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The Green Future Index 2021

A ranking of 76 economies on their progress and commitment toward building a low-carbon future.

Preface

"The Green Future Index" is a research program by MIT Technology Review Insights sponsored by Salesforce, Citrix, and Morgan Stanley. The research was conducted through in-depth secondary research and analysis as well as interviews with global experts on climate change, green energy, and technologies that will drive decarbonization. It measures the degree to which 76 countries and territories are pivoting toward a green future by reducing their carbon emissions, developing clean energy, innovating in green sectors, and preserving their environment, as well as the degree to which governments are implementing effective climate policies. The lead writer of the report was Ross O'Brien, its editors were Claire Beatty and Laurel Ruma, and Nicola Crepaldi was the producer.

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Executive summary

In terms of tackling the global climate emergency, 2020 may come to be seen as a defining moment, when global events catalyzed governments, businesses, and citizens into taking decisive steps to bring carbon emissions under control and giving hope that global warming might be limited to 1.5 to 2 °C compared with pre-industrial levels.

Nature's shock-and-awe campaign is working. Wildfires, storms, and flooding have devastated lives and livelihoods in rich and poor countries, with the top 10 natural disasters of 2019 generating losses of around $140 billion.[1] The most spectacular display of nature's force was covid-19, which on one hand raised awareness about the interconnection of biodiversity and habitats with the climate, human health, and global prosperity, and on the other created a unique set of circumstances that allowed governments to focus on rebuilding their economies through investment in clean technology, infrastructure, transport, and industry.

The Green Future Index is a ranking of 76 leading nations and territories based on their progress and commitment toward building a low-carbon future, taking into account efforts to curb emissions made in recent years as well renewed policy commitments toward carbon neutrality and the degree to which pandemic recovery packages are targeting green industries. The index consolidates scores given to each country or territory across five pillars: carbon emissions, energy transition, green society, clean innovation, and climate policy. The key findings are as follows:

- Europe provides 15 of the top 20 countries in index. In first place is Iceland, which aims to be carbon neutral by 2040. Iceland has become a world leader in clean energy production and carbon capture technology. In December 2020, Denmark (2nd) became the largest producer of hydrocarbons in Europe to stop issuing new oil and gas exploration licenses, with the aim of eliminating fossil fuel-related businesses by 2050.[2] Norway (3rd) is also striving to decouple its economy from fossil fuels.

- Non-European countries in the top 20 include Costa Rica (7th) and New Zealand (8th). Both have made major strides with renewables and have world-leading programs for decarbonization across industry and agriculture. Elsewhere, Canada (14th), Singapore (16th), and Uruguay (20th) have strategies for decarbonization, transitioning energy sources, and government-led initiatives to promote green living, such as Singapore's Zero Waste Masterplan, which includes reducing waste sent to the country's only landfill by 30% between now and 2030.[3]

- Countries ranked from 21 through 40 form "the greening middle." India (21st), despite having a high rate of emissions growth, is also quickly adopting renewable energy and has built some of the world's largest solar plants. Morocco (26th), South Korea (31st), and Israel (38th) have ambitious climate policies and are poised to improve their scores in coming years. Others, including Colombia (25th) and Australia (35th), have climate change agendas, but these are at odds with their economies' hydrocarbon dependency. The United States (40th) has reduced emissions over recent years and is responsible for nearly a fifth of the world's green patents yet is struggling to move away from fossil fuels and carbon-intensive agriculture.

- At the bottom of the index are "climate laggards" and "climate abstainers." The laggards include South Africa (47th), Vietnam (49th), and Indonesia (57th), where pressure to develop the economy is running counter to decarbonization agendas. Japan (60th) has a goal to be carbon neutral by 2050, although the government still has low targets for its transition toward renewable energy. The 16 "abstainer" countries at the bottom include petrostates (Saudi Arabia, Iran, and Qatar), rich territories without a sustainable development policy (Hong Kong), and Russia, a country that largely sees decarbonization as an existential threat to its economic progress.

01 Introduction

Efforts to combat climate change have been taking shape for more than a decade, but, until now, many have largely generated "empty words, loopholes, and greenwash," in the sharp words of climate activist Greta Thunberg.

Since the Paris Agreement came into force in 2016, over 120 countries have committed to hard dates to achieve net carbon zero; so too have hundreds of cities, from New York to Reykjavik, Medellin, and Cape Town, and an estimated quarter of Fortune 500 companies.

