Basque Country's Environmental Performance Index. Available: http://epi.yale.edu/indicators-in-practice/basque-countrys-environmental-performance-index.

9 Hawkins, N. (2014, May 22). Malaysia's Environmental Performance Index. Yale Environmental Performance Index, *Indicators in Practice.* Available: http://epi.yale.edu/indicators-in-practice/malaysias-environmental-performance-index-0.

10 Yale Environmental Performance Index, *The Metric.* (2015, February 15). MyEPI: Malaysia launches 2014 Environmental Performance Index. Available: http://epi.yale.edu/the-metric/myepi-malaysia-launches-2014-environmental-performance-index.

11 Yale Center for Environmental Law and Policy. (2015). Malaysia launches 2014 Environmental Performance Index. Available: https://vimeo.com/149734704.

12 Malaysia Environmental Performance Index. (n.d.). Available: http://www.epi.utm.my/v3/.

13 Zomer, A. (2014, December 9). Improving environmental data and performance in Viet Nam. Yale Environmental Performance Index, *The Metric.* Available: http://epi.yale.edu/the-metric/improving-environmental-data-and-performance-viet-nam.

14 Spawn, A. (2015, April 2). From Global to Regional: The Abu Dhabi EPI. Yale Environmental Performance Index, *The Metric.* Available: http://epi.yale.edu/the-metric/global-regional-abu-dhabi-epi.

Data Sources

The EPI uses primary and secondary data from multilateral organizations, government agencies, and academic collaborations. Primary data are comprised of information gathered directly by human or technological monitoring, including satellite-derived estimates of forest cover and air quality. Secondary data include national-level statistics subject to the reporting and quality requirements established by data collection entities, such as the International Energy Agency (IEA). The EPI applies a set of criteria to determine which datasets to select for inclusion (see Box 2: Selection Criteria for Data in the EPI).

All sources of data are publicly available and include:

- official statistics measured and formally reported by governments to international organizations. These data may or may not be independently verified but are included only if formally reported to international organizations. The EPI does not include ad hoc data submitted by governments directly to the EPI team;
- spatial or satellite data;
- observations from monitoring stations; and
- modeled observations.

Material Thresholds

Is a particular issue relevant to a country's environmental performance?

How do we account for differences in natural resource endowments, physical characteristics, and geography between countries? For example, how do we compare landlocked countries, for whom fisheries and marine sustainability are irrelevant, to island nations, or desert countries with little or no tree cover to nations with vast forests? In these cases, fisheries and forests may be considered "immaterial" or insignificant for a particular country (see Table 1). Only if an indicator meets the criteria for being "material," or relevant, in a certain country is the indicator included in the calculation of the country's score. For nations that do not meet the material threshold (e.g., a minimum area of land that is forested), the indicator or issue category is not included in the score calculation. For these countries, other indicators in the relevant category or categories receive proportionally greater weight.

By this reasoning, Least-Developed Countries (LDCs), which often include Small Island Developing States (SIDS), do not receive a score for Climate and Energy (see Climate and Energy Issue Profile), so the weightings for the remaining policy issues in the Ecosystem Vitality objective, including Agriculture, Water Resources, Biodiversity and Habitat, Forests, and Fisheries, increase proportionally.

Table 1: The materiality rules apply when countries meet certain thresholds listed above.

Indicator or Policy Issue	Not Evaluated If...
Biodiversity and Habitat – Marine Protected Areas	Landlocked or ratio of coastline to land area less than 0.01.
Climate and Energy	Least-developed countries and small-island developing states.
Fisheries	Landlocked or ratio of coastline to land area less than 0.01.
Forests	Total forested area less than 200 sq. km or less than 3 percent of total land area is covered with greater than 30 percent tree canopy.

Table 2: Scoring system for deriving uncertainty bands for the quality of time series data of reconstructed catches, adapted from the Intergovernmental Panel on Climate Change (IPCC) (Pauly & Zeller, 2016, *forthcoming*).

Score	Confidence Interval +/ %	Corresponding IPCC criteria	2016 EPI Penalty
4 Very High	10	High agreement and robust evidence	0%
3 High	20	High agreement and medium evidence or medium agreement and robust evidence	75%
2 Low	30	High agreement and limited evidence or medium agreement and medium evidence or low agreement and robust evidence	50%
1 Very Low	50	Less than high agreement and less than robust evidence	25%

Fisheries Penalties

The 2016 EPI reduces a country's Fisheries score based on expert evaluations of the nation's fisheries data quality. Table 2 describes the penalties applied based on data quality scores that experts provided for each country's Exclusive Economic Zone (EEZ), for each fishing sector (i.e., industrial, artisanal, recreational, and subsistence).[15] See the Fisheries Issue Profile for more information.

15 Pauly, D. & D. Zeller. (2016, *forthcoming*). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications.*

Box 4. DATA GAPS AND DEFICIENCIES

The EPI is not a fully comprehensive picture of national and global environmental issues. The Index's goal is to provide a global assessment of environmental performance among nations, so we only gauge national environmental results on issues for which there are globally comparable data. After more than 15 years of work on environmental performance measurement and seven iterations of the EPI, global data remain incomplete for a number of key environmental issues

These include:

- Freshwater quality
- Species Loss
- Indoor air quality of residential, commercial buildings
- Toxic chemical exposures
- Municipal solid waste management
- Nuclear safety
- Wetlands loss
- Agricultural soil quality and degradation
- Recycling rates
- Adaptation, vulnerability, and resiliency to climate change


Roof garden, New York

HEALTH IMPACTS

The Environmental Risk Exposure indicator assesses human health risks associated with unsafe water and sanitation as well as household and outdoor air quality.

What it measures:

The Environmental Risk Exposure (ERE) indicator assesses hazards to human health posed by five environmental risk factors: unsafe water, unsafe sanitation, ambient particulate matter pollution, household air pollution from solid fuels, and ambient ozone pollution. On a unitless scale from 0 to 1, with 0 indicating no risk and 1 corresponding to maximum risk, the ERE indicator describes the dangers these environmental factors pose to human health, weighting each risk factor's contribution to a nation's burden of disease.

Why we include it:

ERE describes actual health outcomes, complementing the EPI's Air Quality and Water indicators, which characterize the factors that drive these health effects rather than the outcomes themselves. Measuring environmental factors aligns with policy targets promulgated by the World Health Organization and United Nation's Sustainable Development Goals, yet this approach captures a partial picture. →

~5 times

more people die from poor air quality than unsafe water.

ERE fills in the missing half of the equation, reporting on human health risks to environmental pollution and providing a summary of health outcomes across age and gender.

By quantifying environmental health risks for an entire population, the ERE measure gives an aggregate estimate of how environmental pollution affect human health at the national level. Specificity allows policymakers to spot public health threats and identify interventions that would best prevent hazardous exposure and reduce negative health outcomes.

Where the data come from: The Environmental Risk Exposure data comes from the Institute for Health Metrics and Evaluation's Global Burden of Diseases, Injuries, and Risk Factors 2013 (GBD) study, the world's most comprehensive comparative risk assessment of epidemiological trends.[16] GBD works with more than 1,000 collaborators in 114 countries to collect data from studies, surveys, and satellites and transform the information into 79 risks or clusters of risks that track different age groups and sexes over time. For more information, see 2016 EPI Metadata.

> In 2013, unsafe water was responsible for 2% of global deaths (~1.24 million), while poor air quality was responsible for 10% of all global deaths (~5.52 million).

What are the targets: Proximity to 0 (on a unitless scale), meaning that the environmental risks including unsafe water and sanitation as well as household and outdoor air quality are minimal to nonexistent in impacting health.

DESCRIPTION

With her landmark book, *Silent Spring* (1962), Rachel Carson documented the harmful effects on human and ecosystem health — particularly on birds — of the indiscriminate use of pesticides. Carson's research uncovered the chemical industry's disinformation campaign and the government cover up, leading to a nationwide ban on DDT – a hazardous synthetic insecticide. A half-century later, a documentary film called *Under the Dome* (2013),[17] produced by former China Central Television reporter Chai Jing, exposed the link between air pollution and premature deaths in China. The documentary, touted as China's *Silent Spring*, went viral, garnering more than 200 million views in one week before government officials pulled the film from the Internet.

Separated by more than 50 years, *Silent Spring* and *Under the Dome* both strive to raise awareness of anthropogenic pollutants' threat to human health. Like Carson a generation ago, Chai builds her argument with scientific data, lending irrefutable substance to the claim that air pollution is gravely harmful to humans. Both works are calls to action, drawing direct links between our stewardship of the planet, its air and soils, and our individual, physical health. The United States federal government responded to the Silent Spring outcry by tightening the country's pesticide regulations, but in China policymakers have struggled to balance clean air with growth demands.

Both 'Silent Springs' illustrate the inextricable link between human health and the environment – an intersection that the EPI strives to measure through the Health Impacts category. Between 3.4 million and 7 million premature deaths annually are linked to air pollution and millions more people succumb to water and hygiene-related illnesses. Poor and insufficient sanitation trigger 11 percent of child mortalities under the age of five – 2,200 children die every day from diarrhea.[18] Environmental toxicity is inextricably linked to human health

16 Forouzanfar M. H., et al. 2015.

17 Hsu, A., P. Hirsch, A. Moffat, & K. Xu. (2015). Infographic: Setting the Record Straight for Under the Dome. Yale Environmental Performance Index, *The Metric*. Available: http://epi.yale.edu/the-metric/infographic-setting-record-straight-under-dome.

18 Center for Disease Control and Prevention. (2015). Global Water, Sanitation, and Hygiene (WASH) Fast Facts. Available: http://www.cdc.gov/healthywater/global/wash_statistics.html.

as well as to basic human rights. When policymakers enhance access to potable water and reliable sanitation or improve their nation's air quality, they are managing environmental issues while addressing essential human well-being.

Defining a Risk Factor

The ERE indicator is a measure that combines environmental risk factors to gauge a person's risk of getting sick, developing a chronic illness or disability, or dying from exposure to toxic air, foul water, or poor sanitation. Risk factors are variables like a person's age, gender, diet, environmental condition, or any characteristic that could contribute to illness, disability or death. Combined, these risk factors are used to calculate a Global Burden of Disease (GBD) that estimates mortality and morbidity attributable to these risks.

Disentangling environmental factors and attributing health outcomes to these variables is an exceptionally difficult endeavor. Risk factors reflect associations between health outcomes and their possible causes, and confounding variables create uncertainty that remains a perennial attribute of the equation. Correlation can only imply causation; one type of cancer, for instance, could develop from a variety of risk factors, both environmental and non-environmental, that act individually or in concert. The same risk factors could cause a host of other health effects besides cancer.[19] Environmental risk factors adjust for this inherent uncertainty by calculating probabilities that reflect the likelihood that a specific outcome resulted from the suspected risk(s).

Calculating the Attributable Disease Burden of a Risk Factor

IHME relates risk factors to health outcomes for every age, sex, cause, year, and country by computing the fraction of observed outcomes that can be attributed to each environmental characteristic. Health results are measured in deaths, years of life lost, years lived with disability, and disability-adjusted life years (DALYs), which, taken together, constitute the "burden of disease." IHME calculates the "population attributable burden" for exposure to each risk factor by comparing a) the relative risk of becoming ill following exposure to the risk factor; and b) the risk factor's theoretical minimum risk exposure level (TMREL), which is the safest theoretical level of exposure for any population.[20] The relative risk component of the equation is expressed as a ratio of probabilities - one for people who have been exposed the risk at TMREL and another probability for those who have not been exposed.

TMRELs – analogous to the EPI's targets – are informed by research from the world's leading public health institutions and epidemiologists. TMRELs define ideal conditions that are technically possible to achieve but may not be affordable, feasible, or likely to occur. For instance, IHME defines the highest performance benchmark for unsafe water as, "all households have access to water from a piped water supply that is also boiled or filtered before drinking." Other TMREL targets are expressed across a range of acceptable exposure levels, such as concentrations of particulate matter in the air. By comparing observed health outcomes to what would have been expected if every country met these ideal minimum exposure levels, public health officials observe how much of their country's burden of disease can be reduced.[21]

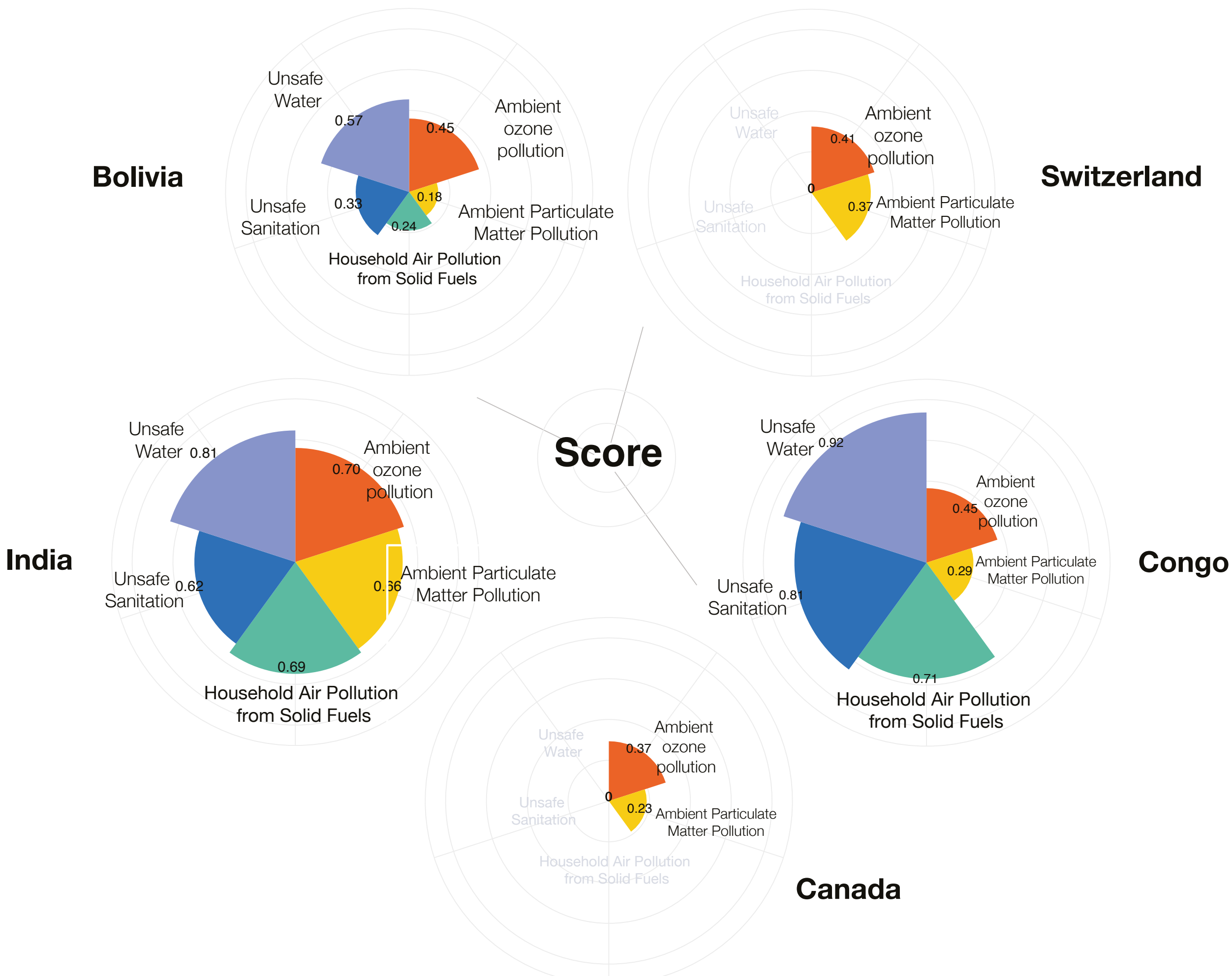
The attributable burdens for unsafe water (only pathogens and not chemical risks), unsafe sanitation, ambient particulate matter pollution, household air pollution from solid fuels, and ambient ozone pollution in each country are standardized by age and combined into a summary statistic, weighted according to each risk factor's contribution to a country's DALYs. The resulting ERE score, ranging from 0 to 1, is provided in 5-year intervals, beginning in 1990 and ending with the most recent statistics from 2013.

19 Kundi, M. (2006) Causality and the interpretation of epidemiologic evidence. *Environmental Health Perspectives*, 114, 7, 969-974.

20 Forouzanfar, M. H., et al. (2015). Appendix A: Methods Overview of Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 386, 2-23.

21 Forouzanfar, M. H., et al. (2015).

Figure 9: Health exposure risk factor scores for five selected countries reveal varying challenges for countries at different stages of development.



What Risk Factors Reveal

The ERE's individual risk factors communicate the relative risk an environmental factor poses, both within a country and between countries. Figure 9 illustrates health risk exposure scores for the five environmental risk factors used in the ERE. Assessing countries' scores side by side demonstrates the ERE variables' strength as a comparable metric, similar to the EPI's indicators that range from a score of 0 to 100. The ERE enables researchers and public officials to compare risk factors within a country (e.g., whether poor sanitation or poor air quality pose a greater risk to human health in a given country) and between countries (e.g., whether household air pollution is a greater risk to human health in one country versus another).

According to the ERE indicator, for example, unsafe water is Bolivia's greatest environmental public health problem with a value of 0.57. Ambient particulate matter pollution is the country's least hazardous environmental health concern, with a value of 0.18. In the Republic of the Congo, the degrees of risk vary more widely. Its people suffer from the ills associated with unsafe water, poor sanitation, and household air pollution from solid fuels, but the nation's outdoor air quality, particularly ambient particulate matter pollution, is relatively good. Switzerland and Canada, by comparison, boast safer conditions with respect to water, sanitation, and household air quality, yet their outdoor air pollution risk factors are similar to those in Congo. This comparison highlights the challenges of industrialization: wealthier nations have resources to invest in clean water infrastructure, although urbanization and rapid growth can simultaneously generate poor air quality. Some countries, like India, perform poorly across all five environmental risk factors almost equally, and no countries lack problem areas.

Regional and Global Trends

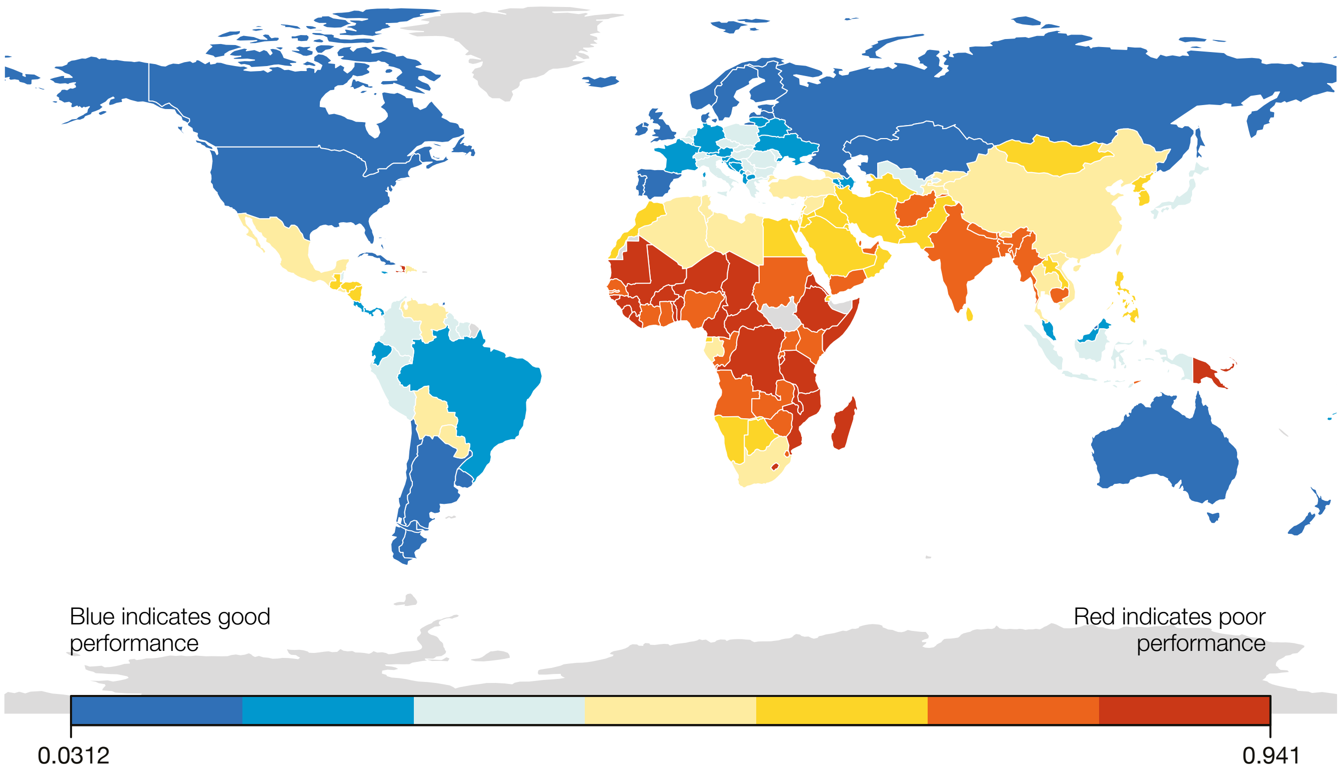
Despite infrastructure improvements and reductions in environmentally related mortality, poor air and water quality continues to be responsible for premature deaths globally. Health risks associated with ambient particulate matter pollution have increased by six percent from 2000 to 2013, pushing this hazard from the 12th largest global risk factor to 11th. The number of global deaths from air pollution has risen from 2.2 million in 2000 to 2.9 million in 2013, while the attributable DALYs have actually fallen, an indication that air pollution is killing rather than sickening or disabling more people than before. Indoor and outdoor air pollution killed at least 5.5 million people in 2013, while another 141.5 million individuals lost a portion of healthy years from their lives.[22] In China, air pollution is now responsible for one out of every five deaths, killing 4,000 people every day,[23] ranking the air people breathe as China's third most dangerous risk factor.[24]

Of the 180 countries that receive ERE scores in the 2016 EPI, almost all (160) show improved marks from 1990 to 2013, meaning their environmental risk exposures have declined over time. A significant portion of these environmental health improvements is attributable to improved global hygiene and water quality. Among the GBD's 79 risk factors, unsafe water was responsible in 2000 for the fourth-highest number of DALYs in the world. The health burden due to poor sanitation also decreased in the same period.[25]

Against the trend of global improvements, 14 countries have seen their ERE scores increase, including worst performers Brunei, Venezuela, United Arab Emirates, and Kuwait. Figure 10 shows that South Asia and most of the African continent exhibit the greatest need to improve environmental public health conditions in the coming years. While many African countries are burdened with poor water quality, air pollution has become one of the world's greatest public health threats. Indoor air pollution is the world's fourth leading cause of ill health, and ambient outdoor air pollution is today the ninth leading cause of premature deaths and poor health worldwide.[26]

22 Forouzanfar, M. H., et al. (2015).
23 Rohde, R. A. & R. A. Muller. (2015). Air pollution in China: Mapping on Concentrations and Sources. PLoS ONE, 10, 8, e0135749.
24 Institute for Health Metrics and Evaluation. (n.d.). China Country Profile. Available: http://www.healthdata.org/china.
25 Forouzanfar, M. H., et al. (2015).
26 Institute for Health Metrics and Evaluation. (n.d.). Air Pollution. Available http://www.healthdata.org/air-pollution.

Figure 10: Global map of EPI 2016 final summary ERE scores.



With falling numbers of deaths due to poor water and sanitation and simultaneously increasing deaths due to air pollution, environmental risk factors accounted for only 12.7 percent of the GBD in 2013. Despite the environment's potent influence on human health, behavioral risk factors like smoking, driving, and dietary choices comprise the largest proportion, at 40.3 percent, of the GBD.[27] What this difference between environmental and behavioral contributions to the global GBD means is that policy efforts to minimize pollution are important to reduce environmentally-related premature deaths, but the need for behavioral interventions to change unhealthy consumption patterns or to prevent reckless driving may be a higher priority for some countries (see Box 5: A Road Safety Crisis in the Middle East). Minimizing environmental risk will certainly help countries improve public health, yet focusing on other factors is also important. Recognizing the connection between environmental health and sustainable development, the 17 global Sustainable Development Goals include a dedicated health goal with many cross-cutting targets.[28] Large-scale datasets, like the Global Burden of Disease, help identify priorities in the public health and environmental sectors that improve health and well-being for the world's people.

27 Forouzanfar, M. H., et al. (2015).

28 World Health Organization. (2015). Health in 2015: from MDGs to SDGs. Available: http://apps.who.int/iris/bitstream/10665/200009/1/9789241565110_eng.pdf?ua=1.

Box 5. A ROAD SAFETY CRISIS IN THE MIDDLE EAST

EPI's Health Impacts focus on environmental risk exposure, yet these exposure numbers make up only one subcategory that contributes to a country's health risks. Environmental risks account for nearly 13 percent of global health risks; occupational and behavioral factors, like driving, account for the bulk of risk.[29] Environmental causes' relative proportion of overall risk depends largely on the hazards that other factors pose.

In the Middle East region, increasing road injuries and traffic fatalities are a central public health concern. Poor road safety in the region goes against the trend typically observed as countries become wealthier – most countries improve their road conditions with economic development.[30]

Traffic fatalities and road injuries in Oman, Qatar, and Saudi Arabia accounted for a significant fraction –from 7 to 16 percent– of these nations' 2013 Disability Adjusted Life Years (DALYs).[31] Oman, Saudi Arabia, Iran and Libya are among the ten worst performers in global road traffic mortality and injury rates.[32] Road injuries in the United States, by comparison, accounted for less than 3 percent

Highway intersection Dubai

of its 2013 DALYs,[33] even though driving is one of the most dangerous activities that Americans undertake on a daily basis.[34]

High driving speeds, a lack of effective policing and penalties, and poor road design and vehicle regulations are compounded by the region's rapid build-out of roads and rising rates of motorization, creating the Middle East's hazardous road conditions.[35] In Oman, excessive driving speeds and poor driving practices contribute to the deaths of more than 900 people each year. Qatar loses an estimated 200 citizens annually, and crashes cause more than 27 deaths per 100,000 residents in Saudi Arabia.[36]

These accidents disproportionately affect the young and the poor. In Middle Eastern and North African countries, traffic injuries are the leading cause of deaths for 10-35 year olds.[37] Poor households make up a majority of road traffic injury victims, and are most severely affected by the estimated $120 billion USD toll that traffic crashes exact on this region's economy.[38]

It would require new legislation, regulation, enforcement, and behavioral changes to reverse this trend. In 2008, a World-Bank-led Global Road Safety Facility recommended investing $4 billion USD in 2010 and up to $9 billion USD in 2020 to cut traffic forecasted traffic fatalities by 50 percent from 125,000 to 65,000 in 2020.[39] This funding should support the creation of road safety agencies that set and monitor progress towards short, medium, and long-term targets. Improving vehicle standards, promoting car ownership and accountability mechanisms, and retrofitting high-risk roads to protect vulnerable users are also priority actions for keeping people safe on the road.[40]

29 Forouzanfar M. H., et al. (2015).

30 Dahdah, S. & Bose, D. (2013). Road Traffic Injuries: A Public Health Crisis in the Middle East and North Africa. World Bank. Available: http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1227561426235/5611053-1231943010251/trn-45_Road_Traffic_Injuries_in_MENA_Countries_FINAL.pdf.

31 Institute for Health Metrics and Evaluation. (2015). Global Burden of Disease Compare. Available: http://www.healthdata.org/results/data-visualizations.

32 Dahdah, S. & Bose, D. (2013).

33 Institute for Health Metrics and Evaluation. (2015).

34 Savage, I. (2013). Comparing the fatality risks in United States transportation across modes and over time. The Economics of Transportation Safety, 43, 9-22.

35 Dahdah, S. & Bose, D. (2013).

36 Global Road Safety Partnership. (2015). Middle East/North Africa country profiles. Available: http://www.grsproadsafety.org/where-we-work/middle-east-north-africa.

37 Dahdah, S. & Bose, D. (2013).

38 World Health Oragnization. (2013). iRAP analysis of road crashes. McMahon & Dahdah (2008), Dahdah, S. & Bose, D. (2013).

39 Dahdah, S. & Bose, D. (2013).

40 Dahdah, S. & Bose, D. (2013).

AIR QUALITY

Air Quality measures exposure to fine particulate matter, nitrogen dioxide, and percentage of the population burning solid fuel indoors.

What it measures:

This category includes four key indicators: Air Pollution- Average Exposure to $PM_{2.5}$ (fine particulate matter in micrograms per cubic meter ($\mu g/m^3$); Health Risk Exposure to $PM_{2.5}$; $PM_{2.5}$ Exceedance (an average of the percentage of the population exposed to PM2.5 levels at 10 $\mu g/m^3$, 15 $\mu g/m^3$, 25 $\mu g/m^3$, and 35 $\mu g/m^3$ - World Health Organization's (WHO) air quality guidelines and interim I, II, and III targets;[41] Household Air Quality – Indoor Solid Fuel Usage; and Average Concentration of NO_2 (in parts per billion).

Why we include it:

Suspended particulates contribute to acute lower respiratory infections and other diseases such as cancer. They can penetrate human lung and blood tissue, leading to higher incidences of cardiovascular and lung disease. Fine particulates or $PM_{2.5}$ (2.5 microns and smaller) lodge deep in lung tissue and are injurious to health. →

Cooking with solid fuels over open fires or in simple stoves exposes households to daily pollutant concentrations that lie between those of second-hand smoke exposure and active smoking. A measure of solid fuel use is a proxy for household air pollution and serves as an estimation of health impacts from household air pollution in the 2013 GBD.[42]

Nitrogen dioxide (NO_2) is produced as a result of road traffic and other fossil fuel combustion processes. Strong associations between NO_2 and mortality have been identified in multi-city studies around the world.[43] Health risks of NO2 come from itself or its reaction products including Ozone (O_3) and secondary particles.[44] According to the United States Environmental Protection Agency, direct exposure to NO_2, ranging from 30 minutes to 24 hours, can cause airway inflammation and diminished respiratory function for people with asthma.[45] NO_2, when combined with volatile organic compounds (VOCs), forms ground-level ozone or smog observable in many cities. Inhalation of ozone leads to increased incidence of acute respiratory illness in susceptible populations including children, the elderly, and people with lung diseases. Small particles are formed when NO_2 reacts with ammonia, moisture, and other compounds. If inhaled, these particles can penetrate deeply into the lungs, causing respiratory disease and aggravating existing heart disease.[46]

Dangerous air pollution is not confined to any one country – it is a global issue.

3.5 billion
people - half of the world's population - live in nations with unsafe air quality.

1.3 billion
of these people live in the East Asia and Pacific region.

Where the data come from: The satellite-derived $PM_{2.5}$data were provided by Aaron van Donkelaar of Dalhousie University. Population data for average exposure $PM_{2.5}$ concentrations and measurement of the proportion of the population above various $PM_{2.5}$ concentration thresholds were obtained from the Global Rural Urban Mapping Project, v.1 at the NASA Socioeconomic Data and Applications Center hosted by the Center for International Earth Science Information Network (CIESIN) at Columbia University.

The Household Air Quality data came from the WHO Global Health Observatory Data Repository[47] and MDG indicators,[46] which provide estimates of the percentage of households using solid fuels (coal, wood, charcoal, dung, and crop residues), liquid fuels (kerosene), gaseous fuels (LPG, natural gas, biogas) and electricity. WHO and MDG data come from household surveys and national censuses. Data for population-weighted annual mean NO_2 were provided by Jeffrey A. Geddes of Dalhousie University, who derived these data from the Tropospheric Emissions Monitoring Internet Service.[49] For more information, see 2016 EPI Metadata.

The Environmental Risk Exposure data for air quality came from the Institute for Health Metrics and Evaluation's Global Burden of Disease (GBD) study,[50] the world's most comprehensive

41 World Health Organization. (2014). Ambient (outdoor) air quality and health. Available: http://www.who.int/mediacentre/factsheets/fs313/en/.
42 United Nations. (n.d.). Millennium Development Goals Indicators. Available: http://mdgs.un.org/unsd/mdg/Metadata.aspx?IndicatorId=29.
43 Geddes J. A., Martin R. V., Boys B. L., & van Donkelaar A. (2015). Long-Term Trends Worldwide in Ambient NO2 Concentrations Inferred from Satellite Observations. Environmental Health Perspectives. http://dx.doi.org/10.1289/ehp.1409567.
44 World Health Organization. (2003). Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide: report on a WHO working group, Bonn, Germany 13-15 January 2003. Available: http://www.euro.who.int/__data/assets/pdf_file/0005/112199/E79097.pdf.
45 United States Environmental Protection Agency. (2015). Health. Available: http://www3.epa.gov/airquality/nitrogenoxides/health.html.
46 United States Environmental Protection Agency. (2015).
47 World Health Organization. (n.d.). Population using solid fuels (%) (Public health and environment). Available: http://apps.who.int/gho/data/node.imr.WHS5_512?lang=en.
48 United Nations. (n.d.). Millennium Development Goals Indicators, Available: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=712&crid.
49 Tropospheric Emissions Monitoring Internet Service. (n.d.). Available: http://www.temis.nl/index.php.
50 Institute for Health Metrics and Evaluation. (n.d.). Global Burden of Disease. Available: http://www.healthdata.org/gbd.

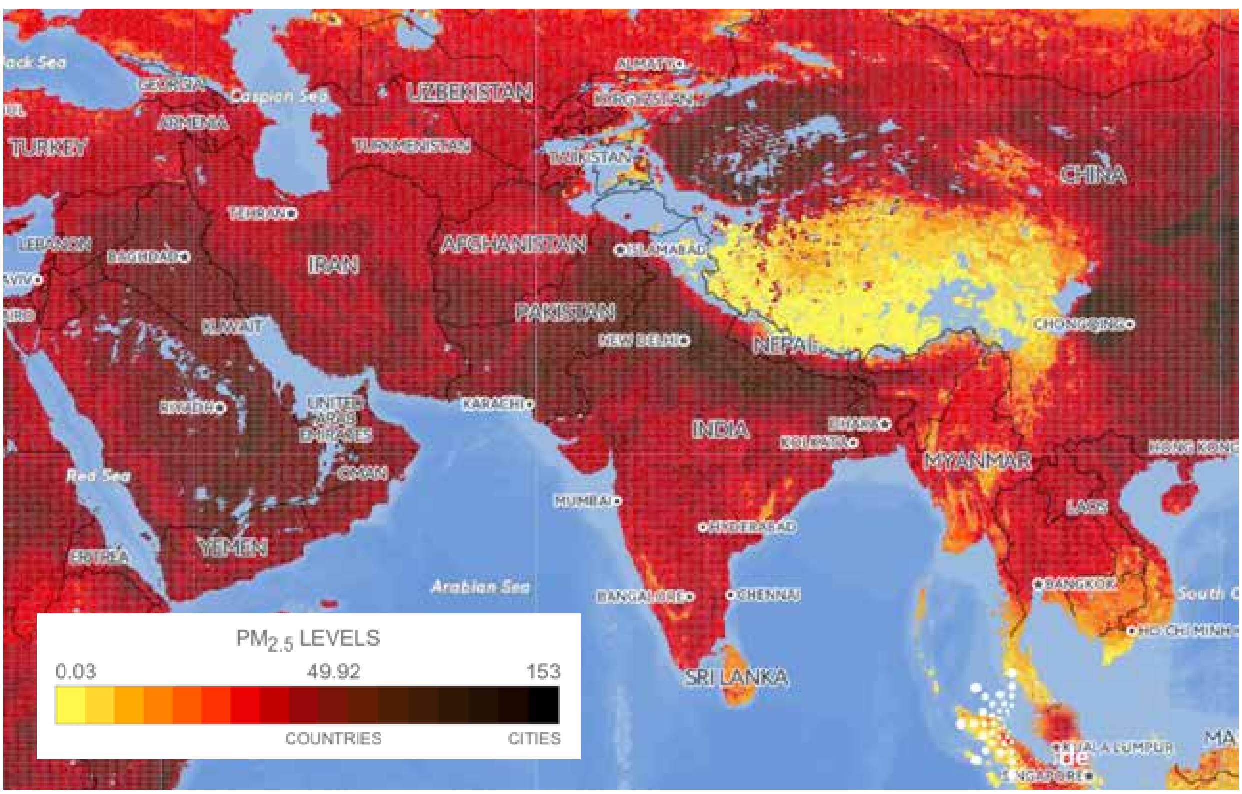
comparative risk assessment of epidemiological trends (see Health Impacts Issue Profile).

What are the targets: 10 μg/m³ for Average Exposure to $PM_{2.5}$ (fine particulate matter); 0 for Health Risk Exposure to $PM_{2.5}$; 0% for $PM_{2.5}$ Average Exceedance; 0% for Household Air Quality – Indoor Solid Fuel Usage; 0 parts per billion for Average Concentration of NO_2.

DESCRIPTION

Particles smaller than 2.5 microns in diameter, known in shorthand as $PM_{2.5}$, are fine enough to lodge deep into human lung and blood tissue. They place exposed populations at risk of heart and lung diseases, ranging from stroke to lung cancer. In severe cases, this pollution contributes directly to fatalities.[51] Airborne particulates originate from a variety of sources. $PM_{2.5}$ is generally the product of combustion, whether anthropogenic, like car emissions and coal burning, or through forest fires and volcanoes. For vulnerable populations, including youth and elderly, high concentrations of $PM_{2.5}$ can be a particularly virulent killer. The leading cause of child mortality ages one to

Figure 11: Interactive map of air pollution, pairing ground-based and satellite-derived PM2.5 data and city-level measurements from the World Health Organization



51 Goldberg, M. (2008). A systematic review of the relation between long-term exposure to ambient air pollution and chronic diseases. *Reviews on Environmental Health*, 23, 4, 243-298.

52 World Health Organization. (2014). Children: reducing mortality. Available: http://www.who.int/mediacentre/factsheets/fs178/en/.

53 Engel-Cox, J., Kim Oanh, N. T., van Donkelaar, A., Martin, R. V., & Zell, E. (2013). Toward the next generation of air quality monitoring: Particulate Matter. Atmospheric Environment, 80, 584-590.

five worldwide is pneumonia, and fine particulates are a major global contributor to its incidence.[52]

Despite its known health impacts, many countries do not monitor $PM_{2.5}$, usually because of lack of capacity, resources, technology, or public demand. Monitoring gaps primarily occur in developing countries outside of North America and Western Europe, where air pollution is more severe.[53] EPI collaborated with Dalhousie University researchers who use satellite data to assess global, national exposure to $PM_{2.5}$. Unlike ground-based monitors, which are primarily concentrated in urban areas and can be sporadically stationed, satellite data provide consistent and complete values using the same methods and technology for every country (see Figure 11).

With this satellite data, the 2016 EPI will include the only national indicator of population exposure to $PM_{2.5}$ on a global scale. More than half of the population in 58 countries lives in regions with annual mean $PM_{2.5}$ concentrations in excess of the WHO guideline of a 10 µg/m3. Large, urbanizing centers with heavy industrial activity and high concentrations of vehicles suffer from heavy contamination.[54] In Beijing, for instance, air quality hit red alert levels for the second time ever in December 2015 causing schools to shut down and limits imposed on vehicle use and outdoor activities.[55]

Air Quality - A Global Challenge

Developed countries are not immune from pollution. In Paris, headlines proclaimed that the City of Light had become the City of Haze, with air pollution ratings worse than Beijing and Delhi.[56] Experts blamed government incentives to use diesel vehicles by subsidizing the cost of diesel fuel by 15 percent. Diesel, which is more popular in Europe, is more fuel efficient, but comes with a cost of nitrogen dioxide oxide emissions that generate ozone pollution and other public health concerns. The severity of pollution in Paris was underscored later in the year when the world's largest carmaker Volkswagen was exposed using specialized software to cover up the true NO2 emissions from their vehicles.[57] In London, new research linking NO2 pollution to 9,500 deaths annually from long term exposure put air pollution concerns back on the map.[58] Similar studies of death and illness related to air pollution have been translated into monetary values to spur policy action.

While air pollution in developed countries is primarily the product of industrialization and urbanization, air pollution in many developing countries commonly has a different source: biomass burning. The combustion of organic refuse, charcoal, wood, animal dung, and agricultural waste, such as straw, nut shells, and rice husks, is prevalent in rural and urban areas of the developing world, and the consequences mat be felt far from the burn sites. For example, massive forest and peat fires in Indonesia have lead to severe cross-boundary air pollution impacting Singapore (see Box 6: Indonesia on Fire, Cross-Boundary Public Health Hazards).

54 World Health Organization. (2005). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005, Summary of risk assessment. Available: http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf.

55 Reuters. (2015, December 18). Beijing grinds to a halt as second ever 'red alert' issued over severe smog. The Guardian. Available: http://www.theguardian.com/world/2015/dec/18/beijing-pollution-second-ever-red-alert-smog-china.

56 Willsher, K. (2015, March 23). Paris chokes on pollution: City of Light becomes City of Haze. Los Angeles Times. Available: http://www.latimes.com/world/europe/la-fg-france-paris-smog-20150323-story.html.

57 The Economist. (2015, September 26). The Volkswagen Scandal. A mucky business. Available: http://www.economist.com/news/briefing/21667918-systematic-fraud-worlds-biggest-carmaker-threatens-engulf-entire-industry-and.

58 Vaughan, A. (2015, July 15). Nearly 9,500 people die each year in London because of air pollution - study. The Guardian. Available: http://www.theguardian.com/environment/2015/jul/15/nearly-9500-people-die-each-year-in-london-because-of-air-pollution-study.

Box 6. INDONESIA ON FIRE, CROSS-BOUNDARY PUBLIC HEALTH HAZARDS

Prescribed fires in Indonesia's Kalimantan and Sumatra regions burned 21,000 km^2 of forest and peatland in 2015. It released more CO_2 emissions in a few weeks than Germany does in a year and sent noxious air pollution into cities and nations throughout the region. What policies can help control this trans-boundary pollution?

Fires in Indonesia, which burned more than 2.1 million hectares of forest and peatlands in 2015,[59] have raged in dry seasons year on year, killing people and wildlife, destroying livelihoods, and producing a thick haze that drifts north from Sumatra and west from Borneo, blanketing Singapore and Malaysia in smoke.[60] The choking haze, which covered a vast expanse of Southeast Asia, killed more than 20 people and sickened at least half a million, offering a stark reminder that pollution and its pernicious effects do not respect national boundaries.[61] It will require local policy and enforcement in Indonesia along with regional cooperation to remedy this environmental and human health disaster.

The more than 94,000 individual Indonesian fires are primarily the result of "slash and burn" land clearing,[62] a practice in which landowners, both large and small, raze forested areas and burn the debris or drain peat bogs and incinerate carbon-rich peat deposits. The fires clear and prepare land for planting crops or sometimes to interfere with their competitors' operations. Indonesia is the world's largest producer of palm oil, and farmers light fires to make way for more palm plantations, pulpwood, and other agricultural operations.[63] Most of the fires raged outside of official agricultural and pulpwood concessions, meaning they were set illegally, and many of these fires reduced protected forest and peatlands to charred fields.[64] Shifting weather patterns have contributed to the disaster, as an extended dry season has allowed the fires to burn longer and over a larger area than ever before.[65]

The impacts from these fires are widespread, both geographically and in the types of damages they cause. Trans-boundary air pollution has in some places exceeded 2,000 on the Pollutant Standard Index. Anything above 300 is hazardous to human health.[66] This air pollution causes widespread respiratory infections and premature deaths.[67] The fires have released more than 1.5 billion metric tons of carbon dioxide this year alone, tripling Indonesia's greenhouse gas emissions and making it the fourth largest emitter of climate pollutants.[68] The fires have also devastated wildlife, threatening one of the most biodiverse ecosystems on Earth. Endangered species, including Orangutans, have lost critical habitat. Many animals

59 Jatmiko, A. & N. Karmini. (2015, November 16). Indonesia's vast forest fires create ecological disaster, health problems, economic losses. Star Tribune. Available: http://www.startribune.com/vast-forest-fires-in-indonesia-spawn-ecological-disaster/350577181/.

60 Minnemeyer, S. (2015, September 24). Indonesian Fires Create "Hazardous" Levels of Air Pollution in Singapore. World Resources Institute. Available: http://www.wri.org/blog/2015/09/indonesian-fires-create-%E2%80%9Chazardous%E2%80%9D-levels-air-pollution-singapore.

61 Jatmiko, A. & N. Karmini. (2015, November 16).

62 Lamb, K. (2015, October 26). Indonesia's fires labelled a 'crime against humanity' as 500,000 suffer. The Guardian. Available: http://www.theguardian.com/world/2015/oct/26/indonesias-fires-crime-against-humanity-hundreds-of-thousands-suffer.

63 Lamb, K. (2015, October 26).

64 Freedman, A. (2015, October 16). Indonesia's peat fires have released more greenhouse gases than Germany does in an entire year. Mashable. Available: http://mashable.com/2015/10/16/indonesia-peat-fires-carbon-bomb/#c7RF0cdmF5qN.

65 Lamb, K. (2015, October 26).

66 Lamb, K. (2015, October 26).

67 Bolch, O. (2015, November 11). Indonesian forest fires: all you need to know. The Guardian. Available: http://www.theguardian.com/sustainable-business/2015/nov/11/indonesia-forest-fires-explained-haze-palm-oil-timber-burning.

68 Bolch, O. (2015, November 11).

have been sickened by the smoke, and the flames have killed untold numbers.[69] In addition to environmental costs, estimates of the economic impacts exceed $14 billion USD.[70]

A transboundary disaster of this magnitude requires responses at all level of government. In 2014, Singapore passed the Transboundary Haze Pollution Act, giving its government the authority to prosecute companies operating in Indonesia that cause air pollution in Singapore.[71] Also in 2014, Indonesia ratified the Association of Southeast Asian Nations (ASEAN) Agreement on Transboundary Haze Pollution, which, among other policies, improves fire monitoring.[72]

Laws are only a starting point for improving environmental performance. In 2015, faceless corporations and anonymous people have burned more land and created more transboundary pollution than in years past, despite new laws forbidding these practices. In order to manage land for the benefit of people and the environment, nations have to take responsibility for enforcing existing laws and welcome international monitoring assistance. National sovereignty must be respected, and yet Indonesia's fires and haze violate the sovereignty of neighboring states. Pollution does not respect political boundaries. The parties responsible for pollution, however, are subject to governmental authority. Only through cooperation and respect for the rule of law can governments make lasting environmental progress.

Singapore - 8th September, 2015

69 Cochrane, J. (2015, October 31). Indonesia's Forest Fires Take Toll on Wildlife, Big and Small. The New York Times. Available: http://www.nytimes.com/2015/10/31/world/asia/indonesia-forest-fires-wildlife.html?_r=0.

70 Otto, B. (2015, October 9). Smoky Haze Costing Southeast Asia Billions of Dollars. The Wall Street Journal. Available: http://www.wsj.com/articles/smoky-haze-envelops-southeast-asia-1444389741?alg=y.

71 Freedman, A. (2015, October 16).

72 Freedman, A. (2015, October 16).

Household Air Pollution

Cooking with solid fuels over open fires or in simple stoves exposes households to dangerous pollutant concentrations. Solid fuel combustion is associated with increased mortality from pneumonia and other acute lower respiratory diseases among children. Among adults it is connected to increased mortality from chronic obstructive pulmonary disease and, where coal is used, lung cancer.[73] In fact, chronic exposure to air pollution produced by the combustion of cooking fuels is among the world's most significant and most silent killers. The most recent Global Burden of Disease (GBD) project found household air pollution from solid fuel responsible for approximately 2.8 million premature deaths worldwide.[74]

The burning of solid fuels is far more prevalent in developing countries and in rural areas where the population lacks access to modern cooking technology. Biomass and coal are often burned in simple stoves or open fires in poorly ventilated cooking spaces. Nearly 730 million people in Sub-Saharan Africa rely on the traditional use of solid biomass for cooking.[75] And its effects are not isolated to kitchens. Data show that smoke may pervade the rest of the house and the outdoors. Families that cook outdoors also experience adverse health effects, though at a lower rate. Households using clean fuel sources amidst a community of solid fuel users may still be exposed to harmful smoke by their neighbors.

The 2016 EPI indicator for Household Air Pollution reveals a clear correlation between national income and household air pollution. The numbers of people significantly affected by solid fuel contamination, low-income households from developing countries, is likely even greater than the data indicate, as families in developing countries tend to be larger. According to the Global Alliance for Clean Cookstoves, a public-private partnership hosted by the United Nations Foundation, three billion people cook over open flames or use basic stoves with traditional biomass fuels.[76]

Solutions to address household air pollution focus on reducing emissions through the use of cleaner fuels, such as liquid petroleum gas and electricity. Installing chimneys or smoke hoods on simple stoves might seem a quick fix, but the scarcity of wood and potential risks to the environment posed by collecting biomass are another compelling argument against in-home biomass use. The Global Alliance for Cookstoves is working to replace traditional stoves with clean cookstoves that are more efficient and reduce household air pollution. Largely prompted by environmental concerns, China in the early 1980s undertook a large-scale attempt at improving rural household stoves. Since then the country has installed nearly 200 million improved stoves, reducing household air pollution and easing the environmental burden of biomass demand.[77] The Global Alliance for Clean Cookstoves tries to foster public and private cooperation to make clean cookstoves and non-biomass fuels widely available in the greater developing world.


Sumba, Indonesia

73 World Health Organization. (2014).

74 Lim S., et al. (2015). Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*. Available: http://www.sciencedirect.com/science/article/pii/S0140673615001282.

75 International Energy Agency. (2014). World Energy Outlook 2014 Factsheet: Energy in sub-Saharan Africa today. Available: https://www.iea.org/media/news/2014/press/141013_WEO_Africa_Energy_OutlookFactsheet1.pdf.

76 Global Alliance for Clean Cookstoves. (n.d.). Available: http://cleancookstoves.org/home/index.html.

77 Sinton, J. E., Smith, K. R., Peabody, J. W., … (2004). An assessment of programs to promote improved household stoves in China. *Energy for Sustainable Development*, 8, 33-52.

While the Household Air Pollution indicator is acutely relevant for many developing countries where majorities rely on indoor fuel combustion for cooking and heating, data to assess indoor air quality in residential and commercial buildings is lacking. This gap is particularly critical, considering more than 50 percent of the global population lives in cities, with another 2.5 billion projected to live in cities by 2050.[78] Combined with the fact that people living in cities spend the majority of time indoors, data to assess air quality in homes and offices is needed to understand health impacts from indoor sources where solid fuels aren't burned but where VOCs and PM are still problems. In countries with high outdoor air concentrations of PM, indoor air quality is frequently no improvement over outdoor air quality. A recent report by real estate developer Jones Lang LaSalle and environmental consultancy PureLiving China evaluated 160 offices in Beijing and found 90 percent had indoor air quality conditions comparable to outdoor air pollution levels.[79]

Clean Cook Stoves

Air in the Sustainable Development Goals (SDGs)

Ultimately, policy has an important role to play in reducing both outdoor and household air pollution.[80] Efforts to address outdoor air pollution emerged during the latter half of the 20th century. National and international laws aimed at phasing out dirty industrial fuels such as coal, regulating auto emissions, and incentivizing better energy efficiency have all proven effective at improving air quality.[81] Despite MDG efforts to encourage policy interventions to reduce household air pollution, the 2016 EPI shows that in one-third of countries had greater than 50 percent of the population continue using solid fuels indoors.

Unlike environmental health issues included in the EPI that improve with economic growth, air pollution for many countries worsens with industrialization and urbanization, making the tasks for policymakers more difficult and urgent. Air is included in the opening text of the Sustainable Development Goals (SDGs), which perceives the issue as central to both sustainable development and human health. The SDGs include targets to reduce death and illness from poor air quality under Goal 3 to ensure healthy lives and well-being. Air quality is also highlighted in Goal 11 on cities (see Box 7: Helping Indian Cities Breathe Easier) and Goal 12 on sustainable consumption and production. Improvements in technology, including low-cost air sensors, are critical in helping to fill air quality data gaps and allow for real time monitoring of health risks. This new data, along with creative visualizations, put air quality squarely into the public eye and help to spur policy discussion.

78 United Nations Department of Economic and Social Affairs. (2014). World Urbanization Prospects, the 2014 Revision. Available: http://esa.un.org/unpd/wup/.

79 Jones Lang LaSalle & Pure Living China. (2015). Every breath we take – transforming the health of China's office space. Available: http://www.joneslanglasalle.com.cn/china/en-gb/Research/indoor-air-quality-whitepaper.pdf?73310343-0858-4c2e-879a-6ffd99c22b1d

80 Hsu, A., Reuben, A., Shindell, D… (2013). Toward the next generation of air quality monitoring indicators. *Atmospheric Environment*, 80, 561-570.

81 Wald, M. L. (2013, November 23). Power Plants Try Burning Wood With Coal to Cut Carbon Emissions. *The New York Times*. Available: http://www.nytimes.com/2013/11/04/business/power-plants-try-burning-wood-with-coal-to-cut-emissions.html?%20ref=earth&_r=1&.

Box 7. HELPING INDIAN CITIES BREATHE EASIER

Responding to pressure from civil society and media, India has created an Air Quality Index to measure and track air pollution in the country's largest cities. How is this new data shaping the national debate on air quality?

In December 2015, Indian officials in Delhi launched an odd-even day driving restriction program as an emergency measure to reduce pollutant loads, marking an important step forward in combating the air pollution that has plagued the rapidly industrializing country for several decades.[82] These challenges peaked in the late 1990s, during which time millions of new cars were introduced to India's roads. While gains have been made, the country still has a long way to go.

Indian officials initially dismissed the fact that air pollution levels in major Indian cities far exceeded thresholds deemed safe[83] by both India's National Ambient Air Quality Standards[84] and the World Health Organization's Air Quality Guidelines.[85] Last year, however, Indian pollution-control regulators changed their posture and launched the country's own air pollution index, called the Air Quality Index (AQI), in April 2015.[86] Their Central Pollution Control Board monitors and regulates the standard spectrum of air pollutants, including tiny, dangerous particles known as $PM_{2.5}$, ozone, carbon monoxide, and others. Indian regulators utilize data on these pollutants to assign AQI values to individual cities, using a relative scale where a city with the worst pollutant reading is given the lowest AQI for that pollutant.

Traffic in India

India's air pollution index has received extensive media attention and mixed reviews since its debut. Despite its expansion to more than 60 cities, the AQI's exact data collection method remains unclear.[87] Additionally, while environmental organizations welcomed the move, many expressed concerns over the absence of a public health advisory system for cities receiving poor AQI scores.[88]

Monitoring and ranking air pollution levels is an important advance in a country where rigorous government measures on air pollution reduction are long overdue. High rates of acute respiratory infection are widespread and increasing, with reported cases rising 30 percent over 2010 levels. One study estimates that half of Delhi's schoolchildren will never recover full lung capacity.[89] Indian leadership did not announce any major changes to the country's air pollution control efforts with the AQI, but since the launch, the government has begun to address the air pollution dilemma.[90] A collaborative state and federal air pollution control plan was released in December 2015, filling a critical regulatory gap made obvious by air quality reports from the AQI. In addition to the odd-even vehicle driving restrictions implemented that month, a large coal-fired power plant in Delhi was shut down.[91] Beginning in 2017, vehicles will be required to comply with new emission standards to curb nitrogen dioxide and particulate matter emissions from diesel engines.[92]

The transition to a more breathable India is facing predictable policy barriers. A recent ban on diesel cars older than ten years in Delhi is on the verge of collapse due to congested traffic checkpoints and enforcement snags faced by city officials.[93] These and other new policies are also hampered by an insufficient capacity of Delhi's police to regulate on-road vehicles and a public transportation system that strains to meet increasing traffic demands. But with its new air quality index continuously informing the policy process, India is showing the will to strengthen and support new controls on the deadly air pollution that once was taken for granted as the cost of modernizing.

82 Gowen, A. (2015, December 4). India's capital launches emergency plan to curb dire pollution. The Washington Post. Available: https://www.washingtonpost.com/world/asia_pacific/delhi-limits-drivers-to-alternate-days-to-curb-choking-pollution/2015/12/04/aeee4008-9a8e-11e5-aca6-1ae3be6f06d2_story.html.

83 AFP. (2014, May 8). India rejects WHO data showing Delhi air as world's dirtiest. The Economic Times. Available: http://economictimes.indiatimes.com/news/politics-and-nation/india-rejects-who-data-showing-delhi-air-as-worlds-dirtiest/articleshow/34826059.cms.

84 Central Pollution Control Board, Ministry of Environment & Forests. (2012). National Ambient Air Quality Monitoring Status and Trends in India - 2010. Available: http://www.cpcb.nic.in/upload/NewItems/NewItem_192_NAAQSTI.pdf.

85 World Health Organization. (2005). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Available: http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf.

86 Vashishtha, A. (2014, July 25). Govt to introduce pollution control index for measuring air quality in cities. India Today. Available: http://indiatoday.intoday.in/story/narendra-modi-government-pollution-control-index-cpcb/1/373980.html.

87 British Broadcasting Corporation. (2015, April 6). India launches air quality index to give pollution information. Available: http://www.bbc.com/news/world-asia-india-32193742.

88 Hsu, A. & Yin, D. (2014, August 14). New Air Quality Index May Help India's Cities Breathe Easier. The Huffington Post. Available: http://www.huffingtonpost.com/angel-hsu/new-air-quality-index-may_b_5674853.html.

89 Burke, J. (2015, September 23). India's doctors blame air pollution for sharp rise in respiratory diseases. The Guardian. Available: http://www.theguardian.com/world/2015/sep/23/india-doctors-air-pollution-rise-respiratory-diseases-delhi.

90 British Broadcasting Corporation. (2015, April 6).

91 Gowen, A. (2015, December 4).

92 Bansal, G. & A. Bandivadekar. (2013). Overview of India's Vehicle Emissions Control Program: Past Successes and Future Prospects. International Council on Clean Transportation. Available: http://www.theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf.

93 Gowen, A. (2015, December 4).

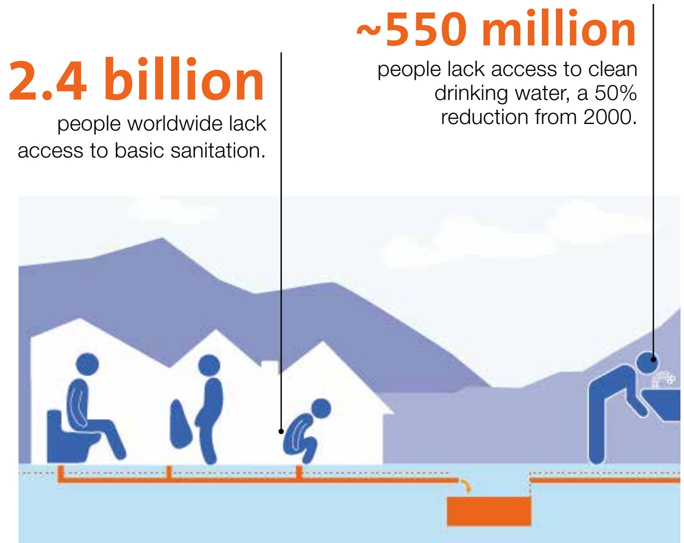
WATER AND SANITATION

Water and Sanitation tracks the portion of a population with access to safe drinking water and sanitation infrastructure.

What it measures:

Access to Drinking Water describes the portion of a country's population with access to an "improved drinking water source" as a main source. An improved drinking water source is defined as a facility or delivery point that protects water from external contamination, particularly fecal contamination. This improved source could mean piped water into a dwelling, plot, or yard; a public tap or standpipe; a tubewell or borehole; a protected spring; and rainwater collection.

Access to Sanitation describes the portion of a country's population that has access to toilets that provide the safe disposal of human waste. Improved sanitation sources include connection to a public sewer, septic system, pour-flush latrine, simple pit latrine, or ventilated pit latrine. The system is considered "improved" if it hygienically separates waste from human contact and is not a public or shared facility. →



The 2016 EPI pairs access to drinking water and sanitation with exposure variables that assess the health risk when exposed to unsafe water and poor sanitation. Safe drinking water is derived from reports on the water's treatment methods (e.g., boiling or filtering; chlorinating or solar filtering, or no treatment). Sanitation is assessed using the proportion of households with access to different types of waste-removal facilities (e.g., unimproved, improved except sewer, sewer connection). Based on these appraisals, risk factors are assigned according to the likelihood of unsafe exposure for each sanitation facility type.

Why we include it: Access to safe drinking water reduces exposure to toxins, disease vectors, and harmful contaminants, promoting general health and wellbeing. Diarrhea, for instance, the leading cause of death among children, is caused chiefly by contaminated water consumption. Access to Sanitation is a vital measure tracking a nation's ability to maintain healthy drinking water supplies, minimize its population's contact with dangerous bacteria and viruses, and diminish other environmental threats associated with improper waste management. We augment these indicators with new data on risk exposure to gauge health outcomes associated with unsafe drinking water and lack of sanitation.

The number of people lacking access to clean water has been nearly cut in half from 960 million in 2000 to 550 million today.

Where the data come from: Data for access to sanitation and drinking water come from the World Health Organization (WHO)/United Nations Children's Fund (UNICEF) Joint Monitoring Programme for Water Supply and Sanitation (JMP). For more information, see 2016 EPI Metadata.

Data for the risk exposure variables for unsafe drinking water and sanitation are based on household surveys and modeled by the Institute for Health Metrics and Evaluation's Global Burden of Disease, Injuries, and Risk Factors 2013 (GBD) study, the world's most comprehensive comparative risk assessment of epidemiological trends.[94] For more about GBD methods, see the Health Impacts Issue Profile.

What are the targets: 100% for Access to Drinking Water; 100% for Access to Sanitation. The 5th and 95th percentiles are used as targets for the Unsafe Water and Sanitation risk exposure variables.

DESCRIPTION

The Sustainable Development Goals (SDGs), which replace the expired Millennium Development Goals (MDGs), include targets "universal access to safe and affordable drinking water" and "adequate and equitable sanitation." These new goals align with the United Nations' (UN) formal acknowledgement that clean drinking water and sanitation are encompassed in the realization of human rights.[95]

Access to safe drinking water is critical for promoting human health, socioeconomic development, and individual wellbeing. Enhanced access to safe drinking water is widely considered one of the great successes of the MDGs eight international development goals. Between 1990 and 2015, 2.6 billion people gained access to improved drinking water sources. As a result, the MDG target of halving the proportion of people without access to improved water sources was met in 2010, a full five years ahead of schedule.

New data on environmental health exposure from the Institute of Health Metrics and Evaluation (IHME) reveals discrepancies between the translation of the MDG's "access to safe drinking water" and the indicator, which measures access to "improved

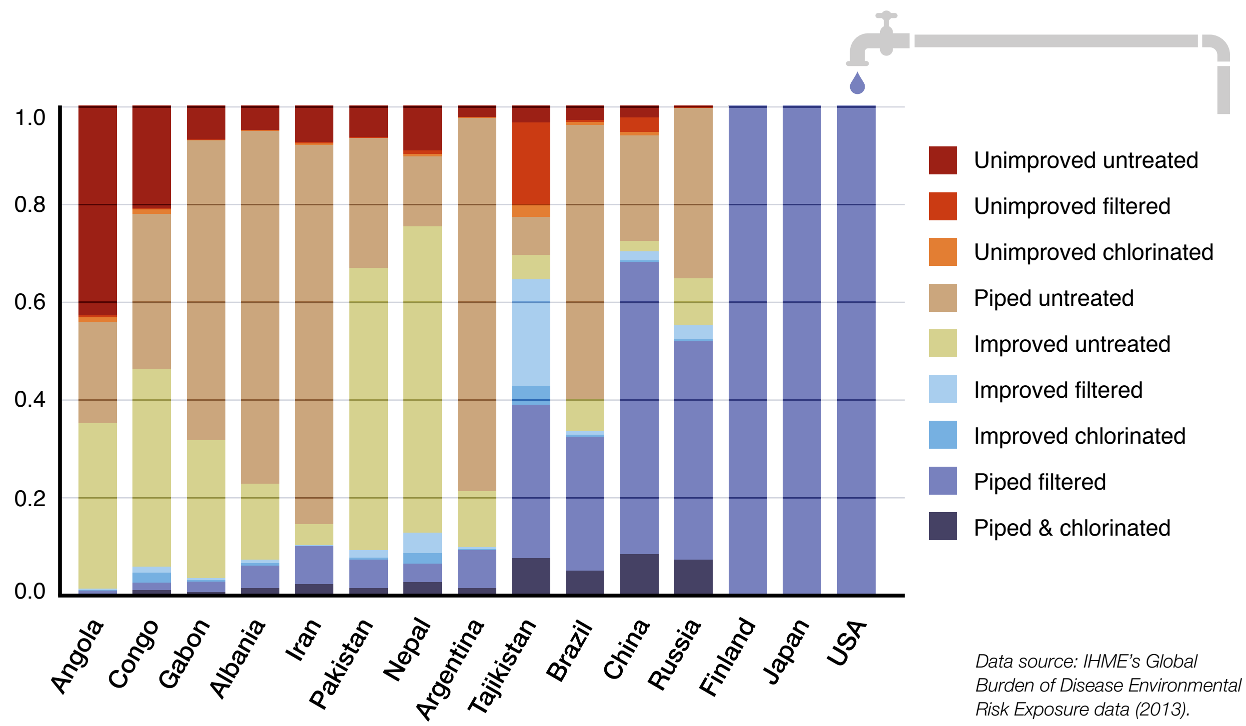
94 Forouzanfar, M. H., et al. (2015).
95 United Nations General Assembly. (2010). The human right to water and sanitation (Sixty-fourth session Agenda item 48). Available: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/64/292.

drinking water sources." "Improved" does not guarantee drinking water quality or safety. Bangladesh, for example, reports that 85 percent of its population has access to an improved drinking water source. Analyzing what proportion of the improved water source is actually treated and safe, however, reveals that around 80 percent of the sources considered improved are untreated. Untreated water bears serious environmental health risks, especially in Bangladesh, where naturally occurring arsenic in groundwater is a health hazard[96] - one that affects nearly 140 million people worldwide who rely on "improved" drinking water sources.

These unsafe water exposure statistics paint a different picture about Bangladesh's performance on the MDGs than the country's improved source data imply. Similar discrepancies are true for other South Asian nations, including Nepal and Pakistan, that claim MDG success stories of up to 90 percent access to improved drinking water sources while 50-60 percent of the water is untreated (see Figure 12). Increases in access to improved drinking water sources are often related to urbanization and expansion of water delivery systems. Without treatment, however, improved drinking water carries significant public health risks.

Sub-Saharan Africa lags behind regional trends on both access to water (74 percent) and drinking water quality (0.89 on a unitless scale, where 0 is the target). By comparison, North America, with Europe as a close contender, leads performance with universal access to drinking water and little to no risk exposure to unsafe water. Issues like aging infrastructure, contamination and spills from mining and other industrial activities, and increasingly climate change, pose threats to drinking water quality, even in more developed countries.[97]

Figure 12: Drinking water quality and improved/unimproved water categories often misalign in select countries. Blue indicates safe drinking water quality; yellow, orange, and red indicate unsafe drinking water.



Data source: IHME's Global Burden of Disease Environmental Risk Exposure data (2013).

96 Uddin, R., & Huda, N. H. (2011). Arsenic Poisoning in Bangladesh. Oman Medical Journal, 26, 3, 207.

97 Friend, T. (2014, February 17). Water in America: Is it Safe to Drink? National Geographic. Available: http://news.nationalgeographic.com/news/2014/02/140217-drinking-water-safety-west-virginia-chemical-spill-science/.

Global Progress in Access to Sanitation and Drinking Water Data

Inadequate access to safe drinking water and sanitation sickens and kills thousands of children every day. Poor sanitation degrades the quality of life for millions of people, exacerbates gender inequality, and stunts economic development. Data from WHO and UNICEF indicate that the poorest, children, the elderly, excluded groups, and women and girls suffer most from poor sanitation.[98]

Global data on drinking water and sanitation access has improved sharply since the MDGs were launched nearly a decade ago. JMP, which has refined its methods over time, is a success story in coordinated international data collection.[99] Prior to 1990, WHO relied on self-reported data provided by country agencies and ministries of health to assess the global status of water supply and sanitation. By the late 1990s, the limitations of self-reported data had become clear, as definitions of access to water and sanitation varied between and within countries.

As the official UN mechanism tasked with monitoring progress towards the MDGs related to drinking water and sanitation, JMP made improvements in data collection, standardization, and reporting beginning in 2000. Today, JMP estimates are derived from user-based data from nationally representative household surveys. Provider-based data is only used when no other source is available. The number of national surveys available to JMP has increased over the years and currently includes over 1,600 national datasets,[100] most of which are nationally representative household surveys and censuses. JMP's 2015 update includes detailed information on the breakdown between private versus shared sanitation services. Some countries with new data on shared facilities saw their scores fall slightly because shared facilities were not being counted as "improved."

Though rigorous, these datasets do not comprehensively address concerns relating water to environmental and public health outcomes. Some key information is from the Access to Water dataset, including the price of water (a factor for access) and whether the water is actually safe for consumption.[101] Providing adequate sanitation and access to improved drinking water minimizes the risk of coming into contact with dangerous bacteria and viruses, yet the dataset that informs the Access to Sanitation indicator does not record what proportion of waste is treated before being released back into the environment. Untreated sewage pollutes freshwater sources and ocean ecosystems and puts human health at risk. To address this deficiency we provide a global dataset on wastewater treatment in the EPI's Ecosystem Vitality objective (see Water Resources Issue Profile.)

While nations across the globe have made progress to improve access to sanitation and drinking water millions of individuals still lack this basic human right.[102] SDG-6, supported with robust indicators that quantify "safe," along with new datasets, such as IHME's risk exposure data, can ensure that improving access to and quality of water and sanitation go hand in hand.