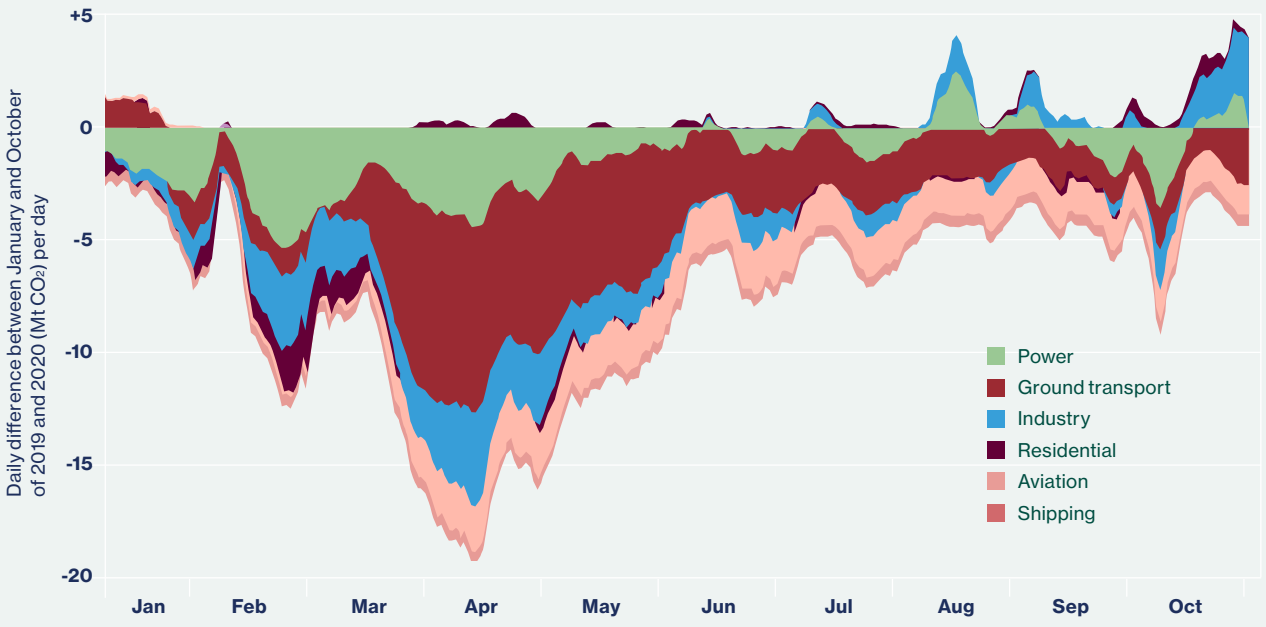
Yet progress has been slow. In a year when global greenhouse gas (GHG) emissions fell significantly–some 7%, according to the UN Environmental Programme's (UNEP) 2020 Emissions Gap Report,[4] see Figure 1–the irony is that this has been achieved through a devastating economic downturn triggered by covid-19. UNEP estimates that this massive drop in emissions will still do little to help the world achieve its Paris Agreement commitments.

While covid-19 has caused the world's oil exploration and production firms to lose an estimated 40% of their revenue in 2020,[5] the industry still likely generated $1.5 trillion for the year, or more than five times what the entire world invested in renewable energy generation in 2019.

A year of wake-up calls

Although the writing has been on the wall with regard to the climate for many years, experts interviewed for this report are cautiously optimistic that 2020 seems to have delivered the convergence of political, private sector, and social will for a decisive new agenda. This is in part because of the clear severity and scale of the climate

Figure 1: Reduction in emissions in 2020 relative to 2019



Source: Compiled by MIT Technology Review Insights based on data from the UNEP Emissions Gap Report 2020

> "Anywhere you look, you're able to find pretty objective measures of bad things happening. It's clear climate change impacts are arriving faster than anticipated and worse than anticipated."
>
> **Julio Friedmann**
> Senior Research Scholar at the Center on Global Energy Policy at Columbia University

emergency. California, the US state with arguably the country's most determined climate agenda, battled more than 9,500 wildfires last year, which consumed some 4.2 million acres of forest.[6] Similarly, 2019 was Australia's hottest summer on record and resulted in bushfires burning an estimated 32 million acres. Satellite data revealed in September 2020 that the year's Arctic sea ice cover shrank to the second-lowest level ever recorded, nearly 2.5 million square kilometers less than the average of the last four decades.[7] And data from the Brazilian National Institute of Space Research estimated there was a 9.5% increase in Amazon deforestation in the year up to July 2020 over the previous year.[8] The economic cost of the damage is mounting; the world's 10 costliest weather disasters of 2020 saw insured damages worth $140 billion in 2020,[9] according to a report by Christian Aid.

"Anywhere you look, you're able to find pretty objective measures of bad things happening. It's clear climate change impacts are arriving faster than anticipated and worse than anticipated," says Julio Friedmann, senior research scholar at the Center on Global Energy Policy at Columbia University. "This means that climate change is not an acute problem like a storm you clean up after, it's a chronic problem, like having diabetes and having to manage your health continuously."