Nigeria

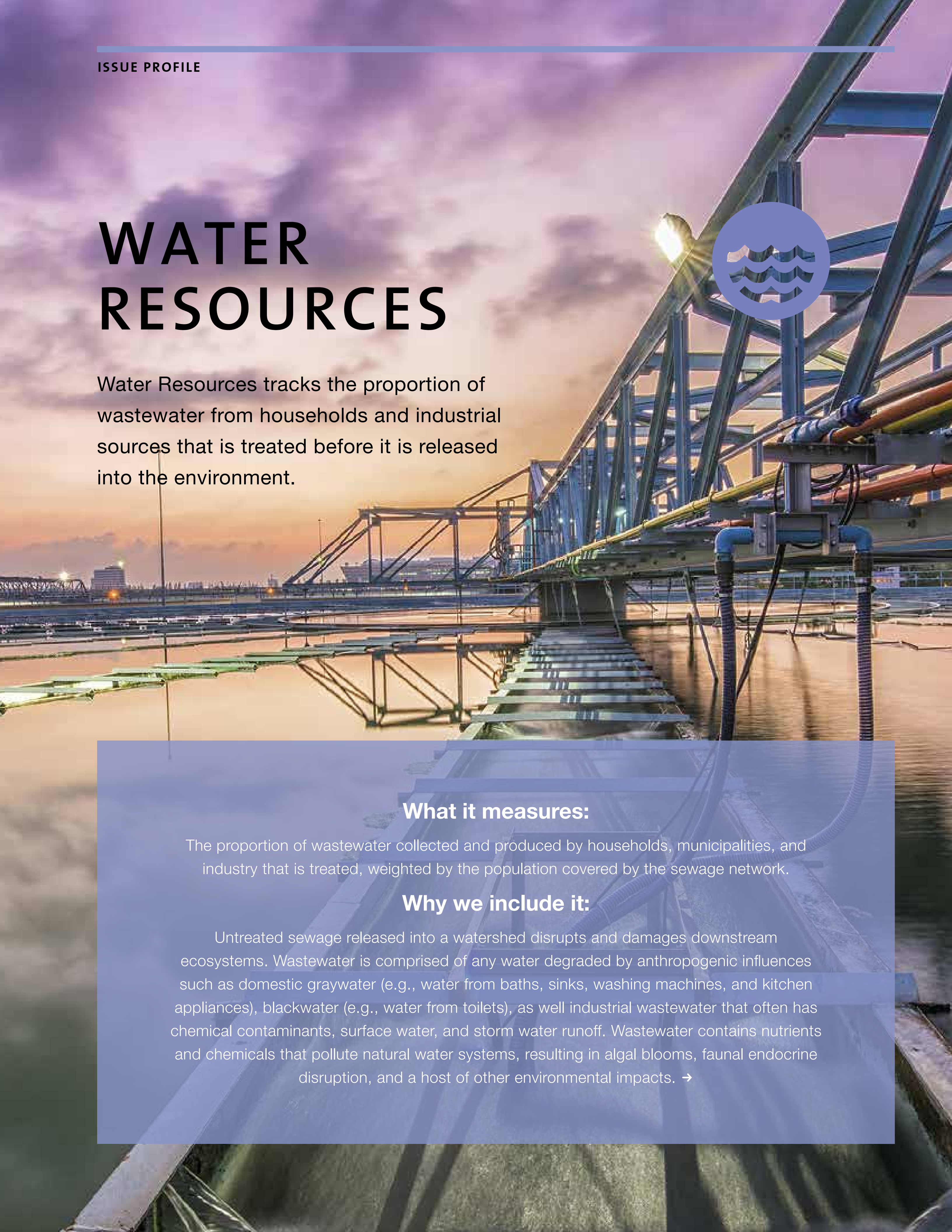
98 World Health Organization/United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Program (JMP) for Water Supply and Sanitation. (2015). Progress on Sanitation and Drinking Water—2015 Update and MDG Assessment. WHO: Geneva, Switzerland. Available: http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-Update-report-2015_English.pdf.

99 World Health Organization/United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Program (JMP) for Water Supply and Sanitation. (2015). History. Available: http://www.wssinfo.org/about-the-jmp/history/.

100 World Health Organization/United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Program (JMP) for Water Supply and Sanitation. (2015). Data Updates. Available: http://www.wssinfo.org/country-collaborations/data-updates/.

101 Cooley, H., Ajami, N., Ha, M., Srinivasan, V., Morrison, J., Donnelly, K., & Christian-Smith, J. (2013). Global Water Governance in the 20th Century. Available: http://www.pacinst.org/wp-content/uploads/2013/07/pacinst-global-water-governance-in-the-21st-century.pdf.

102 United Nations General Assembly. (2010).



WATER RESOURCES

Water Resources tracks the proportion of wastewater from households and industrial sources that is treated before it is released into the environment.

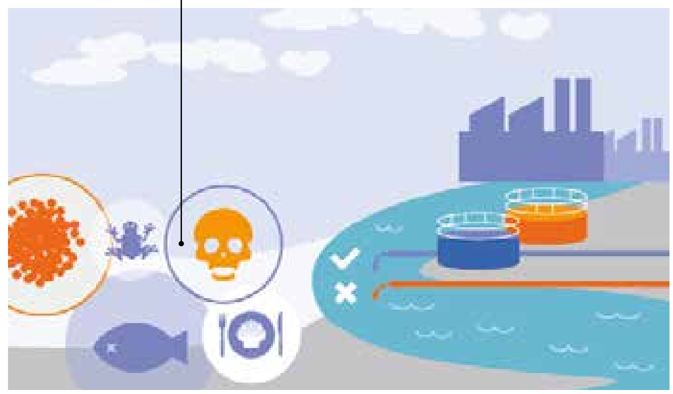
What it measures:

The proportion of wastewater collected and produced by households, municipalities, and industry that is treated, weighted by the population covered by the sewage network.

Why we include it:

Untreated sewage released into a watershed disrupts and damages downstream ecosystems. Wastewater is comprised of any water degraded by anthropogenic influences such as domestic graywater (e.g., water from baths, sinks, washing machines, and kitchen appliances), blackwater (e.g., water from toilets), as well industrial wastewater that often has chemical contaminants, surface water, and storm water runoff. Wastewater contains nutrients and chemicals that pollute natural water systems, resulting in algal blooms, faunal endocrine disruption, and a host of other environmental impacts. →

80%
and more of the world's discharged wastewater is untreated when it is released into the environment.



In rural areas, where pit latrines and septic systems are common, pollutants tend to disperse into the environment. In urban areas, however, functioning sewage systems collect and treat wastewater, concentrating pollutants into discrete discharges that are more easily treatable. Water treatment is vital to maintain aquatic ecosystem health, to protect local residents from waterborne disease vectors, and to ensure that clean water is available for re-use. Good wastewater management is critical for nations facing the worst of climate change impacts along with rapid population growth.

> 23% of countries have no wastewater treatment.

Where the data come from: This dataset was developed by the Yale Environmental Performance Index, see our publication "A global indicator of wastewater treatment to inform the Sustainable Development Goals (SDGs)."[103] The dataset is a combination of environmental statistics reported from national ministries along with official statistics from the Organization for Economic Cooperation and Development (OECD), Eurostat, the United Nations Statistical Division (UNStats), and the Food and Agriculture Organization of the United Nations (FAO), with inputs from Global Water Intelligence, Pinsent Masons Water Yearbook, and additional expert advice. For more information, see 2016 EPI Metadata.

What the target is: 100% for Wastewater Treatment.

DESCRIPTION

Water sustains life, both plant and animal, on earth. Though we could not live without water, there is a dearth of information regarding water quality at the global scale (see Box 8: Challenges of Measuring Global Water Quality). Insufficient comparable data across countries and the importance of landscape-level factors in determining water quality, among other challenges, restricts us from including a direct output measure that assesses how countries maintain water quality.

Sustainable Development Goal (SDG) 6, which "ensure[s] access to water and sanitation for all," requires that innovations in data technology and transparency be applied to measuring and reporting water quality (see Box 9: Water Ripples Through the Sustainable Development Goals). Water targets are included in five SDGs, covering a range of water-related issues like pollution, use efficiency, disease, disaster, and wastewater treatment.[104] Indicators and data that measure progress toward these goals at a global scale, however, are elusive.

As a second-best metric, we rely on drivers of water quality, specifically the treatment of wastewater, as a key component of overall management. More than 80 percent of the world's discharged wastewater is untreated when it is released into the environment.[105] Untreated wastewater leads to high pollution levels, eutrophication of water bodies, high coliform bacteria counts, and hypoxia and fish-kills. It is also a waste of water. The Wastewater Treatment indicator is a measure of treatment at the municipal level, weighting the results by the sewerage network's coverage. The indicator is distinct from other, related metrics, such as JMP's "Access to Sanitation" measures, which survey latrine access at a basic level and do not describe water quality or ecosystem health.

103 Malik, O. A., Hsu, A., Johnson, L. A., & de Sherbinin, A. (2015). A global indicator of wastewater treatment to inform the Sustainable Development Goals (SDGs). Environmental Science and Policy, 48, 172-185.

104 Gleick, P. H. (2015, August 12). The New UN Sustainable Development Goals (SDGs) and Fresh Water. The Huffington Post. Available: http://www.huffingtonpost.com/peter-h-gleick/the-new-un-sustainable-de_b_7979096.html/.

105 United Nations Water. (2015). Water and Sanitation: The Pathway to a Sustainable Future. World Water Day 2015: Water and Sustainable Development. Available: http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/SDG6-Interlinkages%201and2.pdf.

Wastewater is the water that has been used by households and industrial facilities that, without treatment, no longer serves a useful purpose. Graywater, blackwater, and the slurry of industrial and agricultural wastewater flows into natural water systems, if untreated, carries harmful chemicals into the environment, damaging ecosystems and threatening human health. Sound wastewater management requires a system for collection — normally through sewage pipes — and treatment at different stages, which are described below.[106] Treatment plants can be public or private utilities that serve a given municipality or community.

Wastewater treatment plants, even when properly located, often do not have the capacity to treat all the water collected. Overburden can occur when the population of a city outpaces the development of new treatment facilities, due in large part to insufficient funding.[107] Wastewater treatment facilities discharge excess wastewater directly into the waterways when they do not have room to handle it all,[108] and in some cases, treatment plants discharge effluent because they are dysfunctional.

106 Malik, O. (2014, January 22). Primary vs. Secondary: Types of Wastewater Treatment. Yale Environmental Performance Index, *The Metric*. Available: http://epi.yale.edu/case-study/primary-vs-secondary-types-wastewater-treatment.

107 United Nations Water. (2014). Water and Urbanization. Available: http://www.unwater.org/topics/water-and-urbanization/fr/.

108 Corcoran, E., Nellermann, C., Baker, E., Bos, R., Osborn, D., & Savelli, H. (2010). Sick Water? The central role of wastewater management in sustainable development: A Rapid Response Assessment. United Nations Environment Programme. Available: http://www.unep.org/pdf/SickWater_screen.pdf.

109 Srebotnjak, T., Carr, G., de Sherbinin, A., & Rickwood C. (2012). A global Water Quality Index and hot-deck imputation of missing data. *Ecological Indicators*, 17, 108-119.

110 Srebotnjak, T., Carr, G., de Sherbinin, A., & Rickwood C. (2012).

111 Hsu, A. (2013, August 22). 100% Pure? Assessing the State of Environment in New Zealand. Yale Environmental Performance Index, *Case Studies*. Available: http://epi.yale.edu/case-study/100-pure-assessing-state-environment-new-zealand.

112 United Nations Global Environment Monitoring System. (n.d.). Available: http://gemstat.org/.

113 Anderson, C. (2012, November 17). New Zealand's Green Tourism Push Clashes With Realities. *The New York Times*. Available: http://www.nytimes.com/2012/11/17/business/global/new-zealands-green-tourism-push-clashes-with-realities.html?pagewanted=all.

114 Cohen, S. (2015, July 29). Groundwater monitoring via GRACE satellites. Yale Environmental Performance Index, *Indicators in Practice*. Available: http://epi.yale.edu/indicators-in-practice/groundwater-monitoring-grace-satellites.

115 Malik, O. (2014, January 22). Creating the Wastewater Treatment Indicator. Yale Environmental Performance Index, *Case Studies*. Available: http://epi.yale.edu/case-study/creating-wastewater-treatment-indicator.

116 United Nations. (n.d.). Sustainable Development Goal 6: Ensure access to water and sanitation for all. Available: https://sustainabledevelopment.un.org/sdg6.

Box 8. CHALLENGES OF MEASURING GLOBAL WATER QUALITY

Despite the paramount importance of water to human life and ecosystems, we still lack a reliable metric to compare how countries perform on water quality. With advances in data collection and monitoring for other high-priority environmental issues, why do gaps persist for measuring water quality?

Water quality definitions vary widely depending on the source, location, and intended use of the water.[109] No single definition of water quality informs global measurement.

What are the outcomes that performance indicators should illuminate? Water quality is influenced by context-specific factors including background pollution, flow and volume of a water body, and precipitation rate. Governments have little or no control over these factors, making it difficult to direct policy solutions. Additionally, a lack of uniformity and agreement over measurement approaches and parameters complicates target setting.[110] A single goal or target for water quality therefore may not even be possible or desirable to set.

The water quality measure (WATQI) in the 2010 Environmental Performance Index caused a stir when New Zealand ranked second in water quality.[111] WATQI was based on the UN Global Environmental Monitoring System (UN GEMS), the only globally available database of national-level water quality parameters.[112] However, UN GEMS is a self-reported database, and New Zealand scientists questioned the selection of sampling sites, which they felt overlooked other more polluted bodies of water.[113] We dropped WATQI in subsequent editions of the EPI because of these data gaps. Since then, we have strived to develop alternative measures of water quality. Technological advances, including satellites to monitor groundwater, help improve understanding of water quality and scarcity, but they also have limitations.[114]

A lack of coordination in the scientific and policy communities to measure and record data in a consistent and timely fashion hampers assessment efforts. Case in point, The UN GEMS dataset is voluntary, self-reported, and outdated. Additionally, monitoring station density varies considerably by country, calling into question the representativeness of the data points.

What should an indicator of water quality be able to do? While developing the WATQI for the 2010 EPI, experts defined an “ideal” water quality metric capable of being applied at multiple levels (e.g., watershed/basin, river, community or national level). Using this information, decision makers can identify problems and key areas for intervention, direct funds efficiently and effectively, enforce regulations, predict future changes, and formulate effective management strategies.

In an ideal world, the EPI’s measures of water would include indicators of outputs, such as pollutant levels. To date, we’ve settled for input measures that assess water quality drivers, including our indicator of wastewater treatment.[115] While not a perfect proxy for water quality, wastewater treatment is an objective of the United Nations Sustainable Development Goal for Water, which calls on the world to halve the proportion of untreated wastewater by 2030.[116] This reflects policymakers’ understanding that wastewater treatment is a key driver of water quality. Improving data measurement and collection is a first step in reaching water quality goals.

Box 9. WATER RIPPLES THROUGH THE SUSTAINABLE DEVELOPMENT GOALS

In September 2015, the United Nations updated the global roadmap for ending poverty and safeguarding the planet, adopting the Sustainable Development Goals (SDGs).[117] The SDGs aim at a 2030 timeline, and reflect the intersections running through different areas of environmental protection and public health.

Water, for instance, appears twenty-two times across five of the 17 new Sustainable Development Goals (SDGs).[118] SDG-6 focuses on universal access to water and sanitation.[119] Water also crops up in relation to climate change, biodiversity, food security, energy security, health, gender equality, urbanization, institutional capacity, and sustainable consumption and production.

Dividing and distributing water issues across the SDGs has sparked mixed reactions. It could create false trade-offs that will assist some goals while hampering others.[120] However, some water experts, including Joseph Alcamo, former chief scientist for the United Nations Environment Programme, also see opportunities to strategically align different SDGs and achieve synergies.[121] For example, one wastewater treatment strategy simultaneously improves water quality, reduces human exposure to pathogens, and harvests methane to create a new energy source.[122]

In addition to aligning water with a suite of other issues, the SDGs broaden the definition of the "water and sanitation" category. Goal 6 goes beyond the past focus on water access and sanitation metrics to include targets related to water quality, wastewater treatment and reuse, water-use efficiency, sustainable water withdrawals, and integrated water resources management systems.[123]

This expanded focus supports holistic approaches to water management, but it also poses new kinds of monitoring problems. Many governments tasked with overseeing SDG implementation are ill equipped or politically reluctant to generate and share data.[124] Improving the collection and coordinating the availability of data is a challenge even for water and sanitation targets, which can turn to well-established monitoring mechanisms. Tracking the new water quality, wastewater and water resource management targets will be technically trying, and, as with water and sanitation data, information may need to be pieced together across an institutionally fragmented field.[125]

Overcoming these obstacles will require innovative cross-cutting solutions, some of which seem to be emerging. In December 2015, the United Nations Environment Programme began to aggregate the world's water data on UNEP Live, a space that culls data from four different UN databases and citizen scientists in real time.[126] The United Nations' GEMI task force has begun to develop a unified monitoring framework for water and sanitation-related SDG targets.[127] Many water experts also hold "high hopes" that a combination of satellite and modeled data can help supplement on-site measurements.[128]

117 United Nations. (2015). Sustainable Development Goals: 17 goals to transform our world. Available: http://www.un.org/sustainabledevelopment/sustainable-development-goals/.

118 United Nations. (2015).

119 United Nations. (n.d.). Sustainable Development Goal 6: Ensure access to water and sanitation for all. Available: https://sustainabledevelopment.un.org/sdg6.

120 Mosteller, D. (2015, September 16). Water Ripples Through the Sustainable Development Goals. Yale Environmental Performance Index, The Metric. Available: http://epi.yale.edu/the-metric/water-ripples-through-sustainable-development-goals.

121 Alcamo, J. (2015). Global water quality change & critical linkages to the SDGs. Proceedings from: Sustainable Development Goals: A Water Perspective. Bonn, Germany. Available: http://sdg2015.gwsp.org/uploads/media/Alcamo_GWSP-SDG_Conference_Bonn_17Aug_2015.pdf.

122 Alcamo, J. (2015).

123 Loewe, M. & Rippin, N. (2015). Translating an Ambitious Vision into Global Transformation: The 2030 Agenda for Sustainable Development. German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE). Available: https://www.die-gdi.de/en/discussion-paper/article/translating-an-ambitious-vision-into-global-transformation-the-2030-agenda-for-sustainable-development/.

124 Mosteller, D. (2015, September 16).

125 Loewe, M. & Rippin, N. (2015).

126 United Nations Environment Programme. (n.d.). UNEP Live. Available: http://uneplive.unep.org/.

127 United Nations Water. (2015). Integrated monitoring of water and sanitation related SDG targets. Available: http://www.unwater.org/publications/publications-detail/en/c/243070/.

128 Loewe, M. & Rippin, N. (2015).

129 Mosteller, D. (2015, September 16).

130 Mosteller, D. (2015, September 16).

The SDGs are well positioned to demonstrate the unappreciated benefits of environmental management, and to convince otherwise disengaged leaders that safeguarding water will "enhance their legacies."[129] Goal 6's focus on engaging local communities could create space to take indigenous knowledge into account, a process with the potential to "change the game socially and make implementation far more possible."[130]

6 CLEAN WATER AND SANITATION

Improving Wastewater Data for Rural and Urban Areas

An optimal Wastewater Treatment indicator would measure the proportion of all wastewater that gets treated, but figures on total wastewater generation are unavailable for most countries. And while centralized treatment systems may be appropriate for dense urban settings, in many rural areas, decentralized treatment systems, such as septic tanks, are a better solution. Yet rural jurisdictions often do not provide data on these decentralized forms of wastewater treatment, limiting EPI's wastewater treatment indicator's scope. This limitation also presents a problem for capturing wastewater issues in rapidly growing cities where many new residents live in areas outside the municipality's core infrastructure and are not connected to centralized sewage treatment facilities.

EPI's Wastewater Treatment indicator assesses the proportion of wastewater that is treated for households connected to the sewerage system. It measures wastewater treated from household sources, and in some cases from industrial sources that share the same municipal collection network. Since the release of the 2014 EPI's inaugural wastewater treatment indicator, the UN Environment Programme (UNEP)'s Transboundary Water Assessment Program has adopted the metric to assess municipal water quality.[131]

131 United Nations Environment Programme and Global Environment Facility. (2015). Transboundary River Basins Assessment. Transboundary Waters Assessment Programme. Available: http://twap-rivers.org/.

Impacts of Wastewater Pollution

Wastewater pollution leads to eutrophication and algal blooms, which occurs when a body of water is enriched with chemical nutrients, causing certain plant species such as algae to proliferate at the expense of others. Eutrophication can cause fish die-offs as some types of algae deplete the water of oxygen. Killing fish harms ecosystem health and also causes economic hardship for human communities that subsist on aquatic resources.[132] Untreated wastewater also leads to toxin buildup in shellfish as these filter feeding organisms accumulate chemical and biological.[133] The presence of pharmaceutical residues[134] and other chemicals in waterways has unseen harmful biological effects including faunal and human endocrine-disruption.

A host of bacterial, viral, and protozoan organisms persist in human waste and fecal matter, most notably the bacterium Escherichia coli (or E. coli),[135] which causes diarrheal diseases. This waste is often home to the bacteria Vibrio cholerae, Shigella spp., and Campylobacter spp., as well as noroviruses and rotaviruses, a cocktail of pathogens that cause terrible human diseases such as bancroftian filariasis, and worm-borne schistosomiasis.[136] Many of these problems can be ameliorated by sound wastewater treatment that reduce pathogen concentrations to levels safe for human consumption.[137]

Treatment is completed in sequential steps with differing levels of complexity depending on available resources. The typical range of treatment options includes primary, secondary, and tertiary stages.[138] Primary treatment uses basic processes including settlement tanks to remove suspended solids from water and to reduce the biochemical oxygen demand (BOD). Secondary treatment involves biological degradation that allows bacteria to decompose elements in the wastewater, further reducing nutrient levels and BOD. Tertiary treatment encompasses any process that goes beyond the previous steps and can include the use of advanced technology to remove remnant contaminants (see Wastewater Treatment Infographic). Tertiary treatment is typically employed to remove phosphorous or nitrogen content, major causes of eutrophication.[139]

132 United Nations Environment Programme. (2010). Time to Cure Global Tide of Sick Water. Available: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=617&ArticleID=6504&l=en&t=long.

133 Shuval, H. (2003). Estimating the global burden of thalassogenic diseases: human infectious diseases caused by wastewater pollution and the marine environment. Journal of Water and Health, 1, 53-64.

134 United States Environmental Protection Agency. (2014, May 8). Pharmaceuticals and Personal Care Products (PPCPs) in Water. Available: http://water.epa.gov/scitech/swguidance/ppcp/.

135 World Health Organization. (2011). Guidelines for drinking-water quality - 4th ed. Available: http://www.who.int/water_sanitation_health/publications/dwq_guidelines/en/.

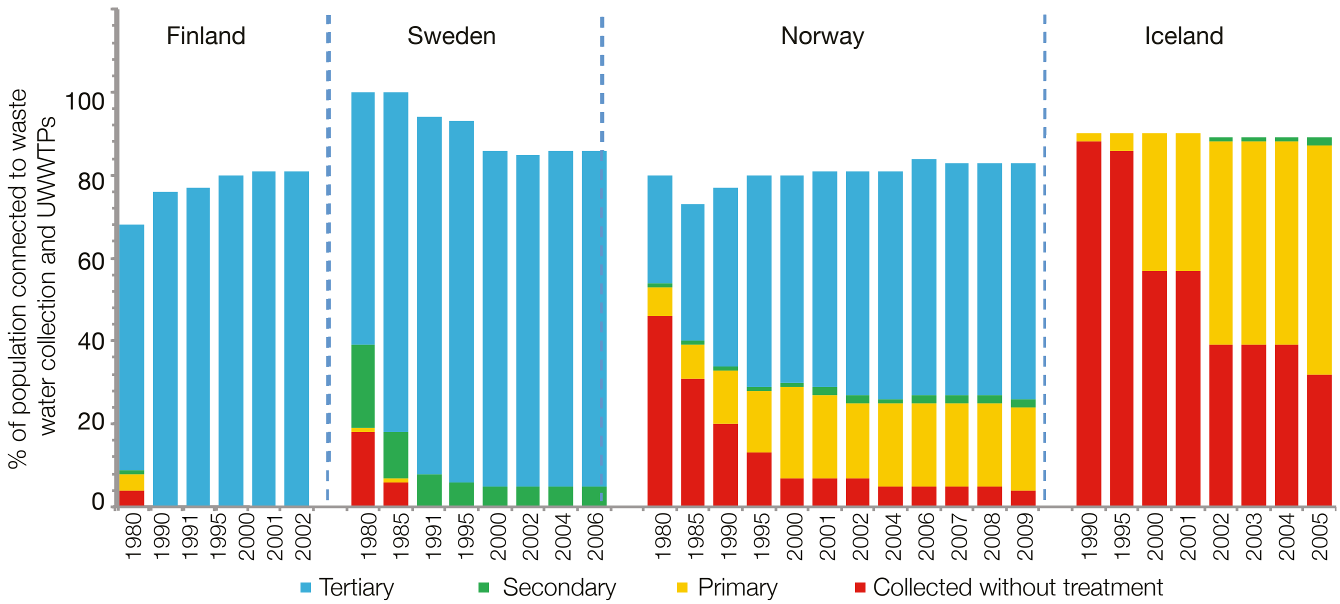
136 Baum, R., Luh, J., & J. Bartram. (2013). Sanitation: A global estimate of sewerage connections without treatment and the resulting impact on MDG progress. Environmental Science & Technology, 47, 1994-2000.

137 World Health Organization. (2011).

138 World Bank Group. (2015). Introduction to Wastewater Treatment Processes. Available: http://water.worldbank.org/shw-resource-guide/infrastructure/menu-technical-options/wastewater-treatment.

139 United Nations Environment Programme. (n.d.).Where Nutrients Come From and How They Cause Eutrophication. Newsletter and Technical Publications: Lakes and Reservoirs vol. 3 Water Quality: The Impact of Eutrophication. Available: http://www.unep.or.jp/ietc/publications/short_series/lakereservoirs-3/3.asp.

Figure 13: The European Environment Agency (EEA) collects and reports data on the percent of the population connected to different levels of wastewater treatment.



Source: EEA-Eurostat, 2013.

Data availability limits the Wastewater Treatment indicator to examine only the wastewater that receives "at least primary treatment" because this distinction is the only common definition for globally comparable measurement. Water and sanitation policies in many nations have in the past decade focused on wastewater treatment – more than ever before, signaling a shift toward including water quality as well as water access in performance metrics.[140] There remains, however, a pressing global need for more and better data on wastewater generation, treatment, and use.

The EPI team worked to update and improve the wastewater indicator, creating an interactive map to crowdsource feedback from experts worldwide[141]. The Water SDG (SDG-6) includes a target to improve water quality, in part by "halving the proportion of untreated wastewater" by 2030.[142, 143] This international goal will encourage improved wastewater treatment and should result in better data for future monitoring. An ideal wastewater indicator for SDGs will include a distinction between primary and secondary types of wastewater treatment,[144] but this level of data is lacking for most countries, although the European Environment Agency does collect and report these data for most countries in Europe (Figure 13). EPI's data collection efforts are an important step to provide a baseline for countries to gauge where they stand. As the world urbanizes, improving wastewater treatment is powerful investment in building healthy societies, as well as in individual health, especially in countries where infrastructure improvements struggle to keep pace with demand for services.

140 Bjornsen, P. (2013). Post-2015 targets and their monitoring: SDG on water. Presentation at World Water Week. 1-6 September 2013. Stockholm, Sweden.

141 See: http://epi.yale.edu/waste_map

142 United Nations Water. (2015). Indicators and Monitoring. Available: http://www.unwater.org/sdgs/indicators-and-monitoring/en/.

143 Sustainable Development Solutions Network. (2015). Indicators and a Monitoring Framework for the Sustainable Development Goals: Launching a data revolution for the SDGs. Available: http://unsdsn.org/wp-content/uploads/2015/05/150612-FINAL-SDSN-Indicator-Report1.pdf.

144 Malik, O. (2014, January 22).

AGRICULTURE

Agriculture tracks nitrogen use efficiency to assess how well countries match fertilizer inputs to crops

What it measures:

Two indicators are used to assess agriculture performance: nitrogen use efficiency (NUE), which measures the ratio of nitrogen inputs to outputs in crops, and nitrogen balance (NBALANCE), which measures excess nitrogen released to the environment as a result of an overuse of fertilizer application.

Why we include it:

Increasing nitrogen use efficiency (NUE) directly enhances crop productivity while decreasing nitrogen runoff and associated environmental degradation. Nitrogen (N) application is a ubiquitous method for intensifying agricultural production – thereby reducing the pressure to convert other landcover types, like forests and wetlands, into croplands. But too much N can be harmful. N not taken up by crops enters the environment through nitrogen leaching, ammonia volatilization, and nitrous oxide emissions. →

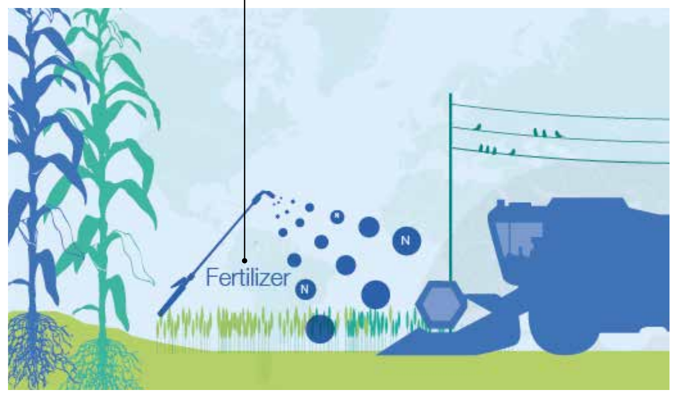
This nitrogen pollution has negative impacts on air and water quality, leads to ozone layer depletion, and exacerbates climate change.[145] Monitoring NUE allows countries to track potential environmental damages caused by their agricultural sectors, and encourages countries to be more judicious in their N applications.

Where the data come from: Researchers from across the United States developed the main databases used for the agriculture indicators.[146] These databases were created using basic models of nitrogen applied to and removed from cropland soils. Model inputs consist of nutrients in fertilizer and manure applications, as well as nitrogen entering soils through atmospheric deposition and biological fixation. Outputs consist of nutrients in harvested crops. For more information, see 2016 EPI metadata.

> Only 20% of countries meet targets for Nitrogen Use Efficiency.

What are the targets: Feeding the growing world population while minimizing nutrient loss and associated environmental damage will require an NUE of at least 70%. Recognizing regional economic, technological, and geographic differences, this aggregate target could be separated into an NUE of 75% in the EU and US, 60% in China and the rest of Asia, and 70% in other countries.[147] An acceptable target range, according to Zhang et al. (2015), for NBALANCE lies between 39 - 79 kg/N/year, but the EPI uses a target range of 0 to 70 kg/N/year.

80%
of countries do not meet
Nitrogen Use Efficiency targets.



DESCRIPTION

Agricultural activities have direct impacts on the environment. From local to global scales, agriculture influences essentially all major environmental issues: soil quality, water quality and availability, air quality, carbon pollution and climate change, habitat fragmentation, deforestation, and biodiversity loss.[148, 149] The dead zones in the Gulf of Mexico and Chesapeake Bay are some of the most well-known and visible examples of agricultural pollution. Nutrient runoff from cropland enters water bodies and cause algal blooms, which suffocate aquatic life.

Fertilizers play a vital role in modern agricultural production. Crop productivity is generally limited by one of three key nutrients: nitrogen, phosphorus, and potassium. Having these nutrients in soils, in the right proportions, is essential for maximizing crop yield. Nitrogen deposits in soils naturally from the atmosphere, and certain types of leguminous plants facilitate this process through a biological mechanism called nitrogen fixation.

The use of synthetic fertilizers became widespread in the middle of the 20th century, contributing to the "Green Revolution" that boosted agricultural production around the world. Using the Haber-Bosch process, an energy intensive chemical reaction that synthesizes nitrogen compounds from the atmosphere,

145 Galloway, J.N., J.D. Aber, J.W. Erisman, S.P. Seitzinger, R.W. Howarth, E.B. Cowling.... (2003). The nitrogen cascade. Bioscience, 53, 341–356.

146 Zhang, X., Davidson, E. A., Mauzerall, D. L., Searchinger, T. D., Dumas, P., & Shen, Y. (2015). Managing nitrogen for sustainable development. Nature, 1–9.

147 Zhang, X., et al. (2015).

148 Tilman, D., Cassman, K. G., Matson, P. A… (2002). Agricultural sustainability and intensive production practices. Nature, 418, 671-677.

149 Aneja, V. P., Schlesinger, W. H., & Erisman, J. W. (2009). Effects of agriculture upon the air quality and climate: research, policy, and regulations. Environmental Science & Technology, 43, 4234-4240.

governments and agricultural firms precipitously ramped up nitrogen fertilizer production year on year throughout the 20th century. Global nitrogen fertilizer production has continued its meteoric rise into the 21st century, and today more than 100 million tons of synthetic N fertilizer are produced every year.[150] Bringing this innovation to scale, along with other technological, socio-economic and political shifts, enabled geometric increases in crop yields. More food has meant fewer people suffer from starvation and has led to a more than doubling of the global population in the last 50 years. Input intensification has also spurred farm consolidation, vast human migrations, and urbanization on an unprecedented scale.

Adding nutrients to cropland soils intensifies agricultural production, allowing for an increase in productivity from a same piece of land. Increasing crop yield per unit of land area lessens the motivation to convert other land types, including forests and wetlands, into agricultural fields. This mitigation is particularly important for habitat conservation, given that agricultural lands occupy as much as half of the planet's terrestrial surface.[151] Fertilizer production and excessive application, however, create a host of environmental and human health problems. Nitrogen runoff leads to eutrophication – the chemical enrichment of an aquatic ecosystem often leading to oxygen depletion and species die-off – habitat destruction, and biodiversity loss in freshwater and marine ecosystems.[152] Nitrogen compound emissions contribute to acid rain, ground-level ozone, atmospheric ozone depletion, and ultimately to climate change. Ground-level ozone has many pernicious health effects, including increased risk of asthma, allergies, and blood disorders. Nitrate infiltration in drinking water increases the risk of chronic diseases and cancer, and nitrous oxide emissions from fertilizer account for 7 percent of global anthropogenic greenhouse gas emissions.[155,155] Through its effects on biodiversity and climate change, nitrogen pollution is estimated to cost the European Union (EU) $70-320 billion EUR a year - more than double the value that nitrogen adds to EU farm income.[156]

New Nitrogen Indicators

The 2016 EPI's agricultural performance indicator evaluates nations' nitrogen use efficiency, or NUE, and Nitrogen Balance. NUE is the ratio of nitrogen inputs to outputs and is expressed as a percentage, with 100 percent representing maximum efficiency. Agricultural experts agree, however, that an NUE of 100 percent is biologically impossible, and a score of 70-80 percent is considered to be indicative of the best nitrogen use practices. Although this indicator does not speak directly to environmental impacts, inefficient nitrogen use is a reliable proxy for environmental damage, as nitrogen compounds readily leach into water tables and volatilize into the air. It is also a measure of crop productivity relative to nitrogen inputs and outputs. NUE is therefore an assessment of a nation's efficient use of nitrogen resources as well as the environmental degradation resulting from fertilizer application.