If the planet was managing (badly) with diabetes, it took 2020's metaphorical heart attack for the world to really grasp the state of its health. This is not to say that prior to covid there was complete inaction. The International Energy Institute estimates that energy-related CO2 emissions in 2019, at roughly 33 gigatons, were the same as 2018, and energy emissions in advanced economies (roughly a third of the world's total) actually dropped 4% last year.

Prospect of a green recovery

Having wiped an estimated 4.4% off the world's GDP this year,[10] covid-19 has put humanity's impact on the environment back in the spotlight. First, it showed how changes in human activity can significantly reduce carbon emissions. Analysis of electricity production, air travel, and other fuel consumption data in the first half of 2020 found that CO2 emissions were 8.8% lower globally than the same period in 2019,[11] a far greater decline than in any previous period of economic contraction.

Second, policymakers realized that the massive stimulus packages ($12.6 trillion globally[12]) earmarked for pandemic recovery could be directed into infrastructure, innovation, and programs that will build economic and environmental resilience for the long term. Germany, the world's "pandemic green leader," is spending over a third of recovery stimulus on transportation transition, renewable energy capability building, and other projects that will serve as a cornerstone of the EU's attempt to make Europe the first carbon-neutral continent. China is using its central planning prowess to develop the world's largest comprehensive decarbonization plan, even though less than $1.5 billion of its post-covid recovery stimulus spending is specifically targeted at green projects. Even in the US, where the past four years have seen a systematic reversing of emission-capping regulations, $26 billion in stimulus is being aimed at sustainability and emissions reduction programs, providing a platform for President Joe Biden to "build back better" and fulfill his promise to rejoin the Paris Accord.

Yet there is a tension for governments around the world as they allocate the economic "pain relief" in balancing short- and long-term objectives. Many are being criticized for not using the crisis as enough of an opportunity to make hard choices and pivot away from fossil fuel-intensive sectors. Claire Healy, program director for climate diplomacy at climate advocacy group E3G, says that covid provided "a pivotal moment—a window into a decade of decarbonization, where decision-makers in government, in banks, in businesses, have to decide how we build back. It's about competitiveness in the future; the promise of green jobs and technologies drives further action and ambition." The Green Future Index benchmarks the progress and commitment that countries are making toward becoming future green leaders.

02 The Green Future Index

Figure 2: The Green Future Index country rankings

The Green Leaders — The 20 countries making the greatest progress and commitment toward building a low carbon future.

1	Iceland	6.45	8	New Zealand	5.71	15	Austria	5.47
2	Denmark	6.44	9	Belgium	5.63	16	Singapore	5.45
3	Norway	6.20	10	Netherlands	5.62	17	United Kingdom	5.44
4	France	5.98	11	Germany	5.55	18	Spain	5.42
5	Ireland	5.95	12	Sweden	5.54	19	Switzerland	5.40
6	Finland	5.90	13	Luxembourg	5.50	20	Uruguay	5.38
7	Costa Rica	5.78	14	Canada	5.48			

The greening middle — The 20 countries that are making progress or commitment toward building a green future.

21	India	5.35	28	Czech Republic	5.15	35	Australia	4.89
22	Italy	5.30	29	Thailand	5.12	36	Mexico	4.86
23	Kenya	5.30	30	Portugal	5.11	37	Greece	4.82
24	Chile	5.29	31	South Korea	5.10	38	Israel	4.77
25	Colombia	5.19	32	Brazil	4.96	39	Hungary	4.71
26	Morocco	5.18	33	Kazakhstan	4.94	40	United States	4.66
27	Ethiopia	5.15	34	Poland	4.92			

Climate laggards — The 20 countries that are making slow and uneven progress or commitment toward building a green future.

41	Cameroon	4.59	48	Romania	4.44	55	Dominican Republic	4.23
42	United Arab Emirates	4.56	49	Vietnam	4.40	56	Malaysia	4.18
43	Philippines	4.56	50	Slovakia	4.37	57	Indonesia	4.15
44	Bulgaria	4.54	51	Zambia	4.36	58	Egypt	4.14
45	China	4.51	52	Angola	4.34	59	Argentina	4.04
46	Taiwan	4.49	53	Nigeria	4.32	60	Japan	3.99
47	South Africa	4.47	54	Uganda	4.25			

Climate abstainers — The 16 countries that will be left behind in the green future through their lack of progress and commitment toward developing a modern, clean, and innovative economy.