The EPI also uses a nitrogen balance variable as a proxy for agricultural drivers of environmental damage. This indicator is a measure of a cropland's excess nitrogen – nitrogen not taken up in the growing period – most of which enters the surrounding environment. In certain instances, soils have a negative nutrient balance, which indicates that nutrients are being "mined" from soils and may soon be depleted. A nutrient balance of zero is the hypothetical optimum, indicating that all applied nutrients go into the area's crops. However, there is general scientific consensus that there will always be some amount of nutrients not taken up by crops. The true optimum varies by region, season, and type of nutrient. This indicator reflects a nation's efforts to limit excessive use of nitrogen fertilizers, and thus minimize environmental damage (see Box 10: Nutrient Measurements: Best Practices).

Although nitrogen use efficiency and nitrogen balance are calculated using the same data, they reveal different things about the effects of fertilizer use on the environment. For

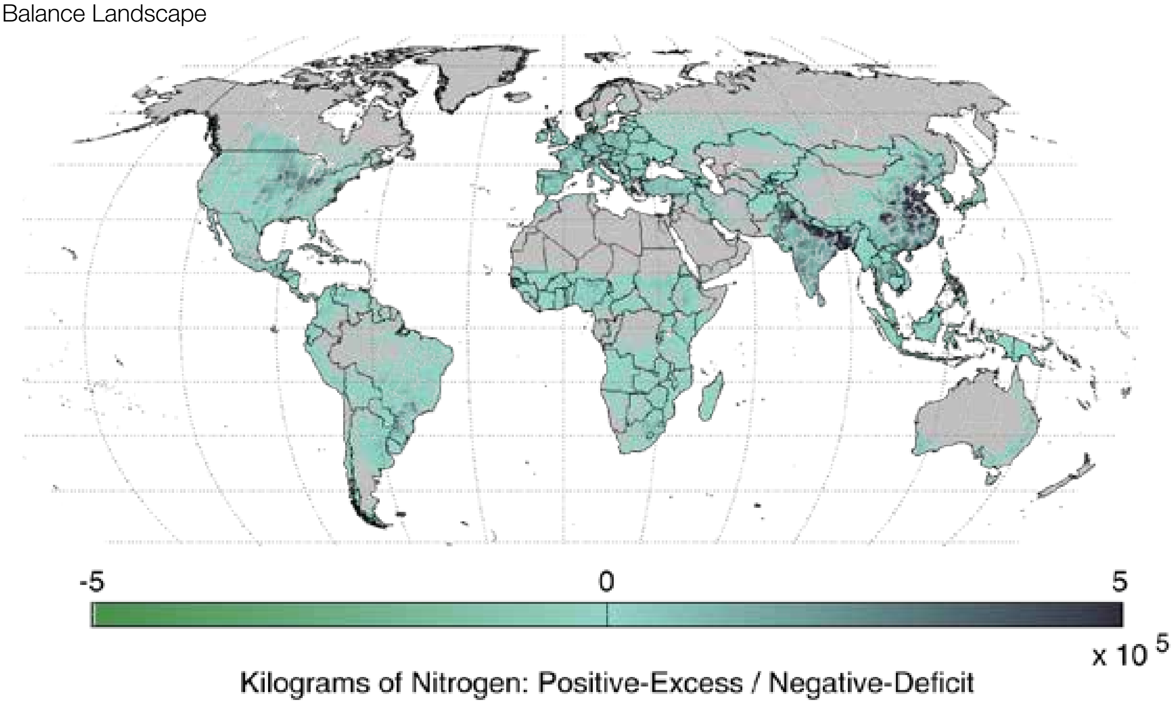
150 Smil, V. (2011). Nitrogen cycle and world food production. World Agriculture, 2, 1, 9-13.
151 Alexandre, N. (2015, July 28). Wasted Opportunities. Yale Environmental Performance Index, The Metric. Available: http://epi.yale.edu/the-metric/wasted-opportunities.
152 Smith, P. (2012). Agricultural greenhouse gas mitigation potential globally, in Europe and in the UK: what have we learnt in the last 20 years? Global Change Biology, 18, 1, 35-43.
153 Galloway, J. N., Aber, J.D., Erisman, J. W., Seitzinger, S. P., Howarth, R.W., Cowling, W.B., Cosby, B.J. (2003). The nitrogen cascade. Bioscience, 53, 341–356.
154 Alexandre, N. (2015, August 9). The Carbon Price of Agriculture. Yale Environmental Performance Index, The Metric. Available: http://epi.yale.edu/the-metric/carbon-price-agriculture.
155 World Resources Institute. (2013). Creating a Sustainable Food Future : A menu of solutions to sustainably feed more than 9 billion people by 2050. World Resources Report 2013-14, 130.
156 Williamson, I. O. (2013). Too much of a good thing? Human Resources Magazine, 18(3), 10.

instance, it is possible that a country could be "efficiently" applying nitrogen but have a high nitrogen balance. This signals that there is a mismatch between the quantity of fertilizer applied, the types of crops grown, and the management practices being used. Conversely, a high NUE and a negative nitrogen balance suggests that not enough nitrogen is actually getting applied - this may be "efficient" from a fertilizer practice perspective, but it implies that nutrients are getting mined from the soil and may soon be depleted. Together, these indicators provide better information on how nitrogen usage could impact the environment then they do individually.

Complicating the nitrogen picture even further, due to the variation in agricultural landscapes and local specifics of soil and climate conditions, countries can be simultaneously in nutrient excess and deficiency (see Infographic). Kenya, for instance, has areas that both have excess Nitrogen and are Nitrogen deficient. National indicators of nitrogen use efficiency and surplus nitrogen therefore are not as accurate in describing on-the-ground realities, depending on where a farm is located. While the EPI's agriculture indicators provide a starting point to understand baseline nitrogen conditions in a country's farming sector, sub-national data are crucial to decision making. These indicators demonstrate the challenge and weakness in generalizing data to the national scale, which is often too coarse to represent local conditions.

It is important to note that nitrogen use efficiency and nitrogen balance are proxy indicators for agricultural environmental performance. These measures represent only part of the information needed to capture a nation's agricultural management practices, given each country's unique environmental assets. These indicators are novel – they are the only known global indicators for environmental degradation caused by agricultural inputs – yet they are also incremental improvements towards directly measuring agricultural impacts. Data availability is limited for many countries, and because geography and agricultural policies often vary within countries, robust policy requires more localized data. Phosphorus, a separate key nutrient whose use and misuse has profound effects on the environment, also needs to be tracked. EPI has begun work on these issues, yet data availability remains a problem (see Box 11: What About Live Stock? The Agriculture Systems Approach).

Nitrogen Balance Landscape



Source: Earthstat.org, West et al., 2014

Box 10. NUTRIENT MEASUREMENTS: BEST PRACTICES

Effective nutrient management techniques require better data, at finer scales. How can institutions help collect the data necessary to manage their nutrient resources?

Rongo, Kenya

The 2016 EPI's nitrogen indicators represent one of the first attempts to measure agricultural environmental performances at a global scale. They offer countries a snapshot of how well their agricultural practices are matching their environmental capacity, as measured through the proxy of nutrient use. However, global data for a number of variables used to calculate these indicators remain shaky and imprecise. Better databases must be developed, and developed in harmony, to enable countries to make accurate comparisons between each other and over time. Furthermore, national-level nutrient indicators can hide significant regional and intra-regional variation. For instance, some regions in Kenya suffer from both high nitrogen deficiencies and nitrogen excess. Such examples point towards the need for regional-level management, but this can only come from regional-level data.

The Organization for Economic Cooperation and Development (OECD) and EUROSTAT developed specific guidelines for collecting data on nutrient use. These represent current best practices for nutrient measurements, although they focus primarily on the national scale and require downscaling to the regional level. Although the OECD recognizes that these methodologies require refinement, they serve as useful guides for countries attempting to identify the types of data required to track nutrient use.

The table below compares OECD's suggested variables for calculating NUE and NBALANCE to the variables used by the EPI. These differences owe to a lack of global coverage for some of the variables the OECD suggested, further highlighting the need for countries and international agencies to collect better data at finer resolutions. For more information, see the OECD's handbook on nutrient budgets.[157]

157 European Commission Eurostats. (2013). Methodology and Handbook Eurostat/OECD. Available: http://ec.europa.eu/eurostat/documents/2393397/2518760/Nutrient_Budgets_Handbook_(CPSA_AE_109)_corrected3.pdf/4a3647de-da73-4d23-b94b-e2b23844dc31.

Table A: Comparisons between the EPI's approach and the OECD approach.

EPI	OECD
INPUTS	
Variable	Variable
N in total fertilizers applied to cropland	N in mineral fertilizers applied to cropland
N in manure applied to cropland	N in manure production
	N in net manure import/export, withdrawals
Atmospheric N deposited on cropland	Atmospheric N deposition
Biological N fixed by leguminous crops	Biological N fixed by leguminous crops
	N in other organic fertilizers (compost, sewage sludge, crop residue etc.)
	N in seed and planting materials
OUTPUTS	
Variable	Variable
N in crops harvested	N in crop production
	N in fodder production
	N in crop residues removed/burnt

Box 11. WHAT ABOUT LIVESTOCK? THE AGRICULTURE SYSTEM APPROACH

Crops are one part of the agriculture system. Livestock are the other. How can better data on nutrient flows in the livestock sector improve nutrient management practices?

The 2016 EPI tracks nitrogen (N) flow through crop systems. Yet, the livestock sector is the single largest contributor to reactive N mobilization on the planet,[158] with the single largest land use footprint of any industrial sector.[159] In countries where livestock production accounts for at least half of the agricultural sector – such as Europe, the United States, and Australia – 80 percent of nitrogen in crops is used to feed livestock.[160] Overall, livestock production is expected to double by 2030, primarily in response to shifts in dietary habits in the developing world.[161] Livestock production and management will play a significant role in the assessment of a country's environmental performance. The EPI has not been able to identify specific statistics on how much nitrogen is lost to the environment from the livestock sector on a global scale, but the numbers cited above imply that it is substantial. An indicator developed from an agricultural systems approach would provide valuable quantifications of N loss from crop-livestock systems.

The agriculture-system approach records all of the nutrients coming into and leaving the agricultural sector.[162] The balance, or the nutrients leftover, is a measure of total nutrient loss to the environment. At a country level, this approach looks at the entire agricultural sector and assesses everything that goes into a farm system, from fertilizer to feedstuffs to what is produced in the form of harvested crops and livestock products. This holistic agricultural systems approach provides a comprehensive, national-scale look at the agricultural sectors' nutrient-related pollution impacts. Whereas the soil-surface approach looks only at cropland, the agriculture-system approach includes livestock production. A global indicator that looks at nitrogen use from an agricultural system perspective might be expressed like this:

$$\text{NUE} = \frac{(\text{N in crops} + \text{N in livestock})}{(\text{N in fertilizer} + \text{N in imported feedstuffs} + \text{N fixation} + \text{N deposition})}$$

NBALANCE = (N in fertilizer + N in imported feedstuffs + N fixation)
+ N deposition
– (N in crops + N in livestock)

Note: the N in manure variable is no longer needed because the manure stays within the system. N livestock consumption gets excreted and applied to cropland, thus leaving the system only through harvested crops, meat products, and excess N lost to the environment.

EPI is investigating indicators for the agricultural system approach as it strives to present a holistic picture of national agricultural practices. There are currently no publicly accessible databases on the N content of livestock products or N in imported feedstuff. Researchers working with the Food and Agricultural Organization (FAO) are developing global life-cycle NUE indicators that specifically look at nitrogen flows through the agricultural sector. (See the livestock environmental assessment and performance (LEAP)[163] Partnership and global livestock environmental assessment model (GLEAM)[164] on the FAO website.) These indicators, however, are not yet available. Folding the livestock sector into assessments of countries' agriculture environmental performance is an important step towards developing an accurate set of indicators that can inform policies for states and strategies, so farmers can close the loop between agricultural waste and crop fertilization.

158 Pelletier N., Pirog R., & Rasmussen R. (2010). Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States. Agricultural Systems, 103, 380-389.

159 Food and Agriculture Organization (2015). World Agriculture: towards 2015/2030. An FAO perspective. Earthscan. Available: http://www.fao.org/docrep/005/y4252e/y4252e00.htm.

160 Sutton, M. A. et al. [Eds). (2011). The European Nitrogen Assessment. European Science Foundation. Available: http://www.nine-esf.org/ENA-Book.

161 Food and Agriculture Organization (2015).

162 Oenema, O., Boers, P. C. M., van Eerd, M. M., Fraters, B., van der Meer, H. G., Roest, C. W. J., ... (1998). Leaching of nitrate from agriculture to ground- water: the effects of policies and measures in the Netherlands. *Journal of Environmental Pollution*, 102, 2, 471–478.

163 Food and Agriculture Organization. (n.d.). Livestock Environmental Assessment and Performance (LEAP) Partnership. Available: http://www.fao.org/partnerships/leap/en/.

164 Food and Agriculture Organization. (n.d.). Global Livestock Environmental Assessment Model (GLEAM). Available: http://www.fao.org/gleam/en/.

FORESTS

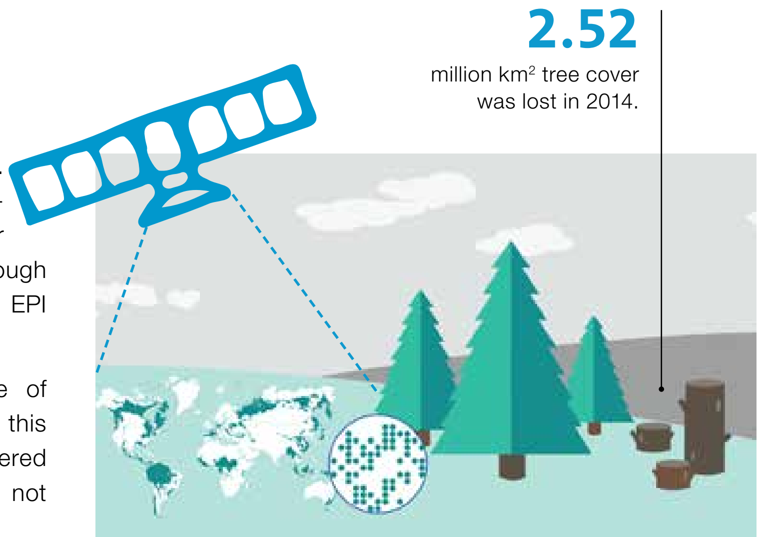
The Tree Cover Loss indicator reports loss in areas with greater than 30 percent tree cover from 2001 to 2014.

What it measures:

TThe Forests category consists of a single measure - Tree Cover Loss. The Tree Cover Loss indicator describes the total area of tree loss from 2000 to 2014, benchmarked against the country's tree cover baseline extent in 2000. The EPI evaluates tree cover loss in areas with at least 30 percent canopy cover; this tree density threshold is a bottom limit of what is considered a forest. In accordance with Global Forest Watch,[165] 'tree cover loss' – captured in the University of Maryland/Google dataset used for this indicator – measures the removal or death of trees, regardless of the cause and inclusive of all types of tree cover, whether through the harvesting of tree plantations or other causes of primary forest deforestation.

Why we include it:

Tree cover loss has significant implications for ecosystem health, habitat preservation, climate change mitigation, and many other environmental services.



Where the data come from: M. C. Hansen, P. V. Potapov, R. Moore, M. Hancher, et al. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 15: 342 (6160), 850-853; Accessed through Global Forest Watch. For more information, see 2016 EPI Metadata.

What is the target: The bottom 5th percentile of performers in forest loss. Countries are excluded from this analysis if less than two percent of their total area is covered by 30 percent canopy cover or more, or if they were not scored on Forests in the 2014 EPI.

> **Tree canopy covering over 30% of the surface is used for EPI analysis.**

DESCRIPTION

Forests are vital to sustaining the planet's biological and physical cycles, biodiversity, and human civilization. Approximately 30.6 percent of the world's total land area is covered by trees – three trillion trees (see Box 12: Three Trillion Trees and Counting), of which 93 percent are natural forests and the remaining 7 percent are planted, predominantly composed of trees established through planting and/or deliberate seeding.[166] Planted areas are on the rise and natural forests are in decline. The loss of trees is troubling because forests help mitigate climate change and provide ecosystem benefits and products for people. Policymakers in all forested nations acknowledge forest ecosystems' importance to humans, and scientists emphasize forests' role as carbon sinks and in regulating the hydrological system.[167]

Unsustainable timber harvesting, urban sprawl, agricultural expansion, and mining and mineral exploitation all threaten global forests. The world has lost an average of 180,749 km^2 (18.1 million hectares) of forest annually since 2000.[168] The rate of global forest loss has increased in the past 15 years, up 19 percent in the period 2012 to 2014 compared with 2009 to 2011, and 42 percent compared with 2001 to 2004. Forests are threatened throughout the world, yet from 2010 to 2015 deforestation was most pronounced in tropical countries such as Brazil and Indonesia, as well as in the Mekong Basin, Gran Chaco region, Congo Basin, and other areas of West Africa. Nations with temperate climates, conversely, have seen growth in forest area, such as in China, Australia, and Chile.[169]

The 2016 EPI calculates overall tree cover loss from 2000 to 2014 in areas with greater than 30 percent tree cover – what most countries consider "forested" area – based on data from a high-resolution map of forest loss and gain developed by Matt Hansen and colleagues at the University of Maryland.[170] The forest loss indicator includes both anthropogenic removal and natural tree deaths, which is why the indicator is framed in terms of "tree loss" and not forest loss, which is often equated with deforestation.[171] Because we use satellite data from the Landsat 7, our EPI indicator cannot distinguish between natural forest cover loss, which may be due to deforestation, and loss that occurs as a result of sustainably-managed plantations. Despite this shortcoming, these data are "globally consistent and locally relevant," allowing researchers and policymakers to consistently compare tree loss between countries and over time.[172]

165 Global Forest Watch. (n.d.). World Resources Institute. Available: http://www.globalforestwatch.org/.
166 Food and Agriculture Organization. (2015). Global Forest Resources Assessment: Terms and Definitions. Available: http://www.fao.org/docrep/017/ap862e/ap862e00.pdf.
167 World Resources Institute. (n.d.). Forests. Available: http://www.wri.org/our-work/topics/forests.
168 Hansen, M. C., Potapov, P. V., Moore, R., ... (2013). High-resolution global maps of 21st-century forest cover change. Science, 342, 850-853.
169 Food and Agriculture Organization. (2015). Global Forest Resources Assessment 2015. Available: http://www.fao.org/3/a-i4793e.pdf.
170 Hansen, M. C., et al. (2013).
171 Tropek, R. (2014). Comment on ''High-resolution global maps of 21st-century forest cover change.'' Science, 344, 981.
172 Miller, S. (2013, November 20). Google, researchers create first detailed map of global forest change. GCN. Available: http://gcn.com/Articles/2013/11/20/hi-res-global-forest-map.aspx?Page=2).

Some countries that have historically experienced more loss in previous decades are improving, such as Brazil and Burkina Faso, which both endured high rates of loss from 2000 to 2005 but have since managed to reduce tree cover loss. For any part of the globe, selecting an appropriate time frame to score national performance on forest loss is challenging. Satellite data only allow for evaluation since 2000, while many forest types, including boreal forests in northern latitudes, have longer regeneration cycles that are not readily captured in a 15-year timeframe.[173, 174] Any timeframe selected will inherently bias some countries over others, depending on tree loss trends, which is why the 2016 EPI uses all available data to provide an assessment of which countries may be experiencing more tree loss over others.

What the Indicator Reveals by Region

The annual rate of tropical forest loss has recently accelerated in many tropical countries including Cambodia, Sierra Leone, Madagascar, Uruguay, Paraguay, Liberia, Guinea, Guinea-Bissau, Viet Nam, and Malaysia. Overall, tropical forests lost 9.9 million hectares of tree cover in 2014, an area large enough to blanket South Korea with room to spare.[179] In the past decade, countries in South America's Gran Chaco region have lost greater portions of national forest cover than their neighbor Brazil, a distinction often missed in rankings of gross forest loss. For instance, from 2000 to 2014, Paraguay lost a staggering 24.6 percent of its tree cover, more than anywhere else on Earth. Argentina lost 12.6 percent of its 2000 forest extent compared to 7.4 percent in Brazil.

Paraguay and Argentina, however, have taken steps to stem the destruction. Argentina has achieved a 60 percent decrease in annual tree cover loss since 2011, due in part to enforcement of the Native Forests Law, which was passed in 2007 but only received funding a few years later. Paraguay has seen a 40 percent decrease in tree cover loss since 2012, aided by the nation's extended Zero Deforestation Law and related conservation initiatives.[181] Progress in reducing tree loss needs to be durable, however, to recover from this devastation.

Brazil used aggressive policy and market-based initiatives to cut annual forest loss in half from 2003 to 2011, yet tree cover loss worsened in 2012 and again in 2014. This backsliding indicates a need to reevaluate anti-deforestation measures. How do nations protect forests during economic recession, like Brazil has recently experienced, and while struggling with conflicts over land tenure and speculation? Costa Rica, a nation that once dramatically rebounded from a period of rampant deforestation, also saw an increase in tree cover loss in 2014. The dominant driver of deforestation in Latin

173 Lindgren, D. (2014, September 22). Deforestation in the North?! NBForest.info. Retrieved from: http://www.nbforest.info/blog/deforestation-north.

174 Fridman, J. (2014, January 9). Response to Hansen et al. (2013). Available: http://comments.sciencemag.org/content/10.1126/science.1244693.

179 World Resources Institute. (2015, September 2). RELEASE: New global data finds tropical forests declining in overlooked hotspots. Available: http://www.wri.org/news/2015/09/release-new-global-data-finds-tropical-forests-declining-overlooked-hotspots.

180 Petersen, R., Sizer, N., Hansen, M., Potapov, P. & Thau, D. (2015, September 2). Satellites Uncover 5 Surprising Hotspots for Tree Cover Loss. World Resources Institute. Available: http://www.wri.org/blog/2015/09/satellites-uncover-5-surprising-hotspots-tree-cover-loss.

181 World Wildlife Fund. (2013, September 3). Paraguay extends Zero Deforestation Law to 2018. Available: http://wwf.panda.org/?210224/Paraguay-extends-Zero-Deforestation-Law-to-2018.

Box 10. THREE TRILLION TREES AND COUNTING

Yale researchers took on the seemingly impossible of task of tallying up the world's trees—a task of great consequence for human and ecosystem health.

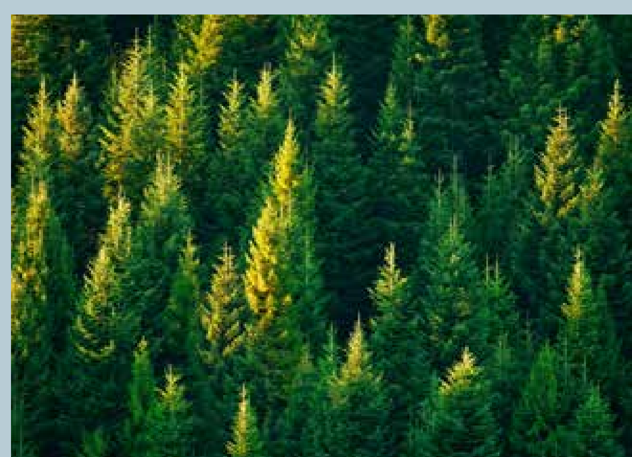
How many grains of sand are there in the world? How many drops of water? What about bees, fleas, or turtles? Curiosities like these have not yet escaped the scientific inquiry of researchers to quantify and better understand our environment and the resources that sustain life on Earth. An international team of scientists led by Yale researchers took on the herculean task of counting the number of trees in the world.[175]

The answer? Over three trillion trees and growing.[176] Featured on the cover of Nature, the new data was gathered through a combination of satellite data and ground-truthing. The latter included nearly half-a-million ground measurements from every continent except Antarctica. Combined with remote sensing technology, this data considered over 50 variables, such as climate, topography, and geography, to model tree density.

Their research revealed a total tree count over seven times the number previously considered. The data also found that there is a global loss of about 15 billion trees annually, and that nearly half of the world's trees have disappeared since the Anthropocene began around 12,000 years ago. The ramping-up of human activities – beginning with agriculture and land use conversion to intensive mining, industrialization, and increasingly to urbanization – are all drivers of forest loss over time.

How does knowing the number of trees in the world relate to policy in a meaningful way? This knowledge will help the world understand what needs to be done to preserve and replenish our planet's forests – to make reforestation targets more accurate, and to better understand habitats, nutrient cycling, and ecosystem functioning. Establishing goals and evaluating the proportional contribution of such projects require a sound baseline and understanding of current and potential tree population numbers at regional and global scales.

In the case of climate change policy, sequestering carbon with trees is an important mitigation option.[177] A more precise total tree tally can point to areas where a forest can be established where there was none before. In response to this new research, the United Nations Environment Programme and Plant for the Planet have revised their restoration goal by an order of magnitude: from one billion to one trillion trees to measurably benefit the environment and human lives.[178]



175 Crowther, T., et al. (2015). Mapping tree density at a global scale. Nature, 525, 7568, 201–205.

176 Ehrenberg, R. (2015, September 2). Global count reaches 3 trillion trees. Nature News. Available: http://www.nature.com/news/global-count-reaches-3-trillion-trees-1.18287.

177 British Broadcasting Corporation. (2015, December 7). COP21: A trillion trees to the rescue. Available: http://www.bbc.com/news/science-environment-35025276.

178 Peng, L. (2015, November 9). Trillions of Trees: Yale study finds three trillion trees on Earth. Yale Scientific. Available: http://www.yalescientific.org/2015/11/trillions-of-trees/.

40%
of deforestation is due to small-holder agriculture

America is commercial agriculture, but subsistence agriculture is responsible for much of the destruction in the 2016 EPI's bottom 25 countries.[182]

Ten African countries have lost seven percent or more of their 2000 tree cover extent. Nations sharing the Congo Basin — the largest expanse of rainforest outside the Amazon — may have seen unabated forest loss since 2000, but the continent's worst performers are found further south. South Africa has lost the greatest percentage of its tree cover (17.2 percent) in Africa, while Swaziland is right behind with 16.4 percent. Madagascar's deforestation rates, which have already removed 11.5 percent of their tree cover since 2000, are accelerating — by 42 percent from 2008-2010 to 2011—2013. A combination of slash-and-burn agriculture and fuelwood and charcoal production drives tree removal in the island nation.[183] Other African countries, particularly in West Africa, have lost significant portions of their tree cover, as well.

Unlike Africa and South America, a more equal blend of subsistence and commercial agriculture drives deforestation in Asia.[184] Indonesia had the highest gross forest loss in Asia in 2014, and it has already lost 11.9 percent of its tree cover since the turn of the century. Tree cover loss in 2015 is expected to be significantly worse than 2014 given a prolonged dry season, forest clearing, and fires employed to expand palm oil production that were producing more daily emissions than the entire United States economy at their height (see Box 6: Indonesia on Fire, Cross Boundary Public Health Hazards).[185] Experts and the public hope that increased international attention will provide the political pressure needed to spur domestic forest sector reforms.[186]


The Philippines

Nations in Southeast Asia's Mekong region have also experienced massive deforestation. Cambodia has consistently witnessed some of the greatest annual losses among Mekong Basin countries from 2000-2014, losing 18 percent of its tree cover; very little natural or primary forest remains. Despite the expansion of protected areas in Cambodia, where protected lands now comprise nearly 20 percent of the nation's territory, and in other countries in the region, enforcement of protected borders is weak in the face of poaching and illegal timber operations. The Cambodian Government recently converted much of its protected areas to economic land concessions for large-scale agriculture and plantations.[187] Malaysia, however, has lost the most tree cover extent in Asia since 2000 (19.1 percent), succumbing to many of the same pressures that have befallen Indonesia.

182 Kissinger, G., Herold, M., & de Sy, V. (2012). Drivers of Deforestation and Forest Degradation: A Synthesis Report for REDD+ Policymakers. Lexeme Consulting. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66151/Drivers_of_deforestation_and_forest_degradation.pdf.

183 Rqibate, A., Plugge, D., Rabefahlry, T., Ramamonjisoa, B., & Kohl, M. (2014). Local livelihoods in the context of deforestation and forest degradation: A study of three regions in Madagascar. in Katila et al. (eds), *Forests under pressure - Local responses to global issues, Edition: 32, Chapter: 20*. IUFRO. pp. 329-344. Available: http://www.iufro.org/download/file/11110/5581/ws32-PII_ch20_Madagascar_pdf/.

184 World Wildlife Fund. (2013).

185 Harris, N., S. Minnemeyer, F. Stolle & O. A. Payne. (2015, October 16) Indonesia's fire outbreaks producing more daily emissions than entire U.S. economy. World Resources Institute. Available: http://www.wri.org/blog/2015/10/indonesia's-fire-outbreaks-producing-more-daily-emissions-entire-us-economy.

186 Palmer, L. (2015, November 5). Will Indonesian Fires Spark Reform of Rogue Forest Sector? *Yale e360*. Available: http://e360.yale.edu/feature/will_indonesian_fires_spark_reform_of_rogue_forest_sector/2928/.

187 World Wildlife Fund. (2013). Ecosystems in the Greater Mekong: Past trends, current status, possible futures. Available: http://d2ouvy59p0dg6k.cloudfront.net/downloads/greater_mekong_ecosystems_report_020513.pdf.

Boreal countries have suffered forest loss as well in recent years. Russia and Canada are among the top three countries with the greatest gross annual tree cover loss in 2014. Timber and other commercial enterprises drive much of the tree removal, yet the bulk of loss in these regions is due to forest fires. These fires worsen in extent and intensity as temperatures in the northern latitudes rise and drier conditions prevail, with effects closely linked to global climate change.[188]

Forests' Relationship to Climate Change

Protection of forests is therefore important from a climate change perspective. Tropical forests store a quarter of the world's carbon, a fact recognized in the recent international climate change agreement, which explicitly mentions the critical role of forests in emissions mitigation (see Climate and Energy Issue Profile).[189] The Paris Agreement includes portions detailing REDD+ (Reducing Emissions from Deforestation and Degradation), a mechanism that incentivizes forest preservation by having wealthy nations invest in developing countries' standing forests. The Paris Agreement's recognition of forest conservation and delineation of a mechanism to protect forests reinforces the urgency of measuring and reporting changes in tree cover at the national level. These are the first steps to prod nations to act to limit tree loss and promote conservation and reforestation efforts.

188 Harball, E. (2015, April 2). Massive Wildfires Speed Loss of Northern Trees. *Scientific American*. Available: http://www.scientificamerican.com/article/massive-wildfires-speed-loss-of-northern-trees/.

189 Catanoso, J. (2015, December 12). COP21 agreement prominently addresses protection of earth's forests. *Mongabay*. Available: http://news.mongabay.com/2015/12/cop21-agreement-prominently-addresses-protection-of-earths-forests/.

FISHERIES

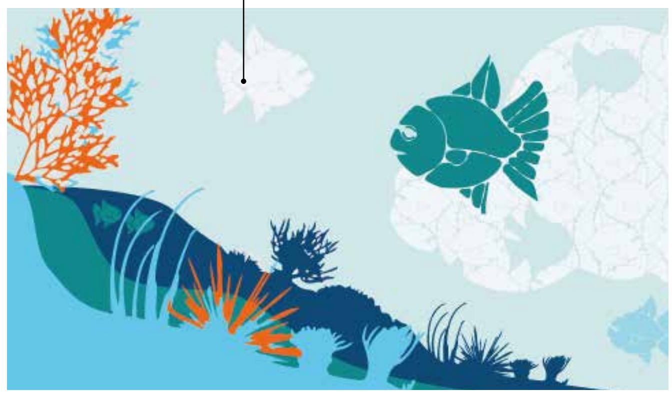
Fisheries assesses the percentage of fish stocks overexploited or collapsed, weighted by the quality of reported catch data

What it measures:

The Fish Stocks indicator is a measure of the proportion of a country's total catch — within its exclusive economic zone (EEZ) — that comes from overexploited or collapsed fish stocks. Overexploitation occurs when a fish stock is harvested at levels that exceed the species' capacity for reproduction and replacement. As a proxy for fisheries management, the Fish Stocks indicator may not adequately capture historically exploited fish stocks that are on the path to rebuilding.

Sea Around Us, an international research group based at the University of British Columbia, develops 'Stock Status Plots' that summarize the status of fish stocks over time. They define a fish stock as overexploited if catches are between 10 percent and 50 percent of peak catches and the year of measurement is after peak catch year. Collapsed stocks describe fisheries for which catches are less than 10 percent of their peak measured after the peak catch year.

34%
of global fish stocks are overexploited or collapsed.



Why we include it: This indicator is an approximation for the sustainability of fishing practices, showing which countries have harvested or continue to harvest marine species at unsustainable rates.

Where the data come from: The data are compiled and calculated by the Sea Around Us, University of British Columbia Fisheries Centre.[190] For more information, see 2016 EPI Metadata.

What is the target: Zero percent of fish stocks overexploited or collapsed, aggregated over a country's EEZ.

> Declining fish stocks show that poor measurement and improper management lead to environmental harm.

DESCRIPTION

World fisheries data are extraordinarily poor. High-level international policy instruments, including Sustainable Development Goal (SDG) 14 to "Conserve and sustainably use oceans, seas and marine resources,"[191] recognize the ocean's critical importance to human societies and yet comprehensive, accurate, and timely data regarding the world's fisheries and national fisheries management is nearly non-existent. Global communities of marine experts have noted that national fisheries data reported to the Food and Agriculture Organization (FAO) are poor and incomplete,[192] as many countries do not adequately report fish catch data from either small-scale or commercial fishing operations (See Box 13: Strengthening Fisheries Management in Viet Nam).

John Gulland, former Chief of FAO's Marine Resources Service, famously said, "Fisheries managers need to know three things: the catch, the catch, and the catch."[193] Catch data is the essential information to estimate past and present fish abundance.[194] In a forthcoming report, marine biologists Daniel Pauly and Dirk Zeller conclude that fisheries landing data assembled by the FAO vastly underestimate actual marine catches.[195] Using a decade-long multinational reconstructed fish catch dataset, these scientists estimate that global fish catch peaked at 130 million tonnes, compared to FAO's reported 86 million tonnes, in 1996, and that fish catches have declined since, much more dramatically than FAO reports.

Even with incomplete information, we know that the story of global fish stocks is one of calamitous loss. The oceans today contain half the fish that they did in 1970, and overfishing is the primary cause for this collapse.[196, 197] The sobering discovery, released September 2015 in WWF's Living Blue Planet Report, shows that the world's wild fisheries have been overexploited

190 Sea Around Us. (n.d.). Available: http://www.seaaroundus.org/.

191 United Nations. (2015). Goal 14: Conserve and sustainably use the oceans, seas and marine resources. Available: http://www.un.org/sustainabledevelopment/oceans/.