61	Saudi Arabia	3.97	68	Turkey	3.75	75	Paraguay	2.72
62	Ecuador	3.97	69	Bangladesh	3.68	76	Qatar	2.61
63	Ukraine	3.97	70	Guatemala	3.66			
64	Hong Kong	3.93	71	Ghana	3.60			
65	Kuwait	3.91	72	Algeria	3.17			
66	Peru	3.86	73	Russia	2.87			
67	Pakistan	3.79	74	Iran	2.85			

Source: MIT Technology Review Insights, 2021

The Green Future Index measures and ranks nations and territories on the degree to which they are building a green future across several pillars:

- **Carbon emissions:** Total emissions as well as the degree of change in emissions in transportation, industry, and agriculture
- **Energy transition:** The contribution and growth rate of renewable energy sources
- **Green society:** A range of indicators covering net forestation, development of green buildings, recycling, and consumption of animal products
- **Clean innovation:** The relative number of green patents, investment in cross-border clean energy, investment in food technology
- **Climate policy:** Policy commitment toward climate targets, carbon finance programs, sustainable agriculture, and the use of covid stimulus for a green recovery

The pillars fall into two categories. The first four (carbon emissions, energy transition, green society, and clean innovation) measure the progress that countries have been making toward reducing their carbon footprint and building the foundations for a cleaner future across industry and society. These "progress pillars" account for 60% of the weighting in the index. The final pillar, climate policy, measures the level of ambition set out in climate policies around energy, agriculture, and finance, and the degree to which these economies are using covid-19 stimulus packages to channel investment into clean industries. This final pillar accounts for 40% of the index weighting.

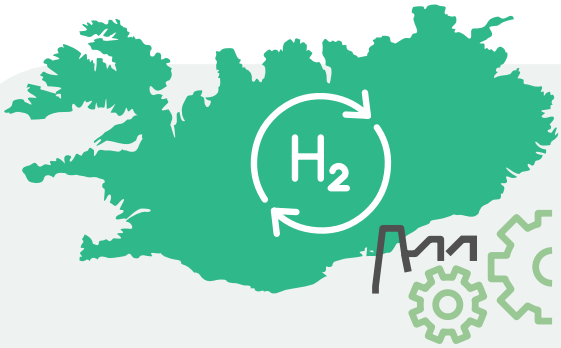
The green leaders

European countries comprise 15 of the top 20 countries in the Green Future Index. In addition to their own national policies for cleaner modes of energy and mobility, the European Union is actively developing initiatives in areas such as carbon pricing and vehicle emission targets (to be reduced nearly 30% in 2021, to 95 grams of CO2 per kilometer) that will accelerate the region's decarbonization.

Iceland, which has been executing a wide-ranging decarbonization program for nearly two decades, is ranked in first place. Thanks to ample geothermal and hydropower resources, Iceland is a world leader in clean energy production. It is also pursuing green hydrogen for transportation and fostering local industry innovation around carbon capture technology. These initiatives position Iceland well for meeting its 2040 carbon-neutral goal.