192 Froese, R., Zeller, D., Kleisner, K., & Pauly, D. (2012). What catch data can tell us about the status of global fisheries. Marine biology, 159, 6, 1283-1292.

193 Saila S., & Roedel P. (Eds). (1980). Stock Assessment for Tropical Small- Scale Fisheries. Proc. Intern. Workshop, Sept. 19–21 (1979). Univ. Rhode Island. Intern. Center Mar. Res. Development.

194 Froese, R., D. Zeller, K. Kleisner, & D. Pauly. (2012).

195 Pauly, D. & D. Zeller. (2016, forthcoming). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nature Communications.

196 World Wildlife Fund. (2015). Living Blue Planet Report: Species, habitats, and human well-being. Available: http://assets.wwf.org.uk/downloads/living_blue_planet_report_2015.pdf.

197 MacDonald, J. (2015, October 7). We're down to half the fish in the sea. JSTOR Daily. Available: http://daily.jstor.org/half-fish-sea/.

Box 13. STRENGTHENING FISHERIES MANAGEMENT IN VIET NAM

Facing contested fishing grounds and roughly 40 percent fully exploited fish stocks, fisheries management in Viet Nam has some serious challenges. Getting the right data and policies in place are necessary first steps to meeting them.

Pounding the snaking 3,260 km coastline, the sea is a defining feature of Viet Nam's geography, culture, and cuisine. Skirmishes over navigation rights in the South China Sea, mainly between China, Malaysia, the Philippines, and Viet Nam, are contributing to mounting tensions over contested fishing territories (see Box 15: Managing Fisheries on the High Seas). In several instances, these tensions have erupted in attacks on fishermen where fishing boats and equipment are captured, leading to calls for more rigorous patrolling of national waters.[205, 206]

Disputes over the South China Sea are entangled in the long and complex history of Southeast Asia, which have grave environmental impacts – especially for declining fisheries. In Viet Nam, incidents at sea are one deterrent against implementing comprehensive fisheries management policies. Underlying these political tensions, a lack of fine-scale national data on fisheries catches pose a great challenge to strengthening Vietnamese fisheries management.

Sea Around Us data shows that marine fishery harvests in Viet Nam have more than tripled in the last 30 years, with very few catches identified beyond the family taxonomic level.[207] While roughly 40 percent of all fish stocks in Viet Nam are considered fully exploited, the remainder are characterized as still developing, suggesting that any existing shortfalls in data reporting and catch statistics will be further perpetuated throughout these developing fisheries as catches continue to increase.

According to the Food and Agriculture Organization, fisheries made up 4 percent of Viet Nam's Gross Domestic Product (GDP) with a gross value of $1.7 billion USD in 2003, but their importance to Vietnamese life looms large. The marine fishing industry supports many Vietnamese livelihoods and provides a critical source of animal protein to the population. Despite the importance of the fisheries sector in Viet Nam, modern fisheries data are characterized by a weak monitoring system. Existing data from international institutions are aggregated at the national scale and average over a decade long.[208, 209]

Viet Nam's Exclusive Economic Zone (EEZ) was established in 1982 (UN, 1982); permitting and management of fishing fleets now occurs primarily at the provincial level.[211] The country enacted a national fisheries law in 2003, based largely on Norway's precedent, but resources for implementation are scarce. In 2007, the government agency responsible for Viet Nam's fisheries was reorganized into the Ministry of Agriculture and Rural Development. According to national fisheries experts, regulation of harvest is poor at the national level and virtually non-existent at the provincial scale.

Despite existing legal and regulatory frameworks, fishing is largely an open-access activity in Viet Nam. The fisheries law mandates data collection on catch rates, but there are no catch limits, and experts report that data are not actually being collected or reported. Enforcement is totally lacking. In the absence of strong data, fishermen themselves report that fish stocks are decreasing. The use of intensive trawling gears results in the catch, killing, and disposal of high percentages of "trash fish," i.e. marine fish with little or no commercial value, but with potential ecological significance.

205 Associated Press. (2015, June 17). Vietnamese fisherman accuse China of attacking them in South China Sea. The Guardian. Available: http://www.theguardian.com/world/2015/jun/17/vietnamese-fisherman-accuse-china-of-attacking-them-in-south-china-sea.
206 Minter, A (2015, November 16). The Cost to doing Nothing in the South China Sea. Bloomberg View. Available: http://www.bloombergview.com/articles/2015-11-16/the-cost-to-doing-nothing-in-the-south-china-sea.
207 Sea Around Us. (n.d.). Catches by taxon in the waters of Viet Nam. Available: http://www.seaaroundus.org/data/#/eez/704?chart=catch-chart&dimension=taxon&measure=tonnage&limit=10.
208 van Zwieten, P. A. M., W. L. T. van Densen, & Dang V. T. (2002). Improving the usage of fisheries statistics in Vietnam for production planning, fisheries management and nature conservation. Marine Policy, 26, 13–34.
209 Food and Agriculture Organization. (n.d.). Fisheries and Aquaculture Department. Available online: http://www.fao.org/fishery/facp/VNM/en.
210 World Bank. (2005). Vietnam. Fisheries and Aquaculture Sector Study. Available:.
211 United Nations. (1982). Statement of 12 November 1982 by the Government of the Socialist Republic of Viet Nam on the Territorial Sea Baseline of Viet Nam. Available: http://www.un.org/depts/los/LEGISLATIONANDTREATIES/PDFFILES/VNM_1982_Statement.pdf.

for decades. Because most fisheries are managed on a country-by-country basis, it is imperative to understand how countries approach their fisheries management – which nations are maintaining their stocks and which are not.

The drastic decline in the world's fish populations in the last 50 years lays bare the difficulties of sustainable fisheries management, which relies on sound marine science as well as long-term economic and political planning. Fisheries have declined the world over even as protections and conservation efforts have advanced, as in the case of the North Atlantic cod fishery, which despite the 1976 passage of the path-breaking Magnuson-Stevens Fishery Conservation and Management Act in the United States and Canada, collapsed in the late 1980s and was commercially extinct by 1993.[198, 199] Many fisheries, including North Atlantic cod, have collapsed because policymakers disregard the warnings of scientists and employ weak regulation, oversight, and enforcement; too little, too late to save these fish populations (see Box 14: Why Are Baltic Cod Stocks Nearly Collapsed?). As fishing technologies have become ever more effective at sweeping the seas clean, national governments and international governing bodies have not kept pace with effective regulatory frameworks to manage their oceanic assets. As a result of this governance failure an estimated 30 percent of all stocks are overexploited and between 7 and 13 percent of all stocks are collapsed. [200]

Fisheries management has historically centered on catch quotas, by which national governments set a fishery's total allowable catch (TAC) for the year and halt harvesting when this limit has been reached. This regulatory system can maintain healthy fish stocks only if TACs align with current scientific knowledge of marine ecosystems and if TACs are strictly enforced. These conditions are often not met, however, as illegal fishing, inadequate science, and excessive catch limits have created a perfect storm of overexploitation.[201] Once fish stocks collapse, they require long-term protection to recover, if they do recover at all.[202] When a fishery collapses the loss creates a trophic cascade that alters marine ecosystems and prevents fish populations from rebuilding.[203] Marine science has in the past few decades vastly improved our understanding of ocean ecosystems' complex interactions, allowing for new, comprehensive of modes of fisheries management. Fisheries experts have called for an integrated approach to marine resource management that combines catch limits, technological controls, protected no fishing zones, and other ecosystem-based regulations rooted in current scientific consensus.[204]

Exclusive Economic Zones as Effective Fisheries Management Tools

Exclusive economic zones (or EEZs), formally established in 1982 by the United Nations Convention on the Law of the Sea, give nations marine jurisdictions that stretch 200 nautical miles outward from a country's coastline. Countries have sovereign rights within their EEZs over the exploration and use of marine resources, allowing national governments to enforce domestic policies on sustainable fishing practices by limiting or prohibiting fishing by foreign fleets. Namibia's fisheries, for instance, have benefited from the creation of an EEZ. Prior to its establishment in 1990, Namibian fishermen caught less than 5 percent of the total fish landed off Namibia's coast. South African, Spanish, Russian, and Ukrainian fishing boats dominated Namibia's waters. By the 1980s, approximately 90 percent of the country's fish stocks was overexploited or had collapsed. Since 1990, the fisheries have recovered by more than 30 percent. [220]

198 Hutchings, J. A., & Myers, R. A. (1994). What can be learned from the collapse of a renewable resource? Atlantic cod, Gadus morhua, of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences, 51, 9, 2126-2146.

199 MacDowell, L. S. (2012). An environmental history of Canada. UBC Press.

200 Branch, T. A., Jensen, O. P., Ricard, D., Ye, Y., & Hilborn, R. (2011). Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Conservation Biology, 25, 4, 777-786.

201 Beddington, J. R., Agnew, D. J., & Clark, C. W. (2007). Current problems in the management of marine fisheries. Science, 316, 5832, 1713-1716.

202 Hutchings, J. A. (2000). Collapse and recovery of marine fishes. Nature, 406, 6798, 882-885.

203 Frank, K. T., Petrie, B., Choi, J. S., & Leggett, W. C. (2005). Trophic cascades in a formerly cod-dominated ecosystem. Science, 308, 5728, 1621-1623.

204 Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., & Jensen, O. P. (2009). Rebuilding global fisheries. Science, 325, 5940, 578-585.

220 Sea Around Us. (2015). Namibia: Mastrandrea Plot. Available: http://www.seaaroundus.org/data/#/eez/516/stock-status.

Box 14. WHY ARE BALTIC COD STOCKS NEARLY COLLAPSED?

Data from Sea Around Us report that Poland's fish stocks are 93 percent collapsed or overexploited, leaving the Baltic country in last-place in the 2016 EPI's Fisheries category.[212] The dire condition of Poland's fish populations reflects a history of overexploitation and environmental destruction brought on by multiple actors. The Baltic Sea's fisheries collapse is an ecological and economic disaster a long time in the making. Populations of cod, the fishery's most economically important species, have been overexploited for more than 30 years. Cod landings peaked in the 1980s and then collapsed, with catch numbers and weight declining dramatically throughout the 1990s and into the 2000s.[213]

The International Council for the Exploration of the Sea (ICES), the leading marine scientific body pertaining to the North Atlantic, has found little or no recovery among the Baltic's collapsed cod populations in the last few years, advising Baltic nations to reduce their catches to enable the fish to recover. The EU's Council of Fisheries Ministers, however, has consistently disregarded ICES's advice and set official quotas for Baltic cod far beyond what scientists say would allow stocks to rebound.[214] This policy failure, along with illegal fishing, has stymied any chance for cod populations to recover to pre-collapse levels. Poland has the unflattering distinction of being the source of more illegal (i.e., unreported) fishing than any other Baltic nation.[215]

Even if exploitation pressures were lifted, cod stocks might take decades to return from their post-collapse numbers – if they return at all.[216] In recent years, climate change has warmed Baltic waters, slowing pelagic currents that bring cold, oxygen-rich seawater from the North Sea into the Baltic's depths. This environmental change has had terrible consequences for cod recruitment (the survival of its spawn) and shows how human and environmental pressures contribute to destroy marine life and the economies that rely on these organisms.[217, 218] The Baltic cod's dire straits call for an ecosystem-based fisheries management strategy that takes into account multiple environmental factors, and not only fish stock abundance.[219]

The world's leading marine scientists have warned Europe's fisheries ministers for decades that Baltic cod stocks are headed towards commercial extinction, yet these fishes' high market value has created a perverse incentive to overfish. To sustainably manage the world's fisheries requires cooperation among nations in pursuit of a public good. To maintain healthy fisheries, policies have to align with science to develop strict regulations and protect marine areas, employing an approach that integrates a holistic, ecosystem-based understanding to manage this sector.

212 Sea Around Us. (n.d.). Catches by taxon in the waters of Poland. Available: http://www.seaaroundus.org/data/#/eez/616?chart=catch-chart&dimension=taxon&measure=tonnage&limit=10.

213 Kronenberg, J., & Bergier, T. (Eds.). (2010). Challenges of sustainable development in Poland. Fundacja Sendzimira.

214 The Fisheries Secretariat. (2015, October 21). 2016 Baltic TACs to be set at October Council. Available: http://www.fishsec.org/2015/10/21/2016-baltic-tacs-to-be-set-at-october-council/.

215 Zeller, D., Rossing, P., Harper, S., Persson, L., Booth, S., & Pauly, D. (2011). The Baltic Sea: estimates of total fisheries removals 1950–2007. Fisheries Research, 108, 2, 356-363.

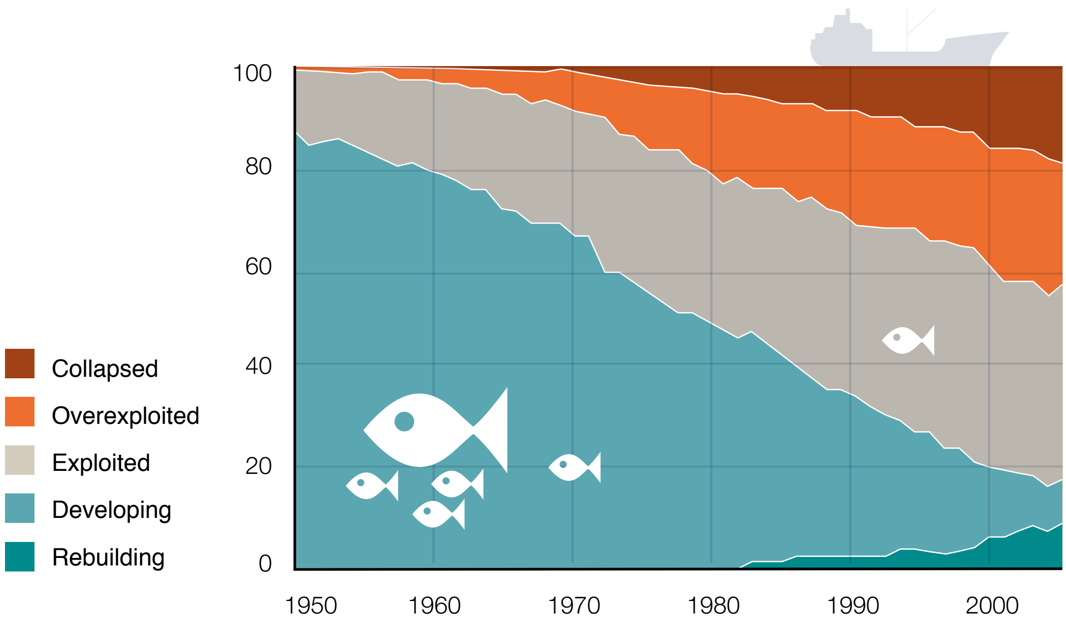
216 Russ, G. R., & Alcala, A. C. (2004). Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecologia, 138, 4, 622-627.

217 Greenpeace. (2006). The cod fishery in the Baltic Sea: unsustainable and illegal. Available: http://www.imcsnet.org/imcs/docs/the_cod_fishery_in_the_Baltic_sea_unsustainable_illegal.pdf.

218 Brander, K. M. (2005). Cod recruitment is strongly affected by climate when stock biomass is low. ICES Journal of Marine Science: Journal du Conseil, 62, 3, 339-343.

219 Lindegren, M., Möllmann, C., Nielsen, A., & Stenseth, N. C. (2009). Preventing the collapse of the Baltic cod stock through an ecosystem-based management approach. Proceedings of the National Academy of Sciences, 106, 34, 14722-14727.

Figure 14: Representative fish stock status plot, pioneered by the Food and Agriculture Organization (FAO) since 1996, is being questioned for its usefulness as an indicator of global fisheries sustainability.



Source: Adapted from Pauly et al. (2013).

Fish Stock Status as a Crude Proxy of Fisheries Management

The 2016 EPI's Fish Stocks indicator compares fish stocks across countries, as a proxy for fisheries management. This metric uses country-specific catch data to assess the proportion of the total catch by biomass comprised of species listed as overexploited or collapsed. The measure indicates to what extent each country engages in sustainable fisheries exploitation. Fish stocks are defined as a particular species or taxon regularly harvested from the same area. Sea Around Us (SAU) defines five categories for fish stocks according to the timing of peak catch reported for that fishery: developing, exploited, overexploited, collapsed, or rebuilding. The last category – rebuilding – describes fisheries that have collapsed and are experiencing a recovery (Figure 14).

FAO, which harmonizes submitted data from member countries, systematically underestimates artisanal, subsistence, recreational, discarded bycatch, and unreported catch.[221] Gaps in nationally-reported fish catch data, most notably for non-commercial fish species and small-scale fisheries, which are often omitted or substantially underreported,[222] spurred SAU to work the last several years to "reconstruct" national catch data for the world.

SAU has reconstructed global catch data from various sources, instead of relying exclusively on FAO landings data, to generate estimates for fisheries components missing from officially reported data. The historical catch baseline since 1950 is created using data from the International Council for the Exploration of the Sea (ICES) and Commission for the Conservation of Antarctic Marine Living Resources. This national and agency reported data, unlike FAO reports, includes information about catches taken from other countries' EEZs and the high seas, information that would

221 Pauly, D. & D. Zeller. (2016, forthcoming).

222 Zeller, D., Harper, S., Zylich, K. & Pauly, D. (2015). Synthesis of under-reported small-scale fisheries catch in Pacific-island waters. *Coral Reefs*, 34, 25–39.

otherwise have been omitted or improperly assigned (see Box 15: Managing Fisheries on the High Seas). SAU also reassigned data from countries that once belonged to now-defunct imperial colonies, empires, or parent countries so that the entire period's catch information reflects the current world map instead of what predated it. SAU researchers interviewed local experts and reviewed academic and grey literature to include data from overlooked sectors (industrial, artisanal, subsistence, and recreational) and taxa, regional fisheries development or management projects, colonial archives, and even historical nutritional surveys.[223]

SAU's reconstruction has improved the quality and availability of data nodes. In cases where these "anchor points" (specific data pertaining to a single place and year) did not match the geographical extent of the regulated fishery's jurisdiction, SAU used innovative statistical techniques to extrapolate data from one part of a country's shoreline to the entire nation and estimate reporting gaps from one year to the next. These data were then recombined and harmonized with the original baseline reported data to account for overlaps. SAU quantified the uncertainty[224] for each reconstruction, following the concept of "pedigrees"[225] that the Intergovernmental Panel on Climate Change (IPCC) uses to describe their confidence intervals.[226]

SAU data includes estimates of discarded catch, which often is not reported in landings and represents an important improvement to our understanding of total fisheries catch. Discards (also known as bycatch) are a key and often overlooked aspect of fisheries management. In the United States, for instance, up to 17 percent of the total catch is discarded because commercial fishermen lack permits or quotas to land certain species.[227] Other species are thrown back dead because there is no economic appetite for them. This is a major assail on biodiversity in the United States, where only three species (shrimp, salmon, and tuna) make up the majority of seafood consumed. In many parts of the world, illegal, unregulated, and unreported catches make up a significant portion of the total catch and are not counted in total landings data.

The Sea Around Us project attempts to account for discards and illegal fishing and establish a comprehensive understanding of total catch. Collateral damage done to non-target species in the fishing process is, however, excluded from this reconstruction, as are impacts on marine mammals, reptiles, corals, sponges, marine plants, aquarium-destined taxa, and fish caught for the Live Reef Fish Trade. These omissions underscore the reality that SAU's reconstructed dataset lends to a conservative metric, and thus underestimates fishing's impacts on the planet's marine ecosystems.

223 D. Pauly & D. Zeller, (Eds.). (2015). Catch Recons Mastrandrea truction: concepts, methods and data sources. Sea Around Us. University of British Columbia. Available: www.seaaroundus.org.

224 Zeller, D., Harper, S., Zylich, K. & Pauly, D. (2015).

225 Funtowicz S. O. & Ravetz J. R., (Eds.). (1990). Uncertainty and quality of science for policy. Springer, Kluver, Dortrecht. XI + 231 p.

226 Mastrandrea M. D., Field C. B., Stocker T. F., … (2010). Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. Intergovernmental Panel on Climate Change. Available: www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf.

227 W. A. Karp, L. L. Desfosse, S. G. Brooke, (Eds.). National Marine Fisheries Service. (2011). U.S. National Bycatch Report. U.S. Department of Commerce, NOAA Technical Memo. NMFS-F/SPO-117C, 508 p.

Preliminary Data Holds Future Promise

SAU's reconstructed catch data are a significant improvement over FAO's nationally-compiled statistics, yet the new data are in early phases of assimilation and are still being vetted. Because the reconstructed fish catch data are unvetted, the Ocean Health Index (OHI)[233] declined to use the data for its 2015 release, noting:

"New Fisheries scores could not be calculated for 2015. The Index planned to use new catch reconstruction data produced by Sea Around Us. Sea Around Us experienced an unexpected delay in updating the taxonomic classifications of some catches. Since accuracy of catch identification is an important component of the Fisheries goal, scores for some countries would have been unfairly penalized by use of those data before completion."

OHI instead used its 2014 Fisheries goal data, which relies on a separate model to assess fisheries status. The Stock Status (B/BMSY) model expresses a fish stock's status as the ratio of its population biomass (B) – the live weight in the ocean – and the catch biomass that would be the population's maximum sustainable yield (MSY). The goal is to have B within 5 percent of the value that produces the maximum sustainable yield. This model penalizes countries for overfishing and underfishing, with penalties increasing the further a stock's biomass B is from the goal, although underfishing is penalized half as much as overfishing.[234]

Using this B/BMSY model, resource economist Christopher Costello and colleagues estimated that 18 percent of previously unassessed fish stocks are collapsed.[235] The B/BMSY model has the advantage of taking into consideration multiple predictors of stock status, and not limited solely to the catch data that SAU's Stock Status Plots rely on. Declining catch is a precursor to a collapsed fishery, yet it

is not by itself a sufficient indicator for a collapsed fishery. The B/BMSY model incorporates information on a fish stock's historical abundance and harvests, allowing for the creation of a robust indicator of the population's current state.[236]

Some experts favor multiple regression models over the use of Stock Status Plots to estimate the status of global fisheries. University of Washington Fisheries researchers Ray Hilborn and Trevor Branch, for example, argue that declining catch data are not an accurate indicator of overexploited or collapsed fisheries.[237] Better regulation and management can lead to catch reductions, as is the case of the United States' Pacific coast fisheries. Taxonomic reclassification can also lead to reported catch declines, as occurred with sharks, classed in seven distinct species in the 1950s to more than 36 in the early 2000s.[238]

Reliable data is a prerequisite for any model's accuracy. Using SAU's reconstructed catch data as well as FAO nationally-reported catch data, the 2016 EPI introduces a new reconstructed fish stock status indicator that is a first step towards the development of a set of comprehensive fisheries measures.

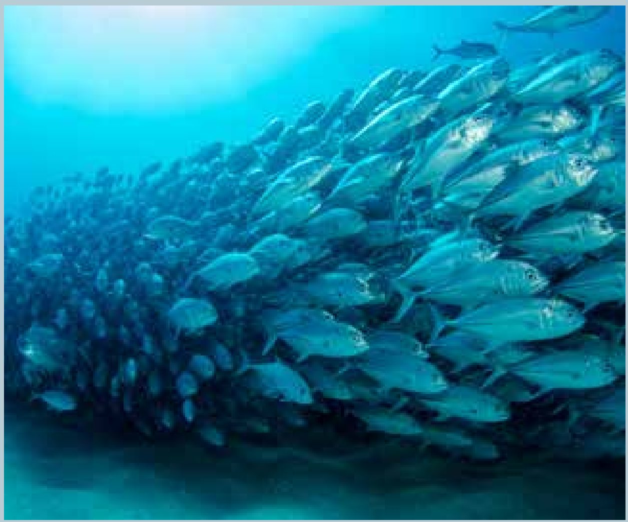
233 Ocean Health Index. (2015). Available: www.oceanhealthindex.org.
234 Ocean Health Index. (2015). Fisheries: Status. Available: http://www.oceanhealthindex.org/methodology/components/fisheries-status.
235 Costello, C., Ovando, D., Hilborn, R., Gaines, S. D., Deschenes, O., & Lester, S. E. (2012). Status and solutions for the world's unassessed fisheries. Science, 338, 6106, 517-520.
236 Costello, C., et al. (2012).
237 Pauly, D., Hilborn, R., & Branch, T. A. (2013). Fisheries: Does catch reflect abundance? Nature, 494, 7437, 303-306.
238 Pauly et al. (2013).

Box 15. MANAGING FISHERIES ON THE HIGH SEAS

Many important fisheries stocks are found on the high seas, creating a unique challenge that requires international cooperation to ensure sustainable management now and in the future.

When we order tuna at a sushi restaurant, we probably don't think about the complex international laws that enable that fish to arrive on our plates. Many tunas and other commercially important species are caught on the high seas (ocean waters outside individual country jurisdictions) and managing high seas fisheries is a particularly challenging undertaking.

High seas fisheries target three types of stocks: (1) high seas resources, which live permanently in the high seas, (2) highly migratory resources, which are found both in countries' exclusive economic zones (EEZs) and in the high seas, and (3) straddling stocks, which spend part of their life cycle in the high seas. We know less about the status of high seas stocks than we do about most other fisheries, simply because we have only recently begun to fish on the high seas. To put this in perspective, European colonists began catching New England cod in the 1600s. Most high seas fisheries have only been harvested since the 1950s.[228]



High seas catches have risen sharply since the onset of high seas fishing (see Figure 15). The basic foundation for high seas fisheries management was established by the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the 1995 UN Fish Stock Agreement.[229] UNCLOS grants freedom of access and fishing rights on the high seas to all nations, and the UN Fish Stock Agreement provides a management blueprint with a focus on highly migratory species and straddling stocks. Collectively, the fisheries requirements laid out by UNCLOS and the UN Fish Stock Agreement are codified in the UN Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries, which establish international standards and practices to ensure effective conservation, management and development of high seas fisheries resources.[230]

In response to recommendations by UNCLOS, member nations have formed voluntary Regional Fisheries Management Organizations (RFMOs) to collaboratively manage high seas fisheries on a species-by-species or geographic basis. RFMOs oversee international cooperation around stock management efforts, including collecting fishery statistics, monitoring and assessing

228 Maguire, J., et al. 2006. The state of world highly migratory, straddling, and other high seas fishery resources and associated species. FAO Fisheries Technical Paper 495: Food and Agriculture Organization of the United Nations. Available: http://www.fao.org/docrep/009/a0653e/a0653e00.htm.

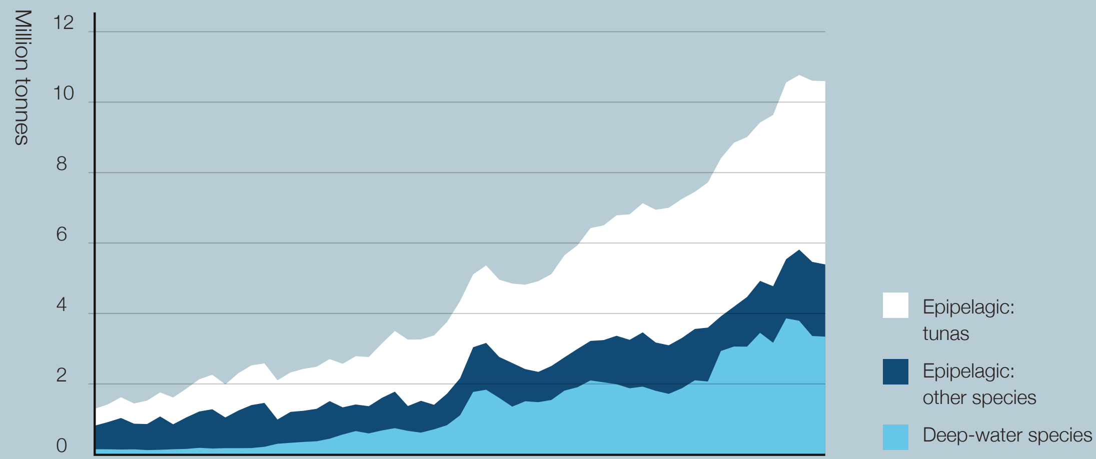
229 United Nations, Division for Ocean Affairs and Law of the Sea. (1982). United Nations Convention on the Law of the Sea of 10 December 1982. Available: http://www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm.

230 United Nations Food and Agriculture Organization. (n.d.). Code of Conduct for Responsible Fisheries. Available: http://www.fao.org/docrep/005/v9878e/v9878e00.htm.

231 Global Ocean Commission. (2013). Improving accountability and performance in international fisheries management (Policy Options Paper #9). Prepared for the third meeting of the Global Ocean Commission, November 2013. Available: http://www.globaloceancommission.org/wp-content/uploads/POP-9_Reform-of-Fisheries-Management_FINAL-1.pdf.

232 Pramod, G., ... (2014). Estimated of illegal and unreported fish in seafood imports to the USA. *Marine Policy*, 48, 102-113.

Figure 15: Trends in harvest of high-seas fish species



Source: FAO, 2008.

stock statuses, analyzing management options, and establishing catch and vessel limits. Implementation and enforcement of these management measures typically remain the responsibility of individual nations, so RFMOs are limited in their capacity to enforce management decisions.

Despite this strong foundation in international treaty law, the Global Ocean Commission reported in 2009 that two-thirds of high seas stocks are either overexploited or depleted.[231] This overharvest is largely a product of an untold number of participating vessels and an unreported amount of fish being harvested, including unknown quantities of illegal and unregulated fishing. Illegally caught fish are estimated to make up between 20 and 32 percent of seafood imports by weight into the United States alone.[232]

The international community is beginning to crack down on illegal fishing, most notably through the 2009 UN FAO Port State Measures Agreement, which requires party nations to implement stricter port procedures to limit access by illegal fishing vessels. Separately, ocean policy groups like the Global Ocean Commission are working to bolster management and enforcement capacities in RFMOs. As the international community increasingly turns its attention toward strengthening high seas fisheries management, abetted by improved data and greater political will, more effective governance strategies should continue to emerge.

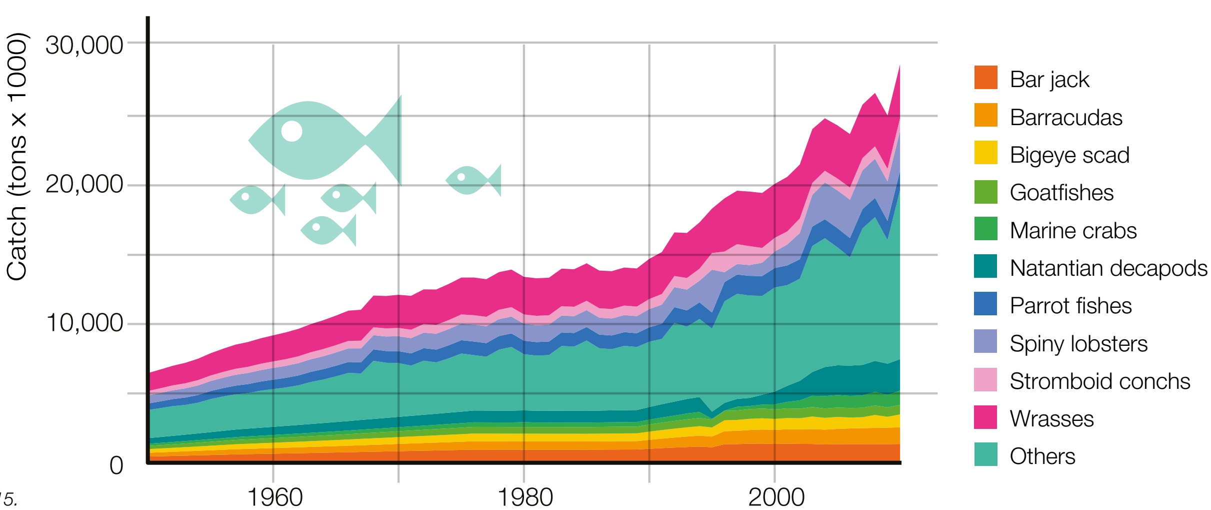
Penalizing Poor Quality Fisheries Data

Calculating Stock Status Plots requires catch data specific to at least the species level and yet many countries do not adequately report this information. Stock Status Plots are therefore absent for some countries – Djibouti and Sweden are two examples of countries where "too few data are available for meaningful use," as described by SAU. In other cases – Haiti, for instance – catch data exist but are largely extrapolated from multiple data points (see Figure 16 below), resulting in unreliable stock status estimations.


Mapou River, North Haiti

To account for these differences in the quality of time series of reconstructed catch data, Pauly and Zeller provide uncertainty estimates of the reconstructed catch data for each fishing sector (e.g., industrial, artisanal, recreational, or subsistence) and EEZ. They follow the IPCC's approach to quantifying uncertainty in climate assessments, asking experts involved in the reconstruction process to provide a data quality score of 1 (worst) to 4 (best) to reconstructed datasets for each time period (1950-1969, 1970-1989, and 1990-2010, see Table 2). The 2016 EPI uses these quality pedigrees to downweight a country's fish stock indicator, with the highest quality data rank of 4 receiving no penalty and countries with a score of 1 receiving 25 percent of their original score. Because SAU is refining and finalizing its reconstructed fish catch data, we downweighted the Fisheries issue category to five percent of a country's Ecosystem Vitality score, reducing this indicator's impact on nations' overall EPI score.

Figure 16: Haiti's fish catches by taxon from 1950 to 2011 shows steady linear increases through intermittent time intervals, from 1950 to around 1975, and then again from 1975 to 1990, and from 1990 to 1995, suggesting incomplete reporting of catch data and reliance on interpolated estimates



Source: SAU, 2015.

Table 2: Scoring system for deriving uncertainty bands for the quality of time series data of reconstructed catches, adapted from the Intergovernmental Panel on Climate Change (IPCC) (Pauly & Zeller, 2016, *forthcoming*).

Score	Confidence Interval +/ %	Corresponding IPCC criteria	2016 EPI Penalty
4 Very High	10	High agreement and robust evidence	0%
3 High	20	High agreement and medium evidence or medium agreement and robust evidence	75%
2 Low	30	High agreement and limited evidence or medium agreement and medium evidence or low agreement and robust evidence	50%
1 Very Low	50	Less than high agreement and less than robust evidence	25%

Investments Needed for Improved Fisheries Data

Fisheries experts debate what fish catch data indicates about global fish abundance and fisheries management, but there is consensus that better data are needed. The only fisheries data collected and made publicly available in 80 percent of maritime countries are weight estimates of annual fish landed.[239] Fisheries catch data, although imperfect, provides a useful signal on which to base an indicator.

Marine experts agree that improved data is critical for sustainable fisheries management, and creating a comprehensive dataset will be expensive. Fisheries scientists Ray Hilborn and Trevor Branch at the University of Washington estimate that focusing on six to eight fisheries in 40 countries alone will take a decade and cost $20 million USD.[240] The effort would require continuous monitoring and the application of up-to-date technology to better track catch data. Until these improvements are realized, we have to rely on crude proxies that provide a signal of global fisheries management.

239 Pauly, D., et al. (2013).
240 Pauly, D., et al. (2013).

BIODIVERSITY AND HABITAT

Biodiversity and Habitat tracks the protection of terrestrial and marine areas as well as the species that conservation policies aim to protect.