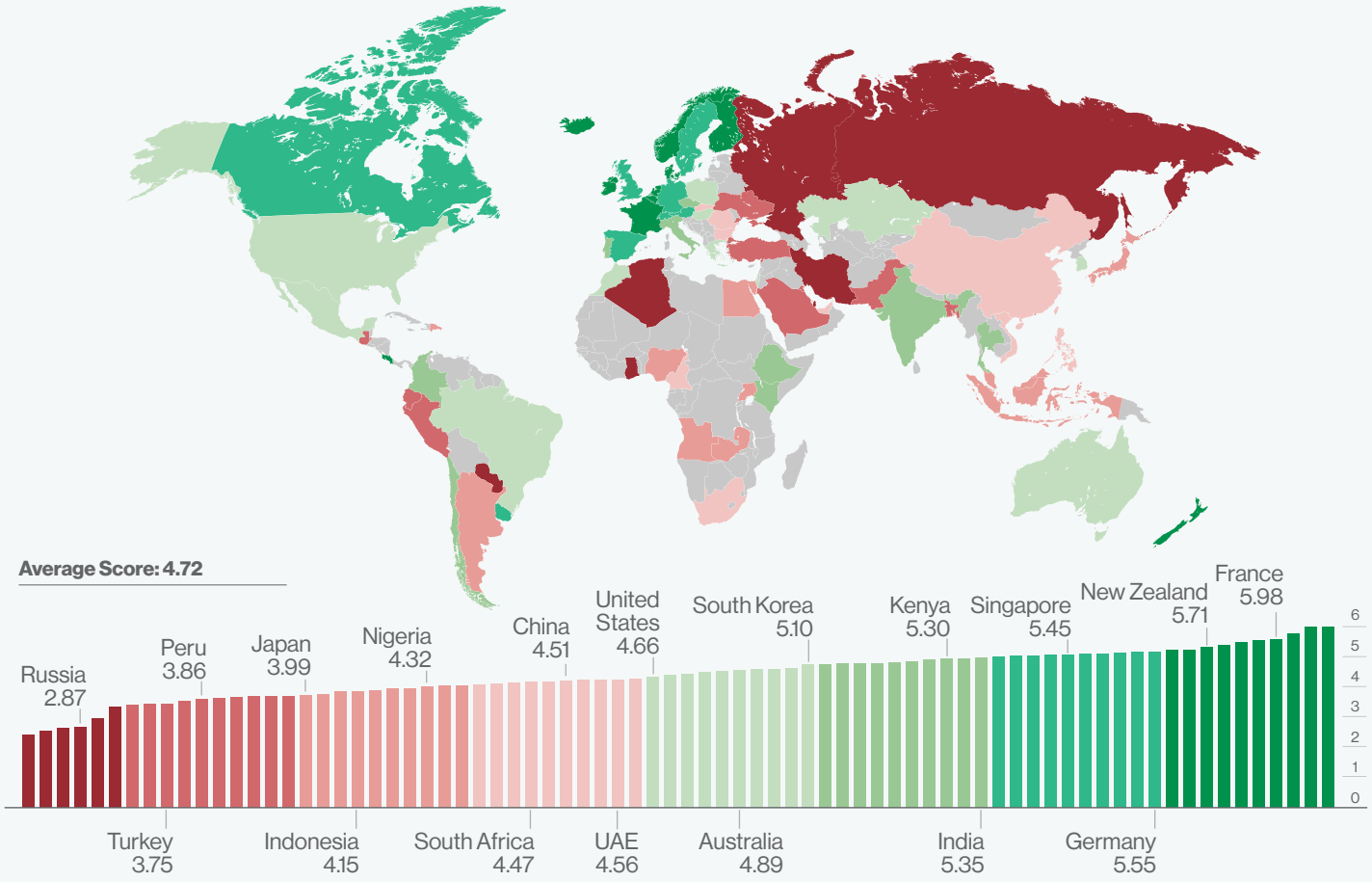
Denmark and Norway are in second and third place, are actively transitioning their oil and gas-dependent economies to become green leaders. Denmark has been decommissioning fossil fuel energy for several years, and in December 2020 became the largest producer of hydrocarbons in Europe to stop issuing new oil and gas exploration licenses, with the aim of eliminating fossil fuel-related businesses by 2050.[13]

Most of the index's top 10 countries have developed policy structures and investment programs for innovative sustainable technology sectors. France (4th) is a global leader in hydrogen production and has recently pledged



Iceland is ranked 1st in the index. The nation is a world leader in clean energy, is developing green hydrogen for industrial use cases, and is fostering innovation around carbon capture and storage.

Figure 3: The Green Future Index rankings world map



Source: MIT Technology Review Insights, 2021

to exceed EU targets for hydrogen-based energy with €7 billion ($8.6 billion) earmarked to create 6.5 gigawatts (GW) of electrolyzer capacity by 2030.[14] Europe is also home to some of the world's most advanced programs to promote sustainable waste management. Belgium (9th) boasts Europe's highest rate of recycling and maintains a network of mobile "green spots" to facilitate easy disposal of electronic and chemical waste.

Costa Rica and New Zealand, the non-European countries within the top 10, rely on nature for the success of their agriculture and tourism industries. New Zealand, first place in the index's climate policy pillar, has enacted a slate of legislation to become carbon neutral by 2050, including a pledge to source all electricity from clean sources by 2035, and reduce biological methane from agriculture by 10% within this decade, halving it by 2050. Costa Rica (7th overall) is known for its climate leadership, aiming to source electricity entirely through renewable sources by 2021, and extending the moratorium on oil extraction and exploitation from 2021 until the end of 2050.

Other non-European entries in the top 20 include Canada (14th), Singapore (16th) and Uruguay (20th)—all countries that have strategies for decarbonization, transitioning energy sources, and government-led initiatives to promote green living, such as Singapore's Zero Waste Masterplan, which includes reducing waste sent to the country's only landfill by 30% between now and 2030.[15]

The greening middle

The next 20 countries in the index form "the greening middle"—countries with greater hydrocarbon dependency than the green leaders (for example, Colombia ranked 25th, Brazil 32nd, and Australia 35th), or countries with

ambitious climate policies albeit at a more nascent stage (including Morocco 26th, South Korea 31st, and Israel 38th).

The greening middle nations are bookended by large economies, India (21st) and the US (40th), which are also the world's third- and second-largest carbon-emitting nations. In many ways, India's ranking is a surprising result, but it is fast adopting renewable energy and has some positive socio-cultural factors including the world's largest vegetarian population. That said, as the world's largest dairy producer, it still ranks behind more than a dozen nations, from Nigeria to Indonesia, in animal product consumption.

Connecting policy goals with action will be critical, says Isabel Cavelier Adarve, co-founder at Transforma, a Bogota, Colombia-based climate advocacy organization. Policy heads in many countries are "comfortable with aspirational proclamations, which include ambitious environmental goals," she says. "But you often don't see actual measures, milestones, or allocations of public funds attached to them." Cavelier Adarve argues that in the developing world, climate programs cannot be implemented or measured without specifically linking them to social and economic outcomes. "You just can't broadly talk about the disadvantages climate change brings the world—you must couple them with issues that press on people's lifestyles and pocketbooks."

Climate laggards

The countries ranked 41 through 60 we refer to as climate laggards. Most governments in this cohort have articulated a climate action agenda with some tangible goals, and all but three of them—Nigeria (53rd), Zambia (51st), and Taiwan (46th)—are signatories of the 2016 Paris Climate Agreement. There are also several countries that have comprehensive plans to decarbonize, including hydrocarbon-dependent United Arab Emirates (42nd), Malaysia (56th), and China (45th). The latter, responsible for 28% of global emissions,[16] has recently pledged to achieve net carbon zero by 2060.

Despite the presence of some political will among the climate laggards, greater pressures hinder their progress toward a green future. These include economic pressures, as countries struggle to lessen their dependency on fossil fuels, either for power generation, or as export commodities—the UAE and Nigeria are the third- and fifth-largest exporters of crude oil, while Indonesia (57th), Vietnam (49th), and South Africa (47th) are all among the world's top 10 coal exporters. While fossil fuel consumption or exports are not explicitly measured in the GFI, these factors do influence climate policy, stifling decarbonization efforts even in advanced economies such as Japan (60th).

Climate abstainers

The 16 countries at the bottom of the index we call the "climate abstainers." These include petrostates Saudi Arabia (61st), Iran (74th), and Qatar (76th), as well as the prosperous and service-oriented economy of Hong Kong (64th). Political will to implement an effective energy transition and sustainable development policy has been absent in Hong Kong, and the territory is highly dependent on coal-fired power. Russia (73rd) recently released its Energy Strategy 2035 for expanding oil and gas production, which also identified the trend toward carbon neutrality as an existential threat.

Methodology

The Green Future Index was developed through in-depth secondary research and analysis as well as interviews with global experts on climate change, green energy, and technologies that will drive decarbonization. MIT Technology Review Insights gathered data for 76 countries and territories (representing about 95% of global GDP) for 18 indicators from a wide range of publicly available sources including the International Energy Agency, the International Renewable Energy Agency, the World Bank, the United Nations Food and Agriculture Association, and BloombergNEF. We also expanded existing datasets in areas such as climate policy and carbon finance initiatives by conducting detailed research and consulting with global experts. A full description of the methodology and data sources can be found in the Appendix.

Partner perspective

Salesforce

At Salesforce, we're thinking big. From our suppliers and our customers, to our technology and our brand, we're identifying our biggest levers of influence to make them change agents in the greatest challenge ever–the climate emergency. Climate change impacts every individual, company, city, and nation, and the effects weigh heaviest on the world's most vulnerable communities, amplifying global inequality.

We need to invest in a more resilient and inclusive economy to ensure the long-term health and wellness of citizens, create jobs, and protect against future shocks like climate change. We're establishing trust with our stakeholders by transparently disclosing our environmental, social, and governance strategy, efforts, and metrics in our annual Stakeholder Impact Report.

We deliver a carbon-neutral cloud to all our customers and commit to 100% renewable energy (RE) for our global operations by fiscal year 2022. Salesforce purchases RE in a way that adds new RE to the grid, avoids and reduces the greatest possible emissions, and blazes a trail for others to follow. We open-sourced our approach and featured third-party guidance in our More than a Megawatt whitepaper.

As part of our 1.5°C science-based emission reduction target, we're collaborating with our suppliers representing 60% of our Scope 3 greenhouse gas emissions to set their own science-based targets by 2024. This target was approved by the Science Based Targets Initiative.

We integrate sustainability into our real estate strategy. Seventy-four percent of Salesforce spaces are certified or pursuing green building certification. Salesforce country leaders deliver on sustainability initiatives through various means, including finding certified green buildings in their regions, and leveraging emissions data on business travel and employee commuting to set reduction targets. We also published a Sustainability at Home Guide to make remote workspaces more sustainable.

We advocate for policies that set the geographies we operate in on a path to a low-carbon economy. We call on countries and government officials to drive the full decarbonization of the economy, including embedding the cost of carbon into the financial system; driving innovation and deployment of new technologies; and creating demand for zero-carbon products and services.

Climate change is a threat to business, and we know that climate change will reshape every one of our customers–from changing customer preference, investor pressure, supply chain transformation, and continuity of operations. We created Salesforce Sustainability Cloud, a carbon accounting tool that accelerates the world's march to net zero by 2050, to bring climate action and transparency to the core of businesses.

In addition to our efforts to reduce emissions, we're also committed to protect and improve carbon sinks that remove carbon from the atmosphere. In support of 1t.org and the trillion tree movement, we set a goal to support and mobilize the conservation, restoration, and growth of 100 million trees by 2030. We built salesforce.com/trees on the Salesforce platform to provide updates on our progress and transparency into the tree projects and communities that we support. We hope you join us to plant the seeds for a more sustainable future.

74% of Salesforce spaces are certified or pursuing green building certification.

03 Energy systems in transition

Energy and heat production are estimated to account for 30% to 35% of total emissions; energy generated from all sources, including industry, construction, and transportation, contributes over 70% of global emissions.[17] Shifting to renewable sources of energy is critical for decarbonization.

The first pillar of the Green Future Index ranks each country according to their relative CO2 emissions contribution, and the emissions growth rate in each country's industry, transportation, and agriculture sectors. The second pillar, energy transition, compares the contribution and growth rate of renewable energy in overall energy production. Combined, these two pillars account for 30% of the index scores.

For two of the global leaders in terms of reducing emissions (Ukraine and Angola), the result is borne of low economic growth rather than concerted policy efforts to improve their carbon footprint. That said, Ukraine has reconfirmed its intent to reduce GHGs by at least 36% from 1990 levels by 2030.

At the bottom of the league, high economic growth in emerging economies has translated into rising production and transportation emissions that outpaced efforts to transition toward clean sources of power. Ethiopia is an exception; the country has fast growing emissions but is also quickly growing capacity in renewable energy sources.

Seven of the top 10 countries for the pace of their energy transition are in Africa. The region has seen a rapid adoption of solar energy, including on- and off-grid solutions. Ethiopia has significant hydropower resources, and its Climate-Resilient Green Economy program connects clean energy initiatives with its goal for becoming a middle-income country by 2025. The laggards in terms of energy transition are economies with established hydrocarbon power generation, making the conversion to clean sources difficult, even for committed climate action leaders such as Singapore.

Seven of the top 10 countries for the pace of their energy transition are in Africa. The region has seen the cost of renewables plummet, leading to rapid adoption of both on- and off-grid solutions.

A phase-out of fossil fuels

Clean energy production has grown enormously over the past decade, thanks to technical innovation and, in particular, China's high-volume production of photovoltaics. The International Renewable Energy Agency (IRENA) calculates that renewable electricity in service increased 7.5% in 2019 on the previous year. While hydropower accounted for more than half of renewable energy, most of the increase came from solar

Figure 4: Highest and lowest performers in the carbon emissions and energy transition pillars

PILLAR 1: Carbon emissions

A high score means a low emissions growth rate.

RANK	COUNTRY	SCORE	RANK	COUNTRY	SCORE
1	Ukraine	8.2	67	Indonesia	4.3
2	Norway	7.5	68	Philippines	4.2
3	Sweden	7.3	69	India	4.1
4	Luxembourg	7.3	70	Vietnam	4.1
5	Switzerland	7.1	71	Bangladesh	4.1
6	Angola	7.0	72	Nigeria	3.9
7	Greece	6.9	73	Paraguay	3.8
8	Ecuador	6.9	74	Turkey	3.7
9	United Kingdom	6.7	75	Ethiopia	3.5
10	Finland	6.7	76	Pakistan	2.4

PILLAR 2: Energy transition

A high score means that renewable energy is growing quickly and contributes a higher share of the overall energy mix.

RANK	COUNTRY	SCORE	RANK	COUNTRY	SCORE
1	Ethiopia	8.1	67	Spain	2.6
2	Angola	7.4	68	Slovakia	2.3
3	Uganda	7.4	69	Egypt	2.2
4	Cameroon	7.4	70	Taiwan	2.2
5	Nigeria	7.3	71	Singapore	2.1
6	Kenya	7.3	72	Hong Kong	2.1
7	Zambia	7.2	73	Iran	2.0
8	Iceland	7.1	74	Russia	2.0
9	Guatemala	6.9	75	Ukraine	1.9
10	Uruguay	6.7	76	Qatar	1.8