What it measures:

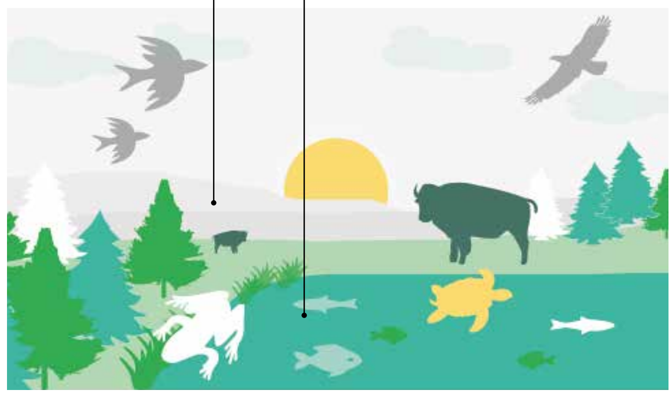
The Biodiversity and Habitat category includes five indicators: two Terrestrial Protected Areas metrics (National Biome Weight and Global Biome Weight), two Species Protection indicators (National Weight and Global Stewardship Weight), and Marine Protected Areas.

Terrestrial Protected Areas - National Biome Weight indicator assesses a nation's area of protected biomes in proportion to the territory that each biome occupies while Global Biome Weight reflects the protection of biomes weighted by their global abundance. This indicator appraises a country's contribution to protecting habitats that are rare or threatened at the global level.

The Species Protection indicators report on countries' efforts to protect species (in the mammals, birds, and amphibians taxonomic classes) in their actual – as opposed to estimated – ranges. →

15.4%
of terrestrial habitats and

8.4%
of marine habitats were protected in 2014, less than 2% away from reaching global biodiversity and habitat targets.



Using data compiled by Yale's Map of Life project,[241] these two metrics strive to assess policy effectiveness in protecting species within national borders. Similar to the Terrestrial Protected Areas indicators, the Species Protection metrics have distinct weighting methodologies: National Weight discerns the extent of a species's range protected as a proportion of a country's biomes; Global Stewardship Weight adjusts according to the proportion of a species' global habitat represented within a country's protected areas.

> **Countries are protecting more area habitats, but biodiversity is still in stark decline.**

The Marine Protected Areas indicator reports the protected proportion of a country's exclusive economic zone (EEZ). EEZs are established by the United Nations Convention on the Law of the Sea and give marine exploration and use rights within 200 nautical miles of a country's coast. The majority of protected marine regions lie within territorial waters (0-12 nautical miles from land), yet several types of valuable marine habitats exist only in EEZs (12 to 200 nautical miles), including deep-sea trenches, submarine canyons, and seamounts.[242] Nations have sovereign rights within EEZs for exploration, resource exploitation, and conservation; management of these marine zones thus has global environmental and geopolitical implications.[243] The International Union for Conservation of Nature's (IUCN) protected area categories I-VI define these regions in both terrestrial and marine realms. [244]

Why we include it: Protecting species and conserving habitats are linked objectives. Many national parks and designated conservation areas are protected in name only – logging, poaching, undisclosed mining, encroachment of agriculture, and climate change impacts defy enforcement and legal designations. The five Biodiversity and Habitat indicators describe national effort – measured in area – for biome protection as well as effectiveness – measured in biodiversity – at protecting wildlife, providing depth and utility to the category. The suite of indicators places national efforts to protect habitat and species in global context, showing the significance of a country's policies at the global scale, though they are rough proxies for species loss prevention and habitat quality conservation. See Biodiversity and Habitat Infographic.

Where the data come from: The data for Terrestrial and Marine Protected Areas come from the World Database on Protected Areas (WDPA), which is maintained by the United Nations Environment Programme's World Conservation Monitoring Centre. Terrestrial Protected Areas also uses data from the World Wildlife Fund's Ecoregions of the World. Marine Protected Areas is built in part with data from the Flanders Marine Institute's Maritime Boundaries Database. CIESIN uses these datasets to calculate the Terrestrial and Marine Protected Areas indicators.

241 Map of Life. (n.d.). Yale University. Available: http://mol.org/.

242 Corrigan, C. & Kershaw, F. (2008). Working Toward High Seas Marine Protected Areas: An Assessment of Progress Made and Recommendations for Collaboration. United Nations Environment Programme, World Conservation Monitoring Centre. Cambridge, UK. Available: https://www.cbd.int/doc/meetings/mar/ewbcsima-01/other/ewbcsima-01-unep-wcmc-en.pdf.

243 Corrigan, C. & Kershaw, F. (2008).

244 International Union for Conservation of Nature. (n.d.). IUCN Protected Areas Categories System. Available: http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/.

Species Protection indicators are developed in collaboration with the Map of Life project at Yale University. The Map of Life integrates a broad spectrum of knowledge about species distribution to provide a clear picture of the state of global conservation. The data include traditional protected areas and ecoregions as well as smaller scale data types, including local ecosystem inventories, range maps constructed by experts, and maps of species occurrence points. For more information, see 2016 EPI Metadata.

What is the target: The 2016 EPI biodiversity and habitat indicators gauge national performance according to the Convention on Biological Diversity's Aichi Targets for terrestrial and marine habitat protection: 17% for terrestrial habitat and species' protection; 10% for marine protected areas.[245]

DESCRIPTION

Biodiversity is in dramatic decline. World Wildlife Fund's 2014 Living Planet Report shows that global wildlife populations have declined by half since 1970. This startling disappearance means the irrevocable loss of wildlife's intrinsic worth as well as the economic and cultural values that expire when habitats and species perish. Recognizing the value in preserving the wild, nations have acted to protect lands from disturbance and degradation (see Box 16: Ecosystem Services Loss is Trillions of Dollars Per Year). From 1990 to 2014, protected areas more than doubled worldwide from 13.4 to 32 million km^2, and today cover more than 15 percent of the earth's total terrestrial surface.[247] Yet contemporary research, including WWF's recent study, shows that habitat protection has not stemmed the tide of species loss.

Of the nine Planetary Boundaries popularized by Johan Rockström at the Stockholm Resilience Institute,[248] the global limits of Biodiversity Loss have been exceeded by the widest margin.[249] Planetary boundaries are defined as physical and biological thresholds that, if crossed, threaten to destroy human civilization. Exceeding these boundaries would alter planetary systems, leading to the collapse of physical cycles on which life on earth depends. Human beings have directly altered half of the Earth's ice-free land surface, transforming biodiverse habitat into agricultural monocrops and urban landscapes. Humans control, directly and indirectly, approximately one-third of the planet's terrestrial primary productivity and use more than half of the world's freshwater – and these figures are on the rise.[250] Scientific study confirms the casual and disturbing observation that the earth is losing fauna at an appalling rate. The vertebrate extinction rate, for instance, in the twentieth century is conservatively estimated to be 100 times the natural, or background, rate.5?

As the world's animals disappear human societies suffer increasing costs from these irrevocable losses. Beyond the incalculable inherent values of the natural world, and our own irrevocable place in it and dependence upon it, are the effects of biological and physical processes at the base of market economies. Pollinators, for instance, are declining throughout the world, and their loss threatens global agricultural production.[251] Forests play such a critical role in hydrological cycles that their true economic value is beyond calculation. The disappearance of biodiverse landscapes and extinction of species are an environmental catastrophe, an impending social and political disturbance, and a global market failure – a glaring example how human activities have deleterious effects for both natural and market economies.

245 Convention on Biological Diversity. (n.d.). Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets. Available: https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf.

246 World Wildlife Fund. (2014). Living Planet Report 2014: species and spaces, people and places. [McLellan, R., Iyengar, L., Jeffries, B. & N. Oerlemans (Eds)]. WWF, Gland, Switzerland. Available: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/.

247 United Nations Environment Programme and World Conservation Monitoring Center. (n.d.). Mapping the world's special places. Available: http://www.unep-wcmc.org/featured-projects/mapping-the-worlds-special-places.

248 Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F...(2009). A safe operating space for humanity. Nature, 461, 7263, 472-475.

249 World Wildlife Fund. (2014).

250 Chapin III, F. S., Zavaleta, E. S., Eviner, V. T., Naylor, R. L., Vitousek, P. M., Reynolds, H. L... (2000). Consequences of changing biodiversity. Nature, 405, 6783, 234-242.

251 Gallai, N., Salles, J. M., Settele, J., & Vaissière, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics*, 68, 3, 810-821.

Box 16. ECOSYSTEM SERVICES LOSS IS TRILLIONS OF DOLLARS PER YEAR

We don't often realize the full value of our environment, including the air, water, and food systems that sustain us. Ecosystem services are one way to capture the value of these resources we use every day but don't pay for directly.

Ecosystem services are the benefits people derive from natural systems. Both the Convention of Biological Diversity (CBD) and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) acknowledge ecosystem services as a driving concept of conservation.[252] Setting aside the utter necessity of biodiversity for human survival, ecosystem services and natural capital have significant implications for the health of economies at all scales. Natural systems' governing of the carbon and water cycles, pollination, and weather patterns to name a few, are not only the bases of all economies, but the bases of all life.

A recent study estimates that the loss of ecosystem services due to land use change worldwide was worth between $4.3 and $20.2 trillion USD a year.[253] It also showed that these services contribute twice as much to human well being than the entire gross domestic product (GDP). A significant number of global policy makers already consider global biodiversity loss to be a serious threat to economic growth.[254]

How to account for the contributions of natural capital to national economies and trade is a fundamental question of economics. Some claim that natural capital is a public good and therefore solutions for its conservation and rational use must be derived beyond the marketplace.[255] Others believe that creating markets for protecting biodiversity, through offsets or programs like the United Nations' Reduced Emissions from Deforestation and Degradation (REDD+) are the way to ensure compliance with conservation goals.[256]

Whether internal or external to markets, biodiversity and habitats have faced tremendous losses as global economies have grown exponentially. To a large extent, economic gain and the creation of wealth are tied to the exploitation of ecosystems. If the protection of biodiversity is to go hand-in-hand with sustainable development, then economic growth will have to be somehow decoupled from the destruction of habitats and exploitation of wildlife. Natural capital accounting by nations and the private sector will be one among a suite of strategies for pursuing this decoupling through measurement and valuation.[257]

Whether accounting for ecosystem services and natural capital represent a meaningful next frontier toward the conservation of biodiversity and habitat or not, the continued effort of policy makers to explicitly set aside protected areas will still be critical toward conserving human life. As the land and resource needs of a growing and ever-wealthier population puts pressure on vulnerable species and their habitats, setting aside areas free of encroachment will be indispensable. But better data on precisely what we are protecting when we set aside those areas, as well as strict enforcement of protection measures, must be priorities.

252 Convention on Biological Diversity. (n.d.).

253 Costanza, R., et. al. (2014) Changes in the Global Value of Ecosystem Services. *Global Environmental Change*, 26, 152-158.

254 Convention on Biological Diversity. (n.d.). Biodiversity for Development and Eradication of Poverty. Available: https://www.cbd.int/undb/media/factsheets/undb-factsheet-development-en.pdf.

255 De Groot, R., et. al. (2012). Global Estimates of the Value of Ecosystems and their Services in Monetary Units. Ecosystem Services, 1, 50-61.

256 International Union for Conservation of Nature. (2014). Biodiversity Offsets: Technical Study Paper. Available: http://www.biodiversityoffsets.net/wp-content/uploads/2014/12/ten-Kate-and-Pilgrim_2014_Biodiversity-Offsets-Technical-Study-Paper.pdf.

257 Burke, L., Ranganathan, J., & Winterbottom, R. (Eds.). (2015). Revaluing Ecosystems: Pathways for Scaling Up the Inclusion of Ecosystem Value in Decision Making. World Resources Institute. Available: http://www.wri.org/sites/default/files/Revaluing_Ecosystems_April_2015_2.pdf.

Aiming for Targets that Protect

The Convention on Biodiversity (CBD) is the key multilateral agreement for promoting conservation in step with sustainable development. In 2010, 196 CBD Parties adopted the Aichi Biodiversity Targets, a series of goals that outline a global strategic plan for protecting biodiversity through 2020.[258] The CBD sets targets to protect 17 percent of terrestrial and 10 percent marine areas by 2020, basing these figures on "modest increases" from the 2010 baseline – 13 percent and 5 percent, respectively, for the planet's protected terrestrial and marine biomes.[259] The relatively modest terrestrial target is meant to encourage nations to focus on improving the quality of protected areas already under management. The more ambitious marine target, doubling marine protected areas from 5 to 10 percent, would expand protected oceanic regions and bring additional attention and resources to marine habitats, whose fauna face an onslaught of threats.

These habitat protection targets may be politically do-able, but there is no guarantee that the increase of protected areas will prevent species and biodiversity loss. Emphasizing efforts to better manage, rather than expand, protected areas, the Aichi Targets try to address the problems of insufficient funding and a lack of skilled personnel to manage parks. Some conservation experts argue that hard targets create false proxy measures for what we truly value.[260] They contend that emphasizing park extent distracts the public from the purpose of protecting species and biodiversity. Analyses of protected areas have found a prevalence for conserving "rock and ice" biomes – marginal lands where natural land cover would exist without formal protection. Because this land is usually not worth a lot of money, it is politically easier to protect than land with agricultural, mineral, or urban development value.[261, 262]

Many countries show improvements in terrestrial and marine habitat protection. Three quarters of all countries report increases in terrestrial protected areas and two-thirds of countries have improved their marine protected areas scores in the 2016 EPI. Part of the reason for improvement in countries' overall scores is not performance-related. Instead, investments in data reporting and an expansion in the definition of what constitutes "protected areas" are largely responsible for these increases (see Figure 17). In 2014 the World Database for Protected Areas (WDPA), a combined effort between the United Nations Environment Programme and International Union for Conservation of Nature carried out a major update to improve online accessibility and timeliness of data updates.[263] Efforts in recent years to standardize data collection, including common definitions and requirements for shapefile formats and source information, have helped WDPA streamline data from multiple contributors, and subsequently increased data availability for protected areas.[264] The number of protected areas national governments have designated has doubled each decade for the last 20 years. The latest United Nations List of Protected Areas includes 209,429 areas covering over 30 million km2 – an expanse larger than the entire African continent. Overall, 3.4 percent of the world's marine area and 14 percent of the world's terrestrial areas are protected.[265]

258 Convention on Biological Diversity. (n.d). Aichi Biodiversity Targets. Available: https://www.cbd.int/sp/targets/.

259 Convention on Biological Diversity. (n.d). Technical Rationale (provided in document COP/10/27/Add.1). Available: https://www.cbd.int/sp/targets/rationale/default.shtml.

260 Pressey, B. & E. Ritchie. (2014, November 11). We have more parks than ever, so why is wildlife still vanishing? The Conversation. Available: https://theconversation.com/we-have-more-parks-than-ever-so-why-is-wildlife-still-vanishing-34047.

261 Venter O., Fuller R.A., Segan D. B., Carwardine J., Brooks T., Butchart S. H. M., ... (2014). Targeting Global Protected Area Expansion for Imperiled Biodiversity. PLoS Biol,12 ,6, e1001891.

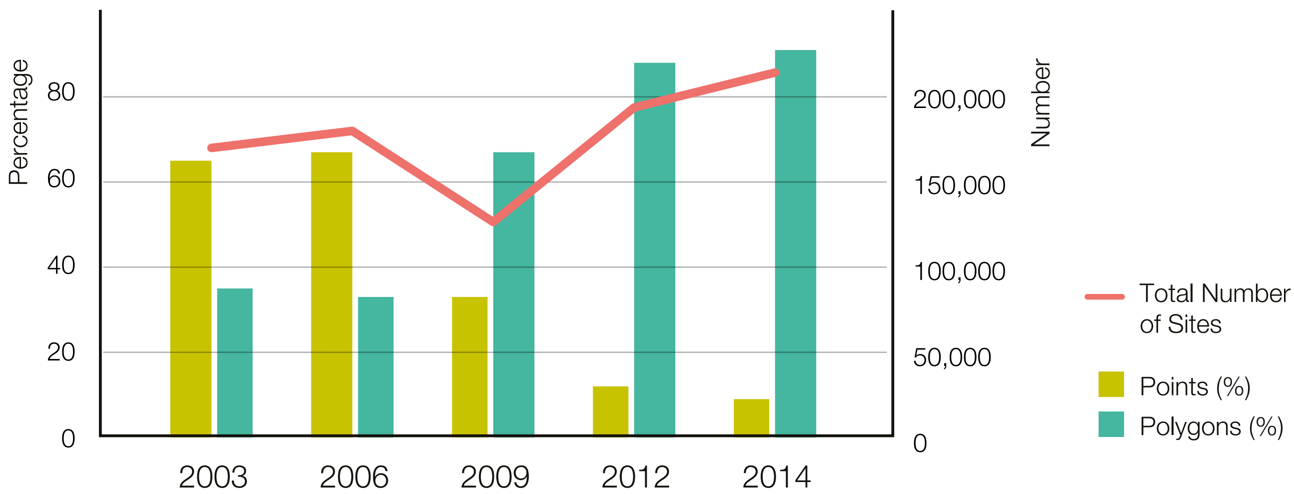
262 Joppa L. N., & Pfaff A. (2009). High and far: biases in the location of protected areas. PLoS ONE, 412, e8273.

263 United Nations Environment Programme - World Conservation Monitoring Center. (2015, June 2). Exploring our Protected Planet just got easier. Available: http://www.unep-wcmc.org/news/exploring-our-protected-planet-just-got-easier.

264 United Nations Environment Programme - World Conservation Monitoring Center. (2012).World Database on Protected Areas Data Standards. Available: http://old.unep-wcmc.org/world-database-on-protected-areas-wdpa-data-standards_966.html.

265 United Nations Environment Programme - World Conservation Monitoring Center. (2012).

Figure 17: Data improvements and a switch from points to polygons resulted in an increase in protected areas recorded in the WDPA from 2003 to 2014.



Source: UNEP-WCMC, 2014.

Introducing New Species Protection Indicators

To determine whether terrestrial protected areas are located in areas that overlap with species' actual habitats or are instead in "rock and ice" territories, our team partnered with Yale's Map of Life to produce new species protection indicators that overlay protected areas with species' habitat ranges. A map displaying a few representative species' habitat protection and nationally-protected areas, produced by the EPI team, was featured in *Nature* magazine. The map illustrates individual species whose habitats do not necessarily align with habitat and protected areas. The European Commission's Digital Observer of Protected Areas (DOPA) is another effort to display critical habitat and biodiversity data in an interactive format. The portal brings together data from a host of international institutions and promotes a cross-disciplinary approach to inform management decisions for parks.

EPI's dual focus on biodiversity and habitat allows nations to analyze and critique their policies' effectiveness toward multiple goals. Mexico, for instance, scores an average of 83 on the 2016 EPI Terrestrial Habitat Protection indicators, but only 68 on the Species Protection indicators. This difference suggests that Mexico's protected areas do not optimally align with its species' habitats and ranges. This gap may also reflect the "paper parks" phenomenon, in which parks are created in name only, while these protected areas are poorly managed and provided insufficient resources. Paper parks pose problems for collecting appropriate biodiversity and habitat data and creating meaningful indicators. The World Parks Congress, hosted by the International Union for Conservation of Nature, spurred an international movement towards developing data and indicators that assesses quality of park management and not just quantity of protected areas.[266]

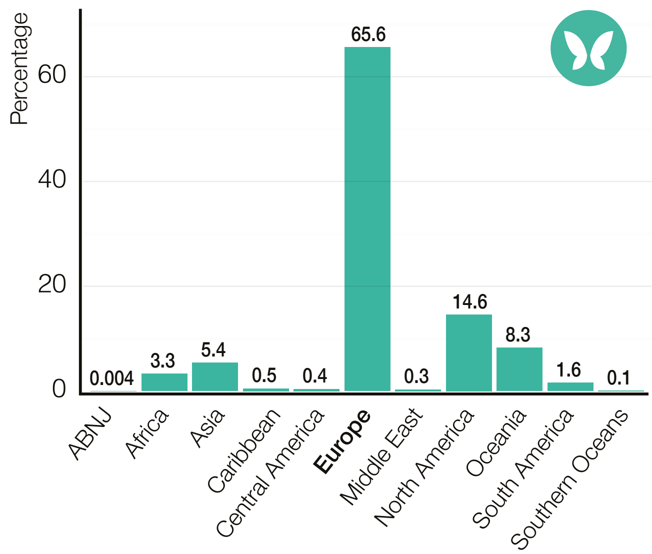
266 Di Minin, E. & Toivonen, T. (2015). Global Protected Area Expansion: Creating More than Paper Parks. BioScience, 65, Issue 7, 637-638.

Recent Efforts to Address Biodiversity Loss

In 2015, President Barack Obama created two new marine sanctuaries, the first in 15 years, one located off the coast of Maryland and the other in Lake Michigan. The protected area in Maryland's Chesapeake Bay is extraordinarily biodiverse, home to a multitude of birds, mammals, and fish.[267] Also in 2015, Chilean President Michelle Bachelet created the largest marine protected area in the Americas, near the Desventuradas Islands, to protect resident and transient marine species.[268]

More than 80 percent of all the world's parks were established after the first World Parks Congress in 1962 (Figure 18). Regionally, Europe boasts the largest number of protected areas, amounting tot 65.6 percent of all areas. Following the creation of the CBD, Europe created a special Habitats Directive in 1992 to establish protected areas and designate over 1,000 animal and plant species for protection.[269] There are 105,000 nationally-designated protected areas in the European Union, ranging in size from the 1.3 million hectares Vatnajokulsthjodgardur National Park in Iceland to sites established to protect individual trees, such as the Kaèja smreka in Godovic, Slovenia. [270]

Figure 18: Regional distribution of protected areas globally show the greatest percentage of protected areas is found in Europe, which has more than 65 percent of protected areas




Chesapeake Bay, Maryland


Iceland

267 Harvey, C. (2015, October 5). Obama just announced the first new marine sanctuaries in 15 years. The Washington Post. Available: https://www.washingtonpost.com/news/energy-environment/wp/2015/10/05/obama-just-announced-the-first-new-marine-sanctuaries-in-15-years/.

268 Lee, J. J. (2015, October 5). Chile Creates Largest Marine Reserve in the Americas. National Geographic. Available: http://news.nationalgeographic.com/2015/10/151005-desventuradas-islands-marine-protected-area-conservation-science/.

269 European Commission. (2015). The Habitats Directive. Available: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm.

270 European Environment Agency. (2012, October 23). Protected areas have increased to cover one-fifth of Europe's land. Available: http://www.eea.europa.eu/highlights/protected-areas-have-increased-to.

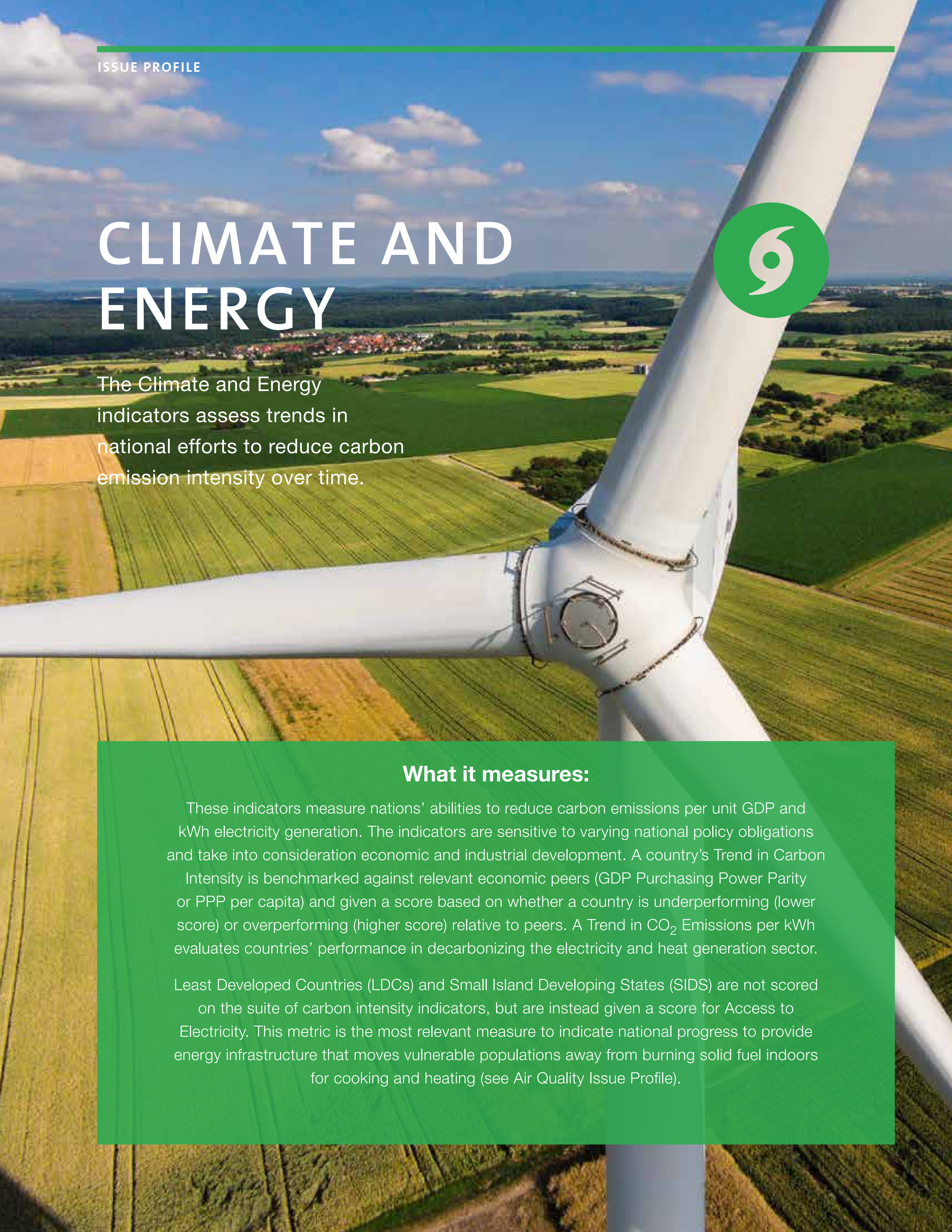
Figure 19: Marine and terrestrial protected areas cover many areas in Europe, although many are fragmented.

Source: UNEP-WCMC, 2015.

Despite the number of protected areas in Europe, these sites' wide dispersal creates habitat fragmentation, creating problems for Europe to protect what remains of its biodiversity (Figure 19).

Official protected area designation brings attention to conservation's importance, yet national protection does not ensure species preservation. Notwithstanding the global increase in both terrestrial and marine protected areas, species are disappearing at alarming rates. We could in fact view Protected Areas as lagging indicators, reflecting nations' reactions – overdue yet virtuous acts – to declining biodiversity. The discordance between species loss and growing habitat conservation trends shows that current protection efforts are not sufficient to address the drivers of biodiversity loss, including increased industrial and agricultural production and consumption.[271] Meaningful habitat and species protection requires collaboration across borders, multinational monitoring, and environmental education from the earliest ages.

271 Tittensor, D. et al. (2014). A mid-term analysis of progress toward international biodiversity targets. Science, 346, 6206, 241-244.



CLIMATE AND ENERGY

The Climate and Energy indicators assess trends in national efforts to reduce carbon emission intensity over time.

What it measures:

These indicators measure nations' abilities to reduce carbon emissions per unit GDP and kWh electricity generation. The indicators are sensitive to varying national policy obligations and take into consideration economic and industrial development. A country's Trend in Carbon Intensity is benchmarked against relevant economic peers (GDP Purchasing Power Parity or PPP per capita) and given a score based on whether a country is underperforming (lower score) or overperforming (higher score) relative to peers. A Trend in CO_2 Emissions per kWh evaluates countries' performance in decarbonizing the electricity and heat generation sector.

Least Developed Countries (LDCs) and Small Island Developing States (SIDS) are not scored on the suite of carbon intensity indicators, but are instead given a score for Access to Electricity. This metric is the most relevant measure to indicate national progress to provide energy infrastructure that moves vulnerable populations away from burning solid fuel indoors for cooking and heating (see Air Quality Issue Profile).

Why we include it: Climate change impacts essentially all of the Earth's physical and biological systems. Little progress has been made to understand which countries' efforts to mitigate greenhouse gas (GHG) emissions are successful and whether efforts to decarbonize economic growth are working. The EPI's Climate and Energy indicators rank progress in reducing carbon emission intensity in the period from 2002 to 2012. See Climate and Energy Infographic.

> **The 2015 Paris Agreement requires all countries to take action on climate change.**

Where the data come from: Carbon dioxide (CO_2) Emissions per kWh of electricity emissions data come from the Climate Analysis Indicators Tool (CAIT) 2.0 database provided by the World Resources Institute.[272] The Trend in CO_2 Emissions per kWh of electricity generation indicator is developed from data provided by WRI-CAIT. GDP data are from the International Energy Agency (IEA).[273] The contributions of oil and mineral rents to each country's GDP from the World Bank's World Development Indicators dataset have been removed so that countries that mainly trade, rather than consume these commodities to produce their GDP, are not unfairly penalized.

Data for the Access to Electricity indicator are from the Sustainable Energy for All Initiative, a joint effort by the World Bank and the IEA.[274] For more information, see 2016 EPI Metadata.

1/3

of countries scored on Climate and Energy are reducing their carbon intensity.

What are the targets: Because there are no globally agreed-upon targets for CO_2 reduction, the data are used to show relative performance for these indicators. The highest performing countries are those that demonstrate the greatest negative trends in carbon intensity, relative to its economic peers.

DESCRIPTION

Coming in the last month of the hottest year in recorded history,[275] the 2015 Paris Climate Change Agreement was a landmark step towards global recognition that all countries, developed and developing, contribute to and suffer from the effects of climate change. For the first time, countries both rich and poor agreed to take actions to mitigate climate change emissions in line with their respective capacities. The Agreement, signed by 196 countries, proposes an international framework to keep global temperature rise from reaching a 2 degrees C increase and achieve net-zero emissions by the second half of the 21st century.[276, 277]

The Paris Agreement secured buy-in and Intended Nationally Determined Contributions (INDCs) from all countries,[278] and produced a range of plans reflecting various national strategies. To monitor countries' individual adherence to their targets and assess the potential mitigation impact that results

272 Climate Indicators Analysis Tool. (n.d.). World Resources Institute. Available: http://cait.wri.org/.

273 International Energy Agency. (n.d.). Statistics. Available: http://data.iea.org/ieastore/statslisting.asp.

274 Sustainable Energy for All. (n.d.). Available: http://www.se4all.org/.

275 World Meteorological Organization. (2015, November 25). WMO Press Release: 2015 likely to be Warmest on Record, 2011-2015 Warmest Five Year Period. Available: https://www.wmo.int/media/content/wmo-2015-likely-be-warmest-record-2011-2015-warmest-five-year-period.

276 United Nations Framework Convention on Climate Change. (2015). Adoption of the Paris Agreement. Available: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

277 Davenport, C. (2015, December 12). Nations Approve Landmark Climate Accord in Paris. The New York Times. Available: http://www.nytimes.com/2015/12/13/world/europe/climate-change-accord-paris.html?_r=0.

278 United Nations Framework Convention on Climate Change. (2015). Intended Nationally Determined Contributions. Available: http://unfccc.int/focus/indc_portal/items/8766.php.

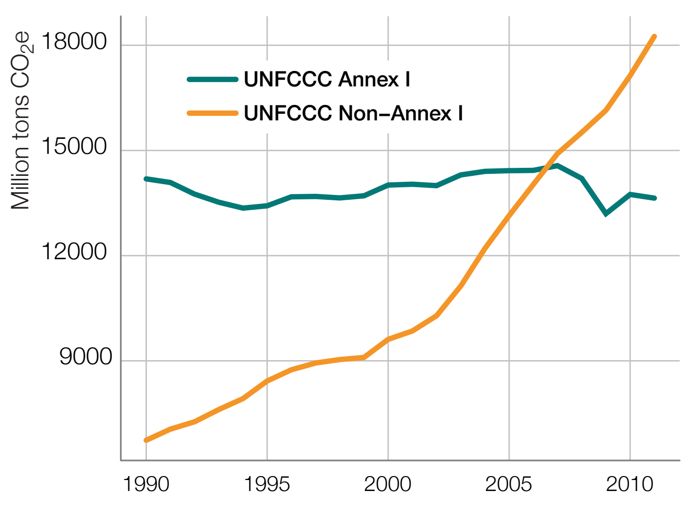
from these goals is extremely difficult without a framework that ensures countries report a consistent set of metrics.

Several organizations have put forth various methods to grasp and interpret climate change performance, and each has its advantages and trade-offs.[279] The Climate Change Performance Index combines countries' greenhouse gas emissions statistics with qualitative data from climate policy experts to hone in on climate policies' role in driving emission reductions.[280] The Climate Action Tracker assesses whether or not national policies are consistent with the action needed to prevent global temperature rise of 2 degrees C.[281] The World Resources Institute's CAIT Data Explorer, which EPI uses for its Climate and Energy indicators, allows users to delve into the equity of climate targets and illuminates data gaps within and between country pledges for climate action.[282]

Evaluating and ranking climate policies' measurable impact is a difficult challenge. Carbon dioxide (CO2) emissions and temperature rise exhibit a nearly linear association, so that CO_2 emissions is the ubiquitous metric used to benchmark the world's advance towards dangerous warming thresholds. In May 2015, average atmospheric CO_2 concentrations reached 400 parts per million (ppm) for the first time in more than 400,000 years, enough CO_2 to raise global temperatures by 1.6 degrees C from a pre-industrial baseline.[283, 284] Seeking a comprehensive signal of global environmental change, researchers look beyond atmospheric conditions, incorporating the oceans, which have absorbed the vast majority of the greenhouse effect's excess heat and half of the anthropogenic CO_2.

Carbon is as much a metric of a country's economic development as it is an indicator of climate. Commonly referred to as a development problem, climate change is primarily the result of industrialization through the burning of fossil fuels. Developed countries, referred to as United Nations Framework Convention on Climate Change (UNFCCC) Annex I countries in Figure 20 below, are historically responsible for the majority of global CO_2 emissions, however in 2007, developing countries' (UNFCCC Non-Annex I Parties) emissions, driven primarily by China's growth, surpassed developed nations' annual contributions for the first time. Because economic growth is powered by fossil fuels, CO_2 emissions are indicators of trends other than and in addition to climate change policy performance. Low CO_2 emissions could mean that a nation is underdeveloped (e.g., a Sub-Saharan African country), an economy is in decline, or it could mean that a country has made concerted efforts to reduce emissions through a policy intervention that, for example, replaces fossil fuel combustion with renewable energy production.

Figure 20: The year 2007 was the first time developing country CO_2 emissions (UNFCCC non-Annex I), driven primarily by China, surpassed those of developed country (UNFCCC Annex I) emissions



Source: WRI-CAIT, 2014.

279 Weinfurter, A. (2014, October 2). Energy Indices and Frameworks. Yale Environmental Performance Index, The Metric. Available: http://epi.yale.edu/the-metric/energy-indices-and-indicator-frameworks.

280 Burck, J., F. Marten, & C. Bals. (2015). The Climate Change Performance Index 2015. Germanwatch. Available: https://germanwatch.org/en/9472.

281 Climate Action Tracker. (n.d.). Available: http://climateactiontracker.org/. Climate Analytics, NewClimate Institute, Ecofys, Potsdam Institute for Climate Impacts Research.

282 Climate Indicators Analysis Tool. (n.d.). World Resources Institute. Available: http://cait.wri.org/.

283 Kahn, B. (2015, May 6). A Global Milestone: CO2 Passes 400 PPM. Climate Central. Available: http://www.climatecentral.org/news/co2-400-ppm-global-record-18965.

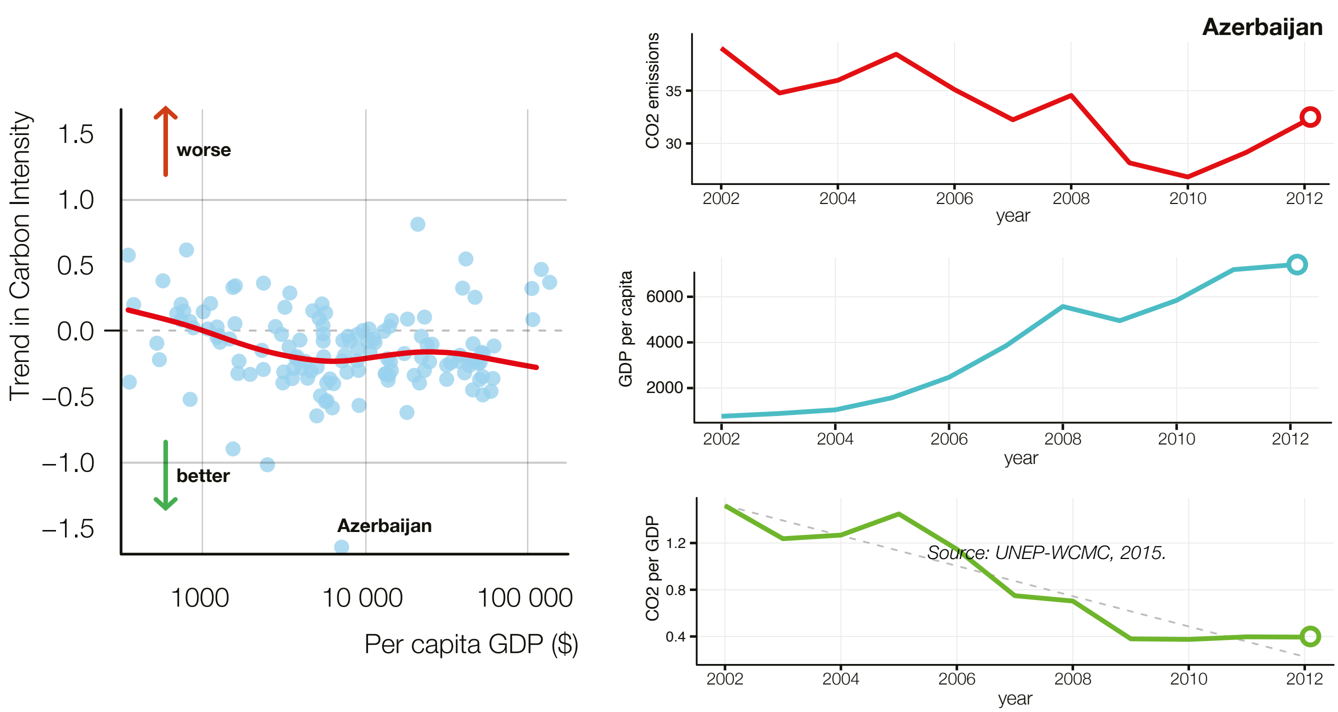
284 Intergovernmental Panel on Climate Change. (2013). WORKING GROUP I CONTRIBUTION TO THE IPCC FIFTH ASSESSMENT REPORT CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS Final Draft Underlying Scientific-Technical Assessment. Available: http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_Chapter01.pdf.

Measuring Climate Change Performance According to Development Status

The 2016 EPI evaluates national climate change performance based on trends in carbon intensity, taking into consideration a nation's level of economic development (Figure 21). The United States, for instance, has committed to reduce emissions by 26-28 percent of 2005 levels by the year 2025.[285] The EPI's Trend in Carbon Intensity indicator evaluates whether the United States is successful in achieving these CO_2 reductions, relative to other wealthy countries.

Metrics that track climate commitments over time are important for gauging a nation's long-term climate mitigation efforts, as political regimes can change and political will often wanes with election cycles. Canada, for instance, submitted an INDC with a 30 percent emissions reduction goal by 2030 based on 2005 levels, an unambitious pledge compared with its peer countries.[286] Interim elections brought a more progressive political party into power at the federal level and in Alberta –the home of Canada's oil industry and its main source of emissions growth. This political change shifted momentum for the country's climate policies to support the Paris Agreement. Prime Minister Justin Trudeau, elected a month before the Paris Climate negotiations, pledged to implement a carbon pricing plan, increase investments in clean energy, and raise the aims of the country's commitments.[287] An ambitious

Figure 21: A model using the relationship between national per capita GDP per Purchasing Power Parity (PPP) and the trend in carbon dioxide emissions (CO2) per unit GDP from 2002 to 2012 allocates higher scores to countries for outperforming economic peers, while giving lower scores to countries who perform worse



285 Climate Action Tracker. (n.d.).

286 Damassa, T. & T. Fransen. (2015, May 15). Canada's Proposed Climate Commitment Lags Behind Its Peers. World Resources Institute. Available: http://www.wri.org/blog/2015/05/canadas-proposed-climate-commitment-lags-behind-its-peers.

287 Fitz-Morris, J. (2015, November 30). Justin Trudeau tells Paris climate summit Canada ready to do more. Canadian Broadcasting Corporation News. Available: http://www.cbc.ca/news/politics/trudeau-address-climate-change-paris-1.3343394.

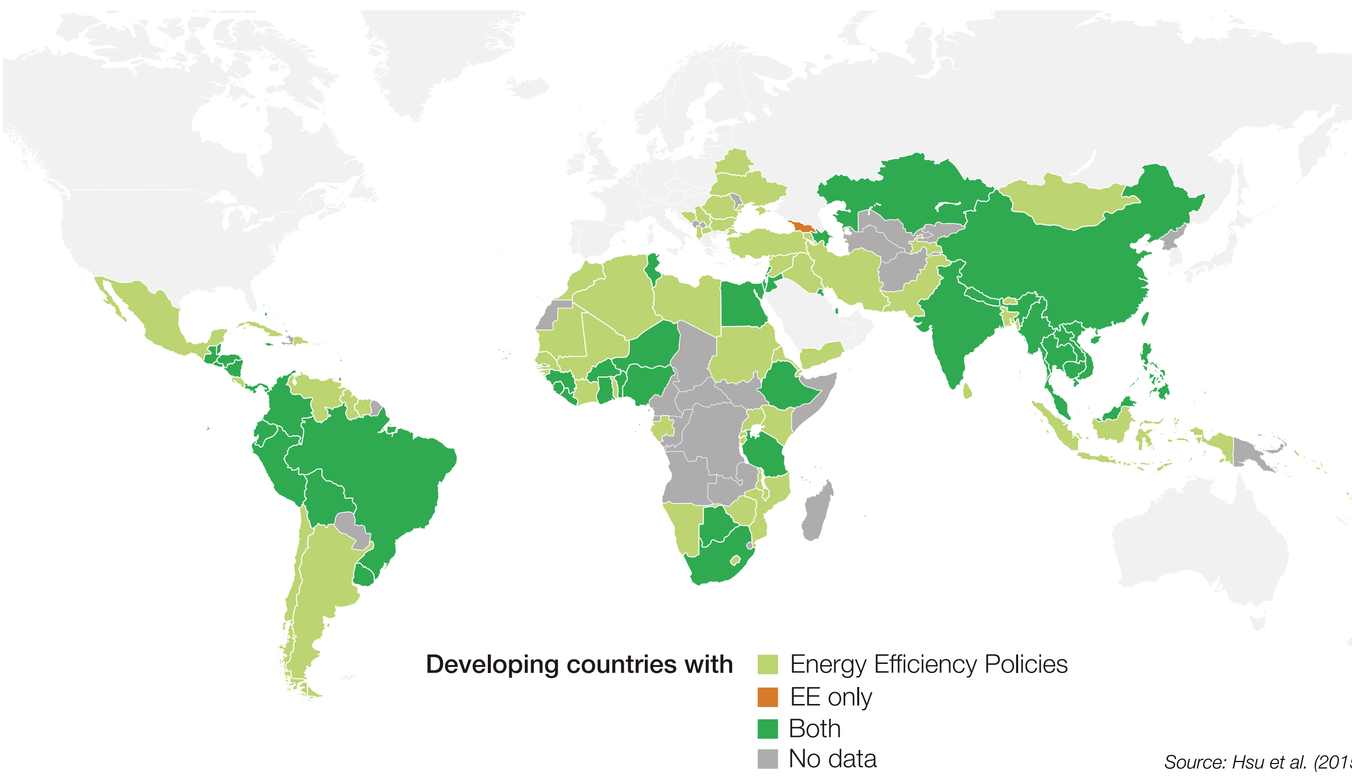
INDC is expected after the new federal officials meet with the provincial governments and set national targets.

Policy commitments must be paired with hard data to demonstrate positive performance. Brazil has pledged to eliminate illegal deforestation in the Amazon rainforest by 2030 and reduce emissions by 43 percent based on 2005 levels. Despite these lofty intentions, deforestation rates in Brazil rose by 16 percent last year, according to the Brazil's Environment Ministry.[288] These statistics, released prior to the Paris climate negotiations, confirmed concerns over Brazil's updated, and weakened, 2011 forestry code. The 2011 policies counter efforts implemented in the previous decade to curb deforestation, which had included strong monitoring, reporting, and use of satellite data[289] (see Forests Issue Profile).

Climate Change Performance in Developing and Emerging Economies

The majority of emissions growth is expected to be generated by middle-income and emerging economies, making climate mitigation in these countries a critical issue for the world. Recognizing the need to develop clean-energy infrastructure, 69, or nearly half of the world's developing countries have adopted national renewable energy and energy efficiency policies (Figure 22).

Figure 22: Nearly half of the world's developing nations (69 out of 150 with available data) have policies for both renewable energy and energy efficiency.



Source: Hsu et al. (2015).

288 Watts, J. (2015, November 27). Amazon deforestation report is major setback for Brazil ahead of climate talks. The Guardian. Available: http://www.theguardian.com/world/2015/nov/27/amazon-deforestation-report-brazil-paris-climate-talks.

289 Smith, J. (2015, October 22). Three Amazon nations, three approaches to reducing deforestation. Mongabay. Available: http://news.mongabay.com/2015/10/three-amazon-nations-three-approaches-to-reducing-deforestation/.

Within this group of emerging and growing economies, Costa Rica has undertaken ambitious efforts to reduce its fossil fuel consumption. The Central American country achieved 99 percent renewable energy generation in 2015[290] – a milestone in the country's 2008 plan to go carbon neutral by 2021. With 80 percent of its electricity generated from hydropower, however, the country will be challenged to sustain its momentum in a changing climate that brought record droughts this past year.

China has recognized its status as the world's largest emitter of carbon emissions and has taken recent efforts to reduce its carbon intensity of economic growth. Its government has made investments to reduce both carbon and energy intensity through nationally-binding reduction targets in its 12th Five-Year Plan,[291] actions that achieved a 19.1 percent reduction in energy intensity from 2006 to 2010. China is also on track to meet its 2009 Copenhagen climate commitment to reduce carbon intensity 40 to 45 percent from 2005 levels by 2020.[292] China's historic bilateral agreement with the United States, announced at a meeting between Presidents Obama and Xi in November 2014, was cited as a major driver behind the 2015 Paris Climate Summit's success.[293]

Because Least Developed Countries (LDCs) and Small Island Developing States (SIDS) bear the smallest amount of the global climate mitigation burden, they are not scored in the EPI's Climate and Energy category. Instead, they are given an indicator that assesses the percentage of the country's population with access to electricity as the more relevant policy goal. Many countries with large portions of their populations lacking access to electricity currently rely on high-polluting, unsustainable forms of fuel, including animal dung, wood, and charcoal. Switching to less-polluting fuels has beneficial climate and household air pollution impacts (see Air Quality Issue Profile). Increasing access to electricity also provides clear social and economic benefits for citizens (see Box 17: Rwanda Turns to Renewable Energy). The 2016 EPI website gives an indicator of Access to Electricity for LDCs, but it does not include the measure when calculating the total EPI score for these countries.

Thar desert in Rajasthan, India

290 Fendt, L. (2015, March 30). The truth behind Costa Rica's renewable energy. The Guardian. Available: http://www.theguardian.com/commentisfree/2015/mar/30/truth-behind-costa-rica-renewable-energy-reservoirs-climate-change.

291 Seligsohn, D., & Hsu, A. (2011, March 7). How does China's 12th Five-Year Plan address energy and the environment? China FAQs. Available: http://www.chinafaqs.org/blog-posts/how-does-chinas-12th-five-year-plan-address-energy-and-environment.

292 Hsu, A., Y. Peng, & K. Xu. (2015, July 7). Five Key Takeaways from China's Climate Pledge. Voices: The Paulson Institute. Available: http://www.paulsoninstitute.org/paulson-blog/2015/07/07/five-key-takeaways-from-chinas-new-climate-pledge/.

293 Davenport, C. (2015, December 13). A Climate Deal, 6 Years in the Making. The New York Times. Available: http://www.nytimes.com/2015/12/14/world/europe/a-climate-deal-6-fateful-years-in-the-making.html?_r=0.

Box 17. RWANDA TURNS TO RENEWABLE ENERGY

As the pressure on traditional energy sources grows, renewable energy offers a path towards cleaner, more reliable power for Rwanda. The country's next challenge: figuring out the finance.

Expanding and diversifying Rwanda's energy profile will be crucial to continuing the country's development gains. Rwanda expanded energy access from 2 to 18 percent of its population between 1990 and 2012.[294] Most citizens, however, still rely on biofuels. Fuel sources like charcoal and firewood accounted for 75 percent of the country's 2012 energy consumption, a rate higher than the 63 percent average across Sub-Saharan Africa.[295] Consuming biofuels at this rate puts pressure on the nation's forests and endangers the health of those who rely on solid fuels for cooking and heating (see Air Pollution Issue Profile).[296] If these trends continue, the country estimates that its current 0.9-megaton biofuel shortfall will grow to 5.9 megatons by 2030.[297]

Renewable energy is poised to play a key role in addressing this shortage. By 2030, Rwanda hopes to bring electricity to 100 percent of both its urban and rural populations and to derive 59 to 73 percent of this energy from renewable sources.[298] The recent construction of the Agahozo-Shalom Youth Village solar power plant demonstrates the country's progress towards this goal. Is it the first large-scale power plant in East Africa, and the facility currently produces 15,000 megawatts per year, with capacity to deliver 8.5 megawatts (approximately 6 percent of Rwanda's current capacity).[299] It will save an estimated 7,500 – 8,400 tons of carbon dioxide equivalent each year, compared to traditional energy sources, while

Gigawatt Project Rwanda

294 Sustainable Energy For All. (2015). Global Tracking Framework: Progress Towards Sustainable Energy 2015. Available: http://www.se4all.org/wp-content/uploads/2013/09/GTF-2105-Full-Report.pdf.

295 Sustainable Energy For All. (2015).

296 World Health Organization. (2014). Household air pollution and health. Available: http://www.who.int/mediacentre/factsheets/fs292/en/.

297 Republic of Rwanda. (2011). Green Growth and Climate Resilience Strategy (GGCRS): National Strategy for Climate Change and Low Carbon Development. Kigali, Rwanda. Available: http://www.uncsd2012.org/content/documents/364Rwanda-Green-Growth-Strategy-FINAL.pdf.

298 Republic of Rwanda. (n.d.). Policy Brief: Costing the Green Growth and Climate Resilience Strategy. Kigali, Rwanda.

299 Scate Solar. ASYV, Rwanda, 8.5 MW. Available: http://www.scatecsolar.com/Portfolio/Rwanda/ASYV-Rwanda-8.5-MW.

300 Gigawatt Global. (2015). Socioeconomic Impact Highlights. Available: http://gigawattglobal.com/projects/rwanda/.

providing 15,000 – 18,000 homes with electricity.[300] Other efforts, including a pilot project to capture 3.6 megawatts of power from the methane gas generated by Lake Kiva[301] – and a 445-megawatt expansion of hydropower[302] – are also helping to diversify Rwanda's energy portfolio.

Using renewable energy to meet 73 percent of Rwanda's 2030 energy needs would cost $7.5 billion USD over 15 years, requiring more upfront capital than the $6.7 billion USD required to fund business-as-usual.[303] The Government of Rwanda calculates, however, that reduced operating and fuel costs would "more than compensate for" the upfront investment needed to develop renewable energy resources.[304] Leveraging public-private partnerships, and taking advantage of support from programs like the Green Climate Fund, could help close this funding gap.[305]

Financing for renewable energy will begin to edge out funding for fossil fuels, as renewables are projected to grab two-thirds of the finance dedicated to new power sources by 2030.[306] Investment in renewable energy in developing countries increased 36 percent between 2013 and 2014, reaching $131.3 billion USD, an amount nearly equal to the $138.9 billion USD invested in renewable energy in developed countries.[307] To avoid the most dangerous impacts of climate change, and to meet the urgent demand for energy access in developing countries, overall investments will need to rise further and faster, to $730 billion USD per year by 2035.[308]

This box is based on a case study of Rwanda's Agahozo-Shalom Youth Village solar power plant, included in the 1 Gigaton Coalition report, Narrowing the Emissions Gap: Contributions from renewable energy and energy efficiency activities.[309]

Challenges in Disentangling Performance

Because carbon emissions are linked to many factors, including economic growth, decline, and energy structure, the EPI's indicators cannot distinguish between mitigation trends that are the result of concerted policy efforts and those that are due simply to economic decline. This shortcoming is one of the reasons why measuring climate change performance is so challenging. Regardless, the EPI's Climate and Energy indicators evaluate declines in carbon intensity, with an overall global goal of decarbonization. Spain, for instance, was downgraded in the 2016 Climate Change Performance Index (CCPI) rankings, falling by 8 places to 41st place. Germanwatch, a thinktank who produces the rankings, cite "Politically retroactive measures […] have ruined the dynamics in the renewables sector [… and] the country is opposing progressive measures on an international scale."[310] Economic recession – and not policy actions – are primarily driving Spain's negative Carbon Intensity Trend, rewarding the country in the EPI for achieving reductions without deliberate efforts. Because of this anomaly, the EPI only uses Spain's data from 2002 to 2008 to gauge its Trend in Carbon Intensity. Indices like the CCPI demonstrate why qualitative data are necessary to contextualize performance and its underlying drivers. They further point to the limitations of quantitative measures that seek to characterize all countries similarly.

301 Bateta, A. (2015, June 7). Rwanda plans to triple power output. East African Business Week. Available: http://www.busiweek.com/index1.php?Ctp=2&pl=3404&pLv=3&srl=69&spl=221.

302 A Gehle, J. (2014, August 14). Rwanda is expanding renewable energies. Sun & Wind Energy. Available: http://www.sunwindenergy.com/review/rwanda-expanding-renewable-energies.

303 Republic of Rwanda. (n.d.).

304 Republic of Rwanda. (n.d.).

305 Green Climate Fund. (n.d.). Available: http://www.greenclimate.fund/home.

306 Roca, M. (2014, July 1). Renewables to Receive Lion's Share of $7.7 Trillion in Global Power Funding. Renewable Energy World. Available: http://www.renewableenergyworld.com/news/2014/07/renewables-to-receive-lions-share-of-7-7-trillion-in-global-power-funding.html.

307 Hsu, A. et al. (2015). Narrowing the Emissions Gap: Contributions from renewable energy and energy efficiency activities. United Nations Environment Programme. Available: http://www.1gigatoncoalition.org/news/first-report-of-1-gigaton-coalition-released/.

308 Doukas, A., & Ryor, J. (2014, June 30). Closing the renewable energy investment gap. World Resources Institute. Available: http://www.wri.org/blog/2014/06/closing-renewable-energy-investment-gap.

309 Hsu, A. et al. (2015).

310 Germanwatch. (2015). 2016 Climate Change Performance Index. Available: https://germanwatch.org/en/download/13626.pdf.

Future Climate Metrics

In an ideal world, data would be available to benchmark climate change performance in all sectors of an economy, providing a level of detail that would reveal which countries' economies are truly improving energy efficiency and moving towards decarbonization. The only sector-level carbon emissions data, however, are available for the power sector, responsible for a quarter of all global greenhouse gas emissions in 2010.[311] The electricity and heat generation sector is relatively comparable country to country and gives an impetus for the EPI's third indicator in the Climate category, Trend in CO_2 Emissions per kWh. This indicator measures the carbon intensity of countries' electricity and heat generation sector.

Iceland tops the rankings in the Trend in CO_2 emissions per kWh indicator, with nearly all of its electricity and heat generation derived from renewable energy sources, including geothermal and hydropower. Geothermal energy provides more than 87 percent of the country's heat and hot water demand, and hydropower supplies 75 percent of its electricity.[312] Developing countries in Latin America and Africa comprise the bottom of the Trend in CO_2 per kWh rankings, reflecting their place at the bottom of the typical "energy ladder" in electrification; countries begin with carbon-intensive electricity generation and move gradually towards cleaner energy sources as their economies develop.

Achieving the Paris Climate Agreement's goal of net zero carbon in the second half of the 21st Century will require gradual elimination of all fossil fuel consumption. Fossil fuels remain the least-cost energy option for many countries, but not necessarily due to the high cost of clean energy alternatives. Government subsidies for fossil fuels, which G-20 countries have committed to reduce each year since 2009, are increasing in some countries (see Figure 23).[313] The United States, for example, has increased fossil fuel subsidies 35 percent since 2009, contributing $20.5 billion USD for oil, coal, and gas production from both federal and state-level subsidies. Only Russia spends more to facilitate the mining and processing of fossil fuels, at $22.8 billion USD a year (see Box 18: Phasing Out Fossil Fuel Subsidies).[314] Achieving global climate goals to contain temperature rise and reach carbon neutrality will require national governments to shift away from policies that finance and encourage fossil fuel consumption.

Iceland

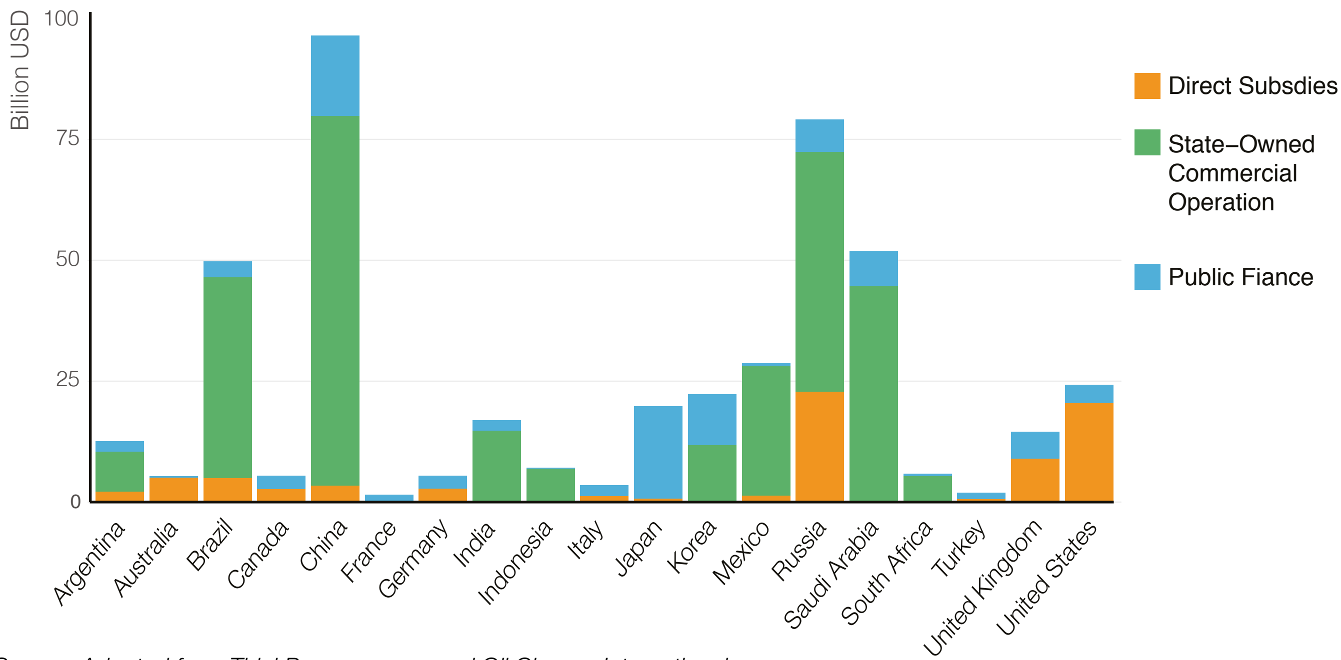
311 Intergovernmental Panel on Climate Change. (2014). Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available: https://www.ipcc.ch/report/ar5/wg3/.

312 Runyon, J. (2013, March 4). Geothermal Energy in Iceland: Too Much of a Good Thing? Renewable Energy World. Available: http://blog.renewableenergyworld.com/ugc/blogs/2013/03/geothermal-energy-in-iceland-too-much-of-a-good-thing.html.

313 Geiling, N. (2015, November 12). Here's How Much The World's Biggest Economies Spend On Fossil Fuel Subsidies. ThinkProgress. Available: http://thinkprogress.org/climate/2015/11/12/3721677/g20-fossil-fuel-subsidies/.

314 Geiling, N. (2015, November 12).

Figure 23: China provides the highest level of government fossil fuel subsidies in the G-20.



Source: Adapted from ThinkProgress.com and Oil Change International.

Encouragingly, national governments are not the only actors contributing towards a low and zero-carbon future. As atmospheric carbon concentrations exceed dangerous thresholds and average global temperatures break records, the global climate policy community has sought actors to propose and implement climate programs in the void left by national governments' inaction. Sub-national actors – cities, states and regions – and non-state actors – private businesses, investors, and civil society organizations – were central to the process in Paris, as these groups have committed to take climate actions that contribute towards and could exceed national pledges.

Climate change, in the words of UN Secretary-General Ban-Ki Moon, is the "defining issue of our era,"[315] and will require coordinated global action from actors at all levels. To reach new global climate goals agreed to in Paris, robust metrics to track progress are critical. While the EPI's Climate and Energy indicators are preliminary signals of which countries are working towards decarbonizing their economies, more timely data and monitoring are needed to better target and fine-tune policy interventions.

315 Moon, B.K. (2015). Statement: Secretary-General's Remarks at Workshop on the Moral Dimensions of Climate Change and Sustainable Development "Protect the Earth, Dignify Humanity" [As Delivered]. United Nations. Available: http://www.un.org/sg/statements/index.asp?nid=8584.

Box 18. PHASING OUT FOSSIL FUEL SUBSIDIES

Government support for fossil fuel production has continued to rise, skewing the global market and slowing the expansion of renewable energy. Can more transparent data hold political leaders accountable to their promises to phase out subsidies?

Despite a 2009 pledge to phase out fossil fuel subsidies, the world's 20 largest economies spent over $400 billion USD on oil, gas, and coal subsidies in 2013 and 2014. Subsidies include any government action that lowers the cost of fossil fuel energy production, raises the price energy producers receive, or lowers the price consumers pay.[316] They materialize as tax breaks, exemptions from government regulations, financing from state-owned financial institutions, purchase requirements, and a host of other options.[317, 318]

Support for fossil fuel production distorts their market signal, separating it from industry costs and performance on the ground. The support for fossil fuels from these 20 economies alone dwarfs the total global support for renewable energy, exceeding it four times over.[319] This distortion makes it harder for clean energy to compete on a level playing field, and to attract investment needed to expand.

Investing in fossil fuels, even in the face of falling oil, coal and gas prices,[320] puts countries at risk of energy price shocks[321] and stranded assets.[322] The world's 20 largest economies nearly double the private sector's $10 billion USD annual investment, outspending the top 20 private coal-mining companies. The returns on this investment largely bypass both wealthy and poor nations.[323]

Continued reliance on fossil fuels carries immediate risks from the pollution generated by combusting fossil fuels for electricity and transportation. The International Monetary Fund estimates that the combined social and environmental consequences of relying heavily subsidized fossil fuels would drain more than $5 trillion USD from the world's governments each year.[324] To reach the global goal of capping temperature rise at 2 degrees Celsius, three-quarters of the remaining fossil fuel reserves must remain in the ground.[325] Even as countries take historic new strides toward tackling climate change,[326] fossil fuel subsidies jeopardize their ability to live up to their commitments.

The world's largest energy consumers pay out the largest fossil fuel subsidies. Together, China and the United States accounted for a projected $3 trillion USD in 2015 energy subsidies, trailed by India, the European Union, Russia and Japan.[327] Charting a different path, Germany has pledged to end coal subsidies by 2018, and Canada has begun to phase out a number of oil, gas and mining subsidies.[328] India has halted its diesel subsidies,[329] and in January 2015, Indonesia pledged to eliminate $16 billion USD in gasoline subsidies,[330] increasing these countries' revenues without destabilizing energy markets.[331]

Other countries across the globe would benefit from following their lead. The International Monetary Fund estimates that eliminating post-tax subsidies for the most-polluting energy fuels could increase aggregate government revenue by $2.9 trillion USD, while cutting premature deaths from pollution-related diseases by

316 Oil Change International. (n.d.). Fossil Fuel Subsidies Overview. Available: http://priceofoil.org/fossil-fuel-subsidies/.

317 Koplow, D. (1998). Quantifying Impediments to Fossil Fuel Trade: An Overview of Major Oil Producing and Consuming Nations. Prepared for the OECD Trade Directorate. Accessed via Oil Change International. Available: http://priceofoil.org/content/uploads/2009/09/koplowtypesofsubsidy.pdf.

318 Oil Change International. (2015).

319 Bast, E., et al. (2015). Empty promises: G20 subsidies to oil, gas and coal production. Oil Change International. Available: http://priceofoil.org/category/resources/reports/.

320 Bast, E., et al. (2015).

321 Cusick, D. (2015, May 19). Fossil Fuel Subsidies Cost $5 Trillion Annually and Worsen Pollution. Scientific American. Available: http://www.scientificamerican.com/article/fossil-fuel-subsidies-cost-5-trillion-annually-and-worsen-pollution/.

322 Carbon Disclosure Project and We Mean Business Coalition. (2015). Carbon Pricing Pathways: Mapping the Path to 2 C. Available: https://www.cdp.net/CDPResults/carbon-pricing-pathways-2015.pdf.

323 Cusick, D. (2015).

324 Cusick, D. (2015).

325 Bast, E., et al. (2015).

326 Meyer, R. (2015, December 16). A Reader's Guide to the Paris Agreement. The Atlantic. Available: http://www.theatlantic.com/science/archive/2015/12/a-readers-guide-to-the-paris-agreement/420345/.

more than half.[332] Reflecting the true cost of energy in fossil fuel prices could drive down greenhouse gas emissions by as much as 24 percent, with the largest percentage reductions in emissions occurring in Asia, the Middle East and North Africa.[333]

Despite a consensus on the need to reform fossil fuel subsidies and the examples set by leading countries, it has been politically difficult to execute. Attempts to reduce subsidies in the United States, for instance, have failed to make headway in Congress.[334] Additionally, governments and companies alike often hide subsidies,[335] further obscuring the issue and thwarting action. Future EPI reports may include a new metric to assess countries' progress on transforming their growth trajectories to low carbon pathways. Continuing to track countries' progress relative to each other and to their own commitments could help to generate the political will needed to phase subsidies out.

327 Cusick, D. (2015).

328 Geiling, N. (2015, November 12). Here's how much the world's biggest economies spend on fossil fuel subsidies. ThinkProgress. Available: http://thinkprogress.org/climate/2015/11/12/3721677/g20-fossil-fuel-subsidies/.

329 Smith, G. (2014, October 20). India's Modi exploits oil price collapse to end diesel subsidies. TIME. Available: http://time.com/3524340/india-modi-diesel-subsidies/.

330 Etebari, M. (2015, October 22). Questions over subsidies loom as Indonesia rejoins OPEC. The Fuse. Available: http://energyfuse.org/questions-over-subsidies-loom-as-indonesia-rejoins-opec/.