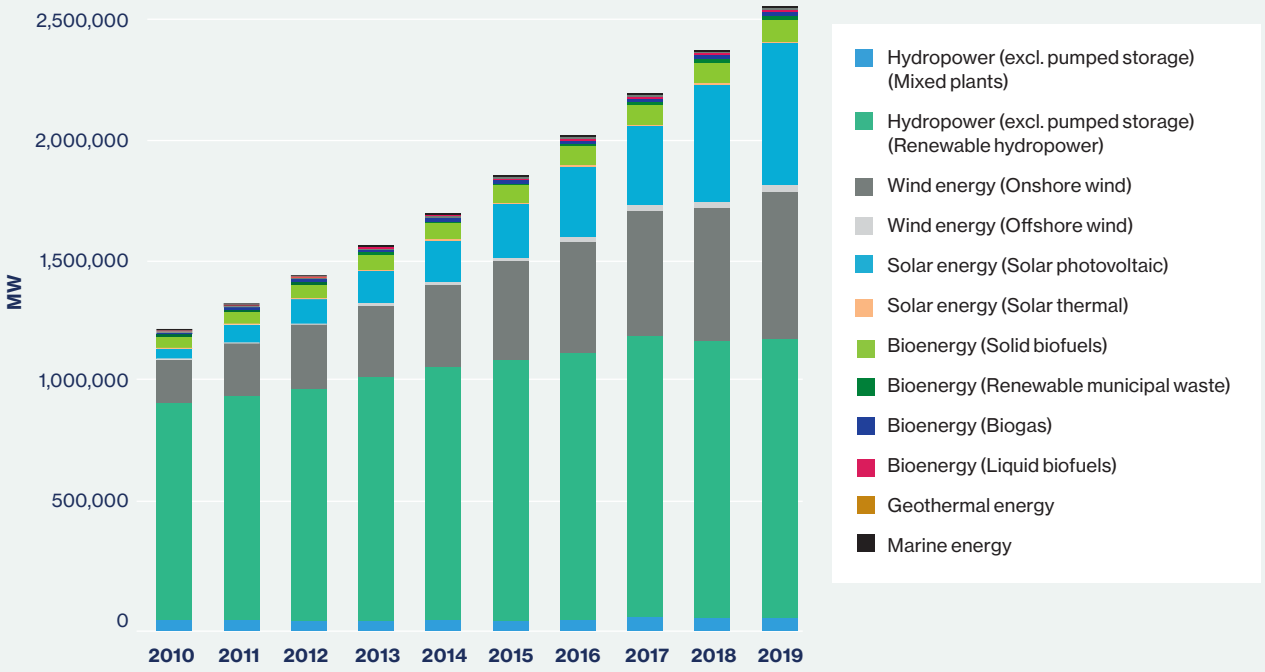
Source: MIT Technology Review Insights, 2021

and wind developments[18] (see Figure 5). Overall, IRENA estimates that 72% of new electricity in 2019 came from sustainable sources.

Coal-fired energy production decreased by 3% in 2019,[19] with large decreases in the United States, the EU, and South Korea. That said, in 2018, coal-fired power plants were the world's largest contributor to global CO2. Signs of coal's potential decline are encouraging, but this is only the beginning of the decommissioning journey. The UN argues that two-thirds of coal-fired electricity plants must close for the world to comply with the Paris Agreement limits on global heating.

China, the world's largest emitter of greenhouse gases, still depends on coal and gas for 70% of its electricity

Figure 5: Renewable power generation capacity installed, by type, 2010-2019



Source: Compiled by MIT Technology Review Insights based on data from IRENA 2020

capacity, and there are more coal plants under construction.[20] More positively, China was also the world's single largest contributor to renewable energy additions in 2019. Combined with hydropower and biomass, renewables were on track to contribute 27% of China's power generation by the end of 2020, according to the country's National Energy Agency.

Development of a renewable energy market in Japan is held back by the low targets set by the government for an energy transition. Renewables will amount to just 24% of total electricity production by 2030, up from 17% in 2018.[21] This means electricity sourced from clean producers is expensive and difficult to obtain. Land and infrastructure shortages also constrain the ability of Japanese firms to self-supply clean energy. BloombergNEF research indicates that domestic firms will be able to generate less than 20% of power demand from on-site projects.[22]

There are signs that Japan is becoming more forward-looking. The Ministry of Economy, Trade, and Industry invested an estimated $560 million in hydrogen funding last year, and several of its largest manufacturers, notably Toyota, are experimenting with hydrogen and other clean sources to develop carbon-neutral production facilities.

Adapting and integrating

For many economies, transitioning energy systems will require integrating very different types of systems. Robert Stoner, deputy director for science and technology at the MIT Energy Initiative, notes that for mature markets, reusing existing energy infrastructure for clean energy distribution is critical. "In the US in particular, we've already got power networks, natural gas networks, and storage facilities representing trillions of dollars of sunk