331 Cusick, D. (2015).

332 Cusick, D. (2015).

333 Cusick, D. (2015).

334 Geiling, N. (2015).

335 Bast, E., et al. (2015).

REGIONAL TRENDS AND RESULTS

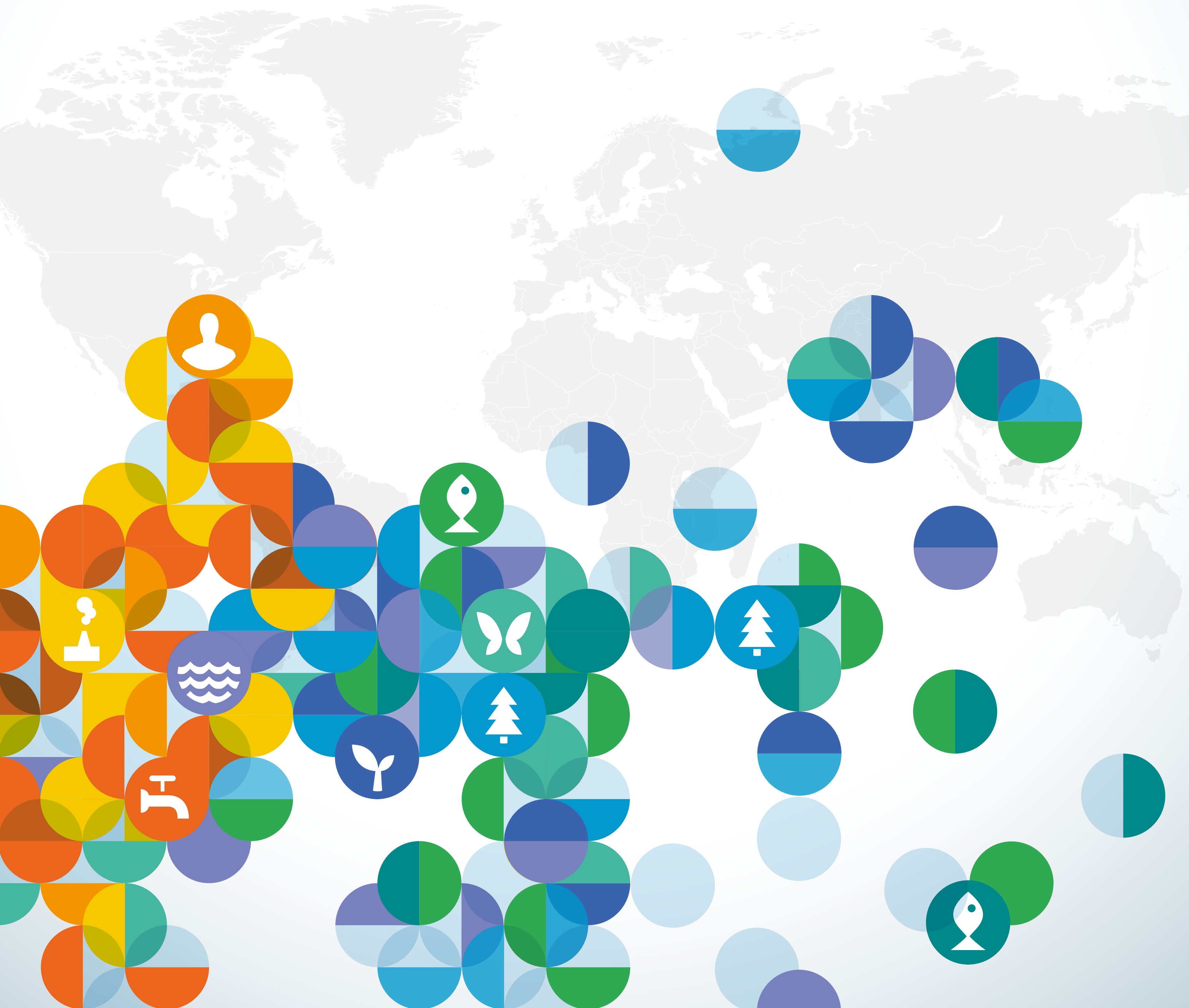
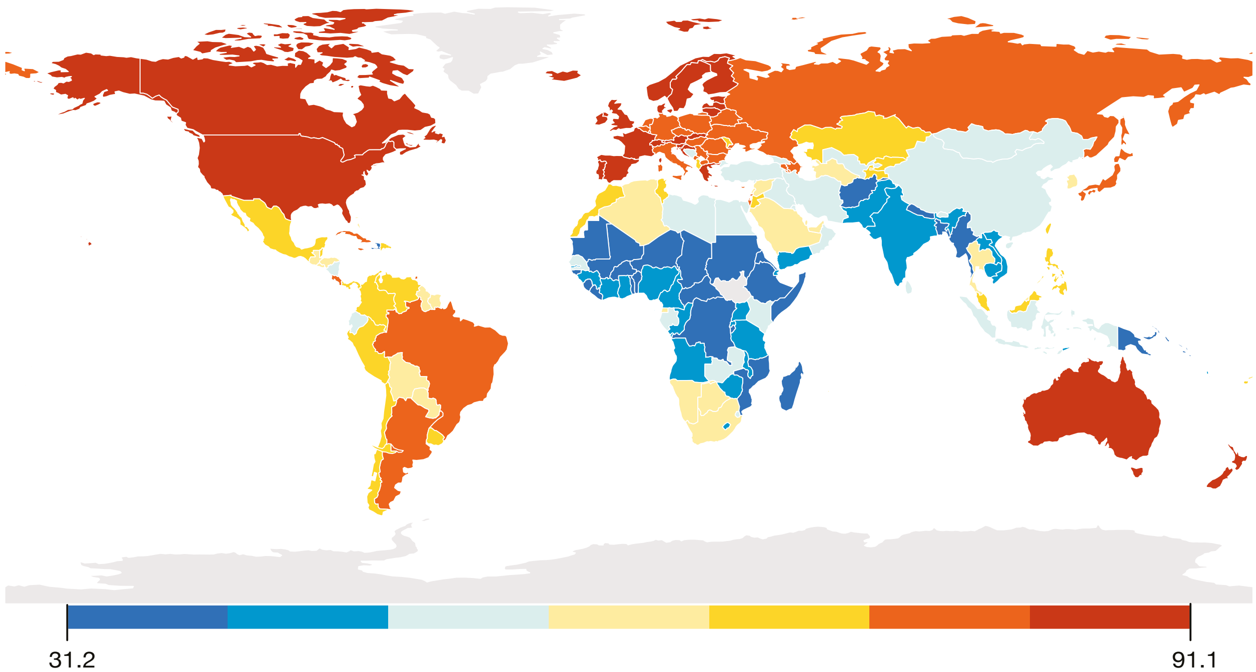


Figure 24: Global 2016 EPI results range from a score of 31.2 to 91.1, with 100 being the best score and 0 the worst.



National Results

The 2016 EPI's innovations have shaken up the rankings since the Index's previous iteration. Finland has taken the top spot, followed by Iceland, Sweden, Denmark, and Slovenia. None of these countries were in the top five in the 2014 EPI. In fact, of these top performers only Sweden cracked the top ten in 2014. Switzerland, 2014's top performer, has tumbled in this year's EPI to 16th place overall. These big shifts reflect the 2016 Index's improved methodology and new indicators. Finland's top ranking stems from its societal commitment to achieve a carbon-neutral society that does not exceed nature's carrying capacity by 2050, a vision replete with actionable goals and measurable indicators of sustainable development. Finland's goal of consuming 38 percent of their final energy from renewable sources by 2020 is legally binding, and they already produce nearly two-thirds of their electricity from renewable or nuclear power sources.

The remaining four top performers also boast good energy mixes and smart policies for managing their natural and built environments. Nations that fell in the rankings despite historically good environmental records – like Switzerland, Germany, and South Korea –see their rankings fall due to the 2016 EPI's more robust and telling air quality measures. These nations, despite showing improvement in most areas, were out-performed by other countries who enhanced their environment to an even greater degree.

The margins at the top are razor thin. Countries at the Index's high end score very similarly to one another – less than 2 points separate top place from fifth and 2.5 points is the entire difference among the top 10 performers. The closeness can be interpreted as a result of healthy competition among peer countries trying to out-do each other and promote environmental health.

The 2016 EPI's poor performers are a familiar group to the Index's low end. Somalia again takes last place (180th) followed, in ascending order, by Eritrea, Madagascar, Niger, and Afghanistan. These African and South Asian nations all have broad governance problems with long, troubled legacies. The Index's bottom third, comprised mostly of African countries with a smattering of South and East Asian nations, is a list of troubled states whose problems extend beyond their inability to sustain environmental and human health. These nations show that environmental performance is an issue of governance – only well-functioning governments are able to manage the environment for the benefit of all.

Islands in the harbour of Helsinki, Finland

Regional Trends

European nations dominate the EPI's top performers, with all of the top 10 slots occupied by European countries. New Zealand, an Asian Pacific country, nearly misses the top 10 at rank 11. At the Index's low end, Sub-Saharan African countries are the poorest performers, occupying 16 of the bottom 20 positions. Only three nations in the bottom 20 are outside the African continent – Afghanistan, Bangladesh, and Haiti. East Asian and Pacific countries, which comprise the most populous region measured, exhibit the broadest spread, with three nations –New Zealand, Australia, and Singapore – among the top 15 performers and seven countries in the Index's bottom third. Latin American and Caribbean countries also exhibit a broad range of scores, with Costa Rica and Argentina at the top of the group in 42nd and 43rd place, respectively, overall; and Haiti the 11th worst performer, far below all other countries in the group, the only nation in the western hemisphere in the bottom 50. South Asian nations perform poorly as a group, with Sri Lanka the group's highest-ranking representative in 108th place. Afghanistan and Bangladesh, both in the South Asia group, are the only countries in the bottom 10 that are not in Sub-Saharan Africa. Canada and the United States are considered in a group of their own apart from other nations in the Americas because European countries are their most comparable peer nations. In this light, Canada and the United States, in 25th and 26th place, respectively, perform on par with the bottom third of European nations.

Regional Results - Tables

East Asia and the Pacific

Rank	Country	Score	10-year % change
11	New Zealand	88	22.07
13	Australia	87.22	21.75
14	Singapore	87.04	-0.43
39	Japan	80.59	5.72
59	Fiji	75.29	23.22
60	Taiwan	74.88	26.96
63	Malaysia	74.23	13.05
66	Philippines	73.7	16.36
80	South Korea	70.61	6.01
85	Samoa	70.2	27.04
91	Thailand	69.54	17.68
98	Brunei Darussalam	67.86	19.28
102	Tonga	66.86	7.94
107	Indonesia	65.85	10.45
109	China	65.1	12.73
114	Mongolia	64.39	21.97
125	Kiribati	60.48	14.52
131	Viet Nam	58.5	20.67
134	Vanuatu	57.74	14.5
138	Timor-Leste	55.79	33.66
146	Cambodia	51.24	17.52
148	Laos	50.29	8.52
156	Papua New Guinea	48.02	15.93
158	Solomon Islands	46.92	8.41

Eastern Europe and Central Asia

Rank	Country	Score	10-year % change
15	Croatia	86.98	22.37
31	Azerbaijan	83.78	18.1
32	Russia	83.52	24.34
35	Belarus	82.3	3.77
37	Armenia	81.6	13.19
44	Ukraine	79.69	25.38
48	Serbia	78.67	14.9
50	Macedonia	78.02	18.81
55	Moldova	76.69	9.09
61	Albania	74.38	27.1
69	Kazakhstan	73.29	25.8
71	Kyrgyz Republic	73.13	23.53
72	Tajikistan	73.05	16.82
84	Turkmenistan	70.24	20.96
99	Turkey	67.68	7.31
111	Georgia	64.96	11.77

South Asia

Rank	Country	Score	10-year % change
108	Sri Lanka	65.55	3.51
110	Bhutan	64.99	8.06
137	Maldives	57.1	22.17
141	India	53.58	20.87
144	Pakistan	51.42	16.07
149	Nepal	50.21	14.53
153	Myanmar	48.98	1.3
173	Bangladesh	41.77	3.21
176	Afghanistan	37.5	21.24

Europe

Rank	Country	Score	10-year % change
1	Finland	90.68	3.19
2	Iceland	90.51	6.91
3	Sweden	90.43	5.58
4	Denmark	89.21	4.98
5	Slovenia	88.98	12.15
6	Spain	88.91	10.01
7	Portugal	88.63	10.88
8	Estonia	88.59	5.91
9	Malta	88.48	11.62
10	France	88.2	8.7
12	United Kingdom	87.38	7.02
16	Switzerland	86.93	4.71
17	Norway	86.9	5.73
18	Austria	86.64	10.44
19	Ireland	86.6	3.48
20	Luxembourg	86.58	5.15
21	Greece	85.81	27.92
22	Latvia	85.71	8.02
23	Lithuania	85.49	9.25
24	Slovakia	85.42	10.4
27	Czech Republic	84.67	7.85
28	Hungary	84.6	11.54
29	Italy	84.48	8.43
30	Germany	84.26	8.43
33	Bulgaria	83.4	12.01
34	Romania	83.24	28.93
36	Netherlands	82.03	8.09
38	Poland	81.26	8.12
40	Cyprus	80.24	8.51
41	Belgium	80.15	10.43
47	Montenegro	78.89	21.07

North America

Rank	Country	Score	10-year % change
25	Canada	85.06	5.17
26	United States of America	84.72	10.93

Latin America and the Caribbean

Rank	Country	Score	10-year % change
42	Costa Rica	80.03	15.33
43	Argentina	79.84	5.4
45	Cuba	79.04	8.81
46	Brazil	78.9	16.94
51	Panama	78	7
52	Chile	77.67	5.75
54	Jamaica	77.02	20.02
56	Venezuela	76.23	5.2
57	Colombia	75.93	14.84
58	Dominican Republic	75.32	24.74
62	Trinidad and Tobago	74.34	8.51
65	Uruguay	73.98	12.96
67	Mexico	73.59	10.69
68	Belize	73.55	16.34
70	Dominica	73.25	18.43
73	Peru	72.95	21.89
75	Guyana	71.14	19.62
76	Bolivia	71.09	20.02
82	Paraguay	70.36	17.01
88	Honduras	69.64	19.78
89	Guatemala	69.64	20.51
93	The Bahamas	69.34	8.04
96	Suriname	68.58	-2.2
97	El Salvador	68.07	15.26
103	Ecuador	66.58	2.38
115	Nicaragua	64.19	6.82
120	Grenada	63.28	10.92
122	Antigua and Barbuda	62.55	4.95
140	Barbados	54.96	14.31
169	Haiti	43.28	12.04

Regional Results - Tables

Middle East and North Africa

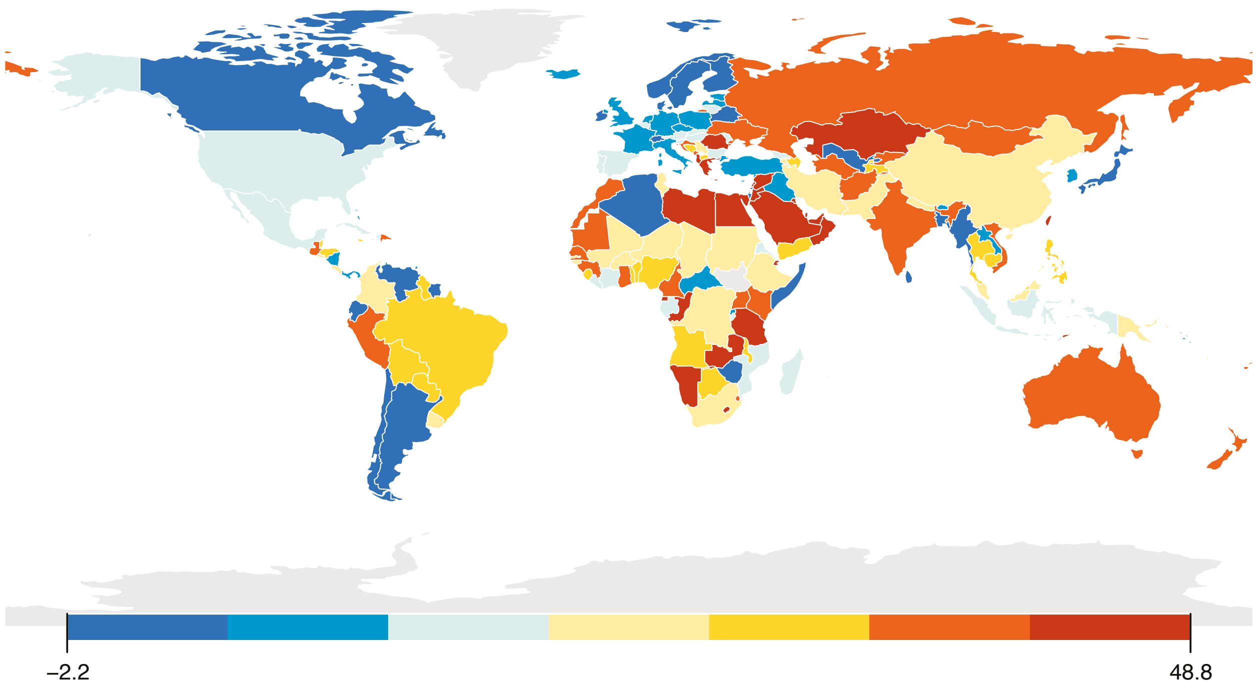
Rank	Country	Score	10-year % change
49	Israel	78.14	5.21
53	Tunisia	77.28	15.71
64	Morocco	74.18	24.65
74	Jordan	72.24	30.09
83	Algeria	70.28	3.69
86	Bahrain	70.07	7.45
87	Qatar	69.94	30.05
92	United Arab Emirates	69.35	26.32
94	Lebanon	69.14	35.22
95	Saudi Arabia	68.63	25.42
101	Syria	66.91	37.45
104	Egypt	66.45	37.21
105	Iran	66.32	15.46
113	Kuwait	64.41	45.26
116	Iraq	63.97	8.24
119	Libya	63.29	26.18
126	Oman	60.13	27.34
150	Yemen	49.79	17.29
170	Sudan	42.25	13.54

Sub-Saharan Africa

Rank	Country	Score	10-year % change
77	Mauritius	70.85	8.75
78	Namibia	70.84	28.82
79	Botswana	70.72	19.22
81	South Africa	70.52	15.19
90	Equatorial Guinea	69.59	27.81
100	Gabon	67.37	10.37
106	Zambia	66.06	30.76
112	Seychelles	64.92	1.25
117	Senegal	63.73	22.7
123	Kenya	62.49	25.36
124	Swaziland	60.63	24.22
127	Cote d'Ivoire	59.89	12.2
128	Congo	59.56	25.84
129	Zimbabwe	59.25	5
130	Ghana	58.89	22.46
132	Tanzania	58.34	31.19
133	Nigeria	58.27	18.75
135	Uganda	57.56	22.13
136	Cameroon	57.13	22.33
139	Guinea	55.4	22.32
142	The Gambia	52.09	20.33
143	Cape Verde	51.98	15.64
145	Angola	51.32	16.53
147	Rwanda	50.34	6.09
151	Malawi	49.69	19.97
152	Comoros	49.2	48.78
154	Sao Tome and Principe	48.28	38.26
155	Guinea-Bissau	48.2	15.56
157	Lesotho	47.17	32.46
159	Central African Republic	46.46	7.37
160	Mauritania	46.31	20.88

Rank	Country	Score	10-year % change
161	Togo	46.1	18.51
162	Sierra Leone	45.98	16.58
163	Ethiopia	45.83	14.75
164	Djibouti	45.29	36.17
165	Burkina Faso	43.71	16.1
166	Benin	43.66	16.21
167	Liberia	43.42	11.33
168	Burundi	43.37	11.12
171	Dem. Rep. Congo	42.05	14.55
172	Mozambique	41.82	11.79
174	Mali	41.48	14.62
175	Chad	37.83	12.49
177	Niger	37.48	12.82
178	Madagascar	37.1	11.21

Figure 25: Nearly all countries show improvement in EPI score over the last decade. Countries already at higher levels of performance, including North America and Europe, have not improved nearly as much as developing countries have improved over the last decade.



Relationship between GDP and the EPI

From Figure 25, a relationship between countries' EPI performance and economic development emerges. For instance, countries located in Europe (shown in green), tend to have higher EPI scores in relation to their Gross Domestic Product (GDP) per capita compared to other regions, in particular Sub-Saharan Africa, which tends to have the poorest results, including Somalia (SOM). This tendency implies that countries with more financial resources can better implement policies to protect human health and the environment. However, this is not always the case. China (CHN) and India (IND) for instance, both have high GDP per PPP but receive low scores on the overall EPI. This result suggests the role of something other than economic development alone (e.g., governance or political investments) that may also be critical in achieving environmental results. For example, Armenia (ARM) has relatively low economic development ($3,716 USD) and a relatively high EPI score (81.5), compared to other countries with similar GDP per capita.

Both the Environmental Health and Ecosystem Vitality objectives demonstrate positive relationships with GDP per capita (Figures 26 and 27), suggesting that as wealth increases, national environmental performance improves. The relationship between Health and GDP per capita, however, is stronger, which is most likely driven by the investments in public health, sanitation, and infrastructure as countries develop. Ecosystem Vitality scores are more dispersed in their relationship with GDP per capita. Many wealthy Organization of the Petroleum Exporting Countries (OPEC) countries, including Kuwait, Qatar, Oman, and Saudi Arabia, underperform on environmental performance relative to similar economic peers. What the difference in relationship between Ecosystem Vitality and Environmental Health scores and GDP per capita suggest is that both wealthy and developing countries alike have room to improve with respect to ecosystem and natural resource management. As countries develop, more focus and attention is paid to public health and creating management systems for clean water, sanitation, and energy.

City of Anı, Armenia

Figure 26: GDP per Purchasing Power Parity (PPP) per capita in 2013 versus 2016 EPI score.

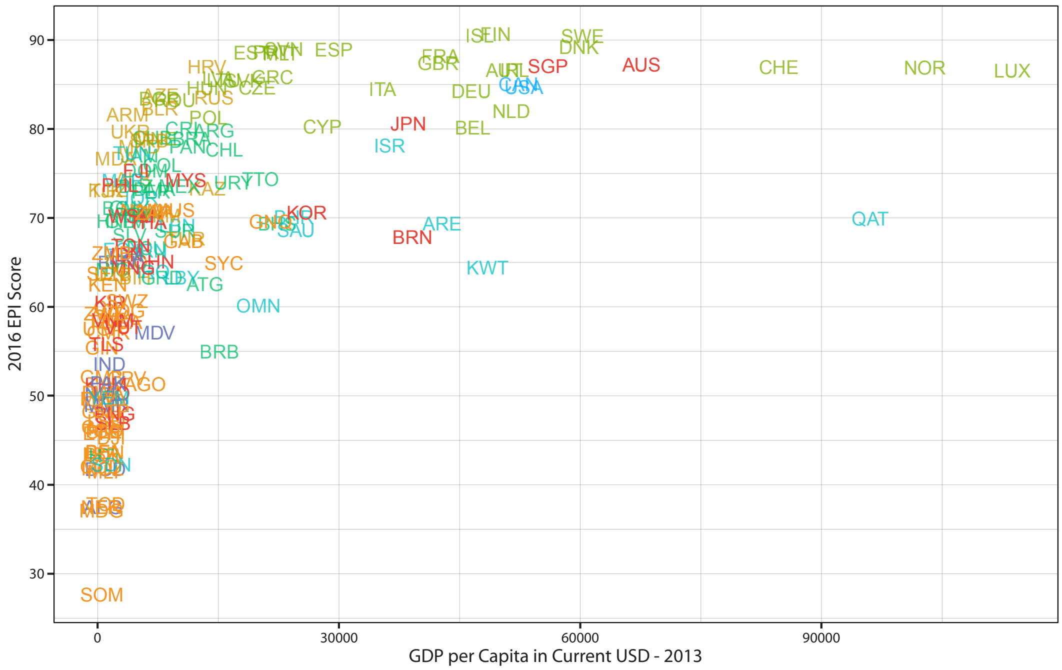
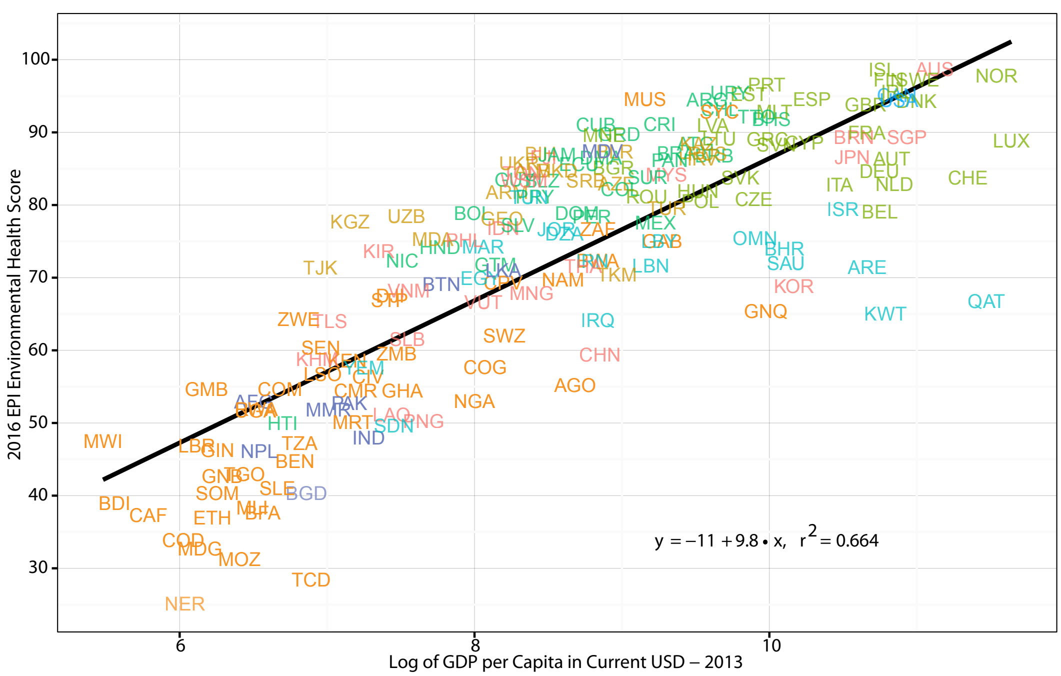
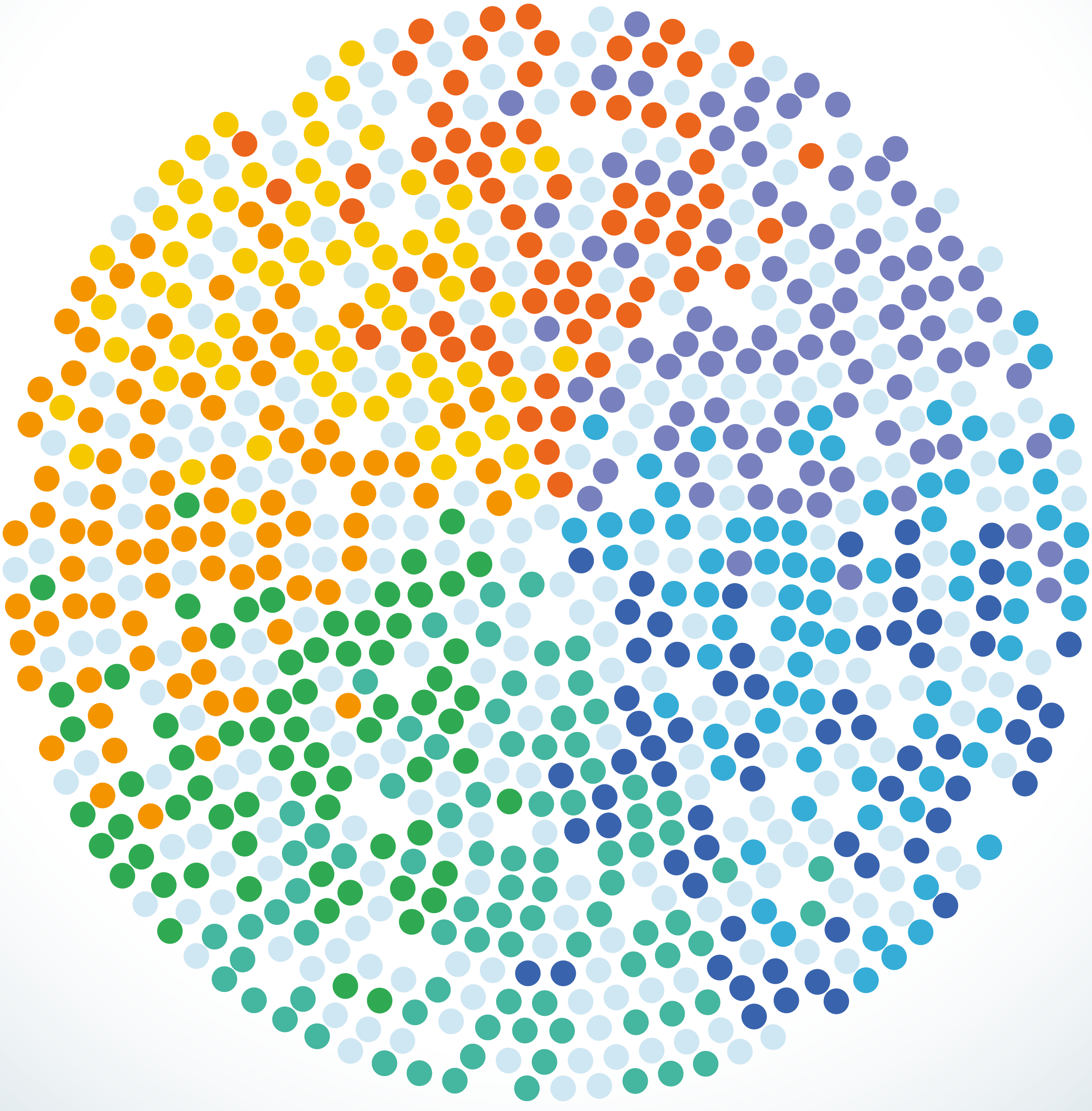


Figure 27: The relationship between Environmental Health and GDP per capita shows is strongly positive.



CONCLUSION



The 2016 EPI has benefited from decades of data development, scientific input, and expert review. This Index builds on previous EPIs, innovating in key areas including, for the first time, human health metrics that capture health risks across all ages and genders instead of using child mortality as a proxy. The 2016 EPI introduces novel measures of agricultural sustainability that form a foundation for a comprehensive suite of agriculture indicators to be developed. This EPI also includes new species protection indicators that speak to key conservation outcomes, shining a light on badly needed measures of biodiversity loss. The air quality category, moreover, has improved with the addition of an NO_2 indicator, which describes pollutants that are especially toxic to humans.

The 2016 EPI launches at an extraordinarily opportune moment to influence future policy. The UN's Sustainable Development Goals (SDGs) are set to take the mantle from the expired Millennium Development Goals (MDGs) in the global campaign for equitable and environmentally minded development. The MDGs have demonstrated the power of global targets and indicators to spur infrastructure investment, including improvements in data collection and monitoring. With its more than 20 indicators, the 2016 EPI will help governing bodies at all levels, and non-state actors dedicated to environmental action, attain rigorous data to inform more effective policies (see Table 3).

The 2016 EPI discerns metrics that speak directly to human and environmental health and that isolate issues most in need of improvement. If an international target or indicator misses the mark, nations could waste scarce resources collecting data that do not assess what is most important to people or ecosystems. For example, through its Access to Drinking Water target, MDG Goal-7 set indicators to inform data collection and monitoring. The 2016 EPI seeks to correct these courses, pointing to critical information overlooked when data are collected according to a "least common denominator" approach (i.e., reporting improved and unimproved water sources that say nothing about the quality of drinking water). Partnering with the Institute for Health Metrics and Evaluation, the 2016 EPI establishes the first ever dataset on drinking water quality.

This EPI has made great leaps with data collection and analysis, yet distilling global environmental information is never a neat process. The Index's aim – to create a single set of environmental metrics appropriate for all countries — may seem hopelessly ideal, yet the 2016 EPI tackles this monumental undertaking by innovating methods to fit every country to its indicators and account for national economic and geographic differences. The Index's careful methodology ensures its indicators are robust and meaningful – that each metric does in fact send a policy signal – and lends confidence to its rankings. Competition among nations drives a race to the top, spurring governments to improve environmental performance.

As information becomes ever more abundant and locally specific, the best indicators will illustrate environmental phenomena at local and regional scales. This means taking a closer look at environmental issues than ever before. The EPI has broken ground with every iteration, expanding knowledge on environmental performance at the national level. To remain relevant and continue pushing boundaries, policy metrics will need to adjust to the expanding data landscape and develop focus on multiple scales of environmental governance.

The 2016 EPI is primarily a comparative tool to judge environmental performance between nations. The Index also highlights global trends in environmental performance and measurement. On both counts, for example, the world's fisheries score poorly as humans have overexploited fish stocks in every ocean; yet relatively little reliable information is reported about fish populations and catches. Agriculture also exhibits too many unknowns to be effectively managed at a global scale, largely because international scientific organizations and governing bodies have been reticent to develop clear metrics for assessing agricultural sustainability. There are signs of hope, however, that recent investments in landscape assessments, a global focus on food security and safety, and industry interest in sustainability measurement will generate new information and ideas for agricultural indicators.

Other key areas that lack adequate measurement include human exposure to toxic chemicals, solid waste management, species protection, freshwater quality, and wetlands protection. The 2016 EPI has compiled information on species protection and freshwater quality, yet these metrics are incomplete. The others are so data poor that the EPI is not able to track them at all. Issue areas that are fundamentally ecological and reflect the most complex systems tend to be measured least effectively. Without accurate measurement, managing these systems for the benefit of people and the protection of ecosystems is extremely difficult and even risky.

Yet measurement, overall, is getting better. Data from novel sources and cutting-edge technologies are helping to improve the accuracy and relevance of indicators. With the advent of "big data" and new technologies, a much wider array of tools is now available for filling key measurement gaps. The EPI makes prudent use of these innovations. Forestry measures, for example, can now draw on satellite data to generate metrics that are far more germane and comprehensive than what emerged from previous modeling efforts and national reports. New data using hundreds of thousands of satellite images yield a superior picture of global forest loss over the last decade.

However, data from these "un-official" sources are imperfect. The world needs better measurement and indicator systems. To meet the growing demand for environmental performance indicators, the global community must build on existing strengths and invest in innovative approaches. The EPI team is committed to working with partners and pushing the envelope to develop useful measures that veer countries toward progress. Part of this commitment entails working with scientific experts and policymakers to design the "next generation" of environmental indicators. The 2016 EPI features new indicators for agricultural sustainability that are the results of pilot efforts in partnership with global experts. Better measures of agricultural sustainability, climate adaptation and resilience, toxic chemicals, and solid waste management are all high priorities. Achieving them will take close cooperation between governments, corporations, scientists, and, not least of all, civil society.

Finally, the EPI documents the tangible benefits that arise when policymakers pursue strong environmental performance and the damage that occurs when they do not. For example, global attention to Access to Drinking Water and Sanitation, and Terrestrial and Marine Habitat Protection has resulted in measurable gains in nearly every country over the last decade. These successes have been driven in large part by international efforts, such as the Convention on Biological Diversity to establish global targets and finite timelines for achievement. When the World Health Organization and United Nation Children's Fund announced in 2012 that the MDG related to safe drinking water was the first to be reached, they stressed the vital role of strengthened data collection and monitoring.[336] However, during the same period, which extends to today, more people are dying from poor air quality than in the past and fish stocks are in severe decline. Wastewater treatment is more a desire than a reality in most countries. And despite improvements in piped water access, large proportions of that water are not being treated.

The 2016 EPI's mixed results point to a single conclusion: where measurement and management align, quantifiable results can be observed and concrete actions can be taken with conviction. Where clear benchmarks and targets are nebulous, as in the case of climate change, little or no progress transpires, or in the case of air quality, things are getting worse. The good news is that the 2016 EPI shows more overall improvement than decline; yet the areas in which we see deterioration are gravely serious. The EPI aims to improve measurement and management of our shared environment, to aid governments in reversing troubling trends and building a healthier world.

336 United Nations Children's Fund and World Health Organization. (2012). Progress on drinking water and sanitation: 2012 update. Available: http://www.unicef.org/media/files/JMPreport2012.pdf.

Table 3: Mapping Sustainable Development Goal Targets and EPI indicators.

Sustainable Development Goal Targets	EPI Metric
SDG-2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture → By 2030 ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality	• Nitrogen Use Efficiency and Nitrogen Balance
SDG-3: Ensure healthy lives and well-being → By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	• Environmental Risk Exposure • Air quality • Water and Sanitation • Wastewater Treatment
SDG-6: Ensure availability and sustainable management of water and sanitation for all → … halving the proportion of untreated wastewater by 2030 → ensure[s] access to water and sanitation for all	• Wastewater Treatment • Drinking Water Quality and Access to Sanitation
SDG-7: Ensure access to affordable, reliable, sustainable and modern energy for all → … halving the proportion of untreated wastewater by 2030 → ensure[s] access to water and sanitation for all	• Access to Electricity • Trend in CO_2 per kWh • Trend in Carbon Intensity
SDG-11: Make cities and human settlements inclusive, safe, resilient and sustainable → Strengthen efforts to protect and safeguard the world's cultural and natural heritage → By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	• Air quality • Terrestrial Habitat Protection • Species Protection
SDG-13: Take urgent action to combat climate change and its impacts	• Access to Electricity • Trend in CO_2 per kWh • Trend in Carbon Intensity
SDG-14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development → By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts → By 2020, conserve at least 10 per cent of coastal and marine areas → By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies	• Fish Stocks • Marine Protected Areas

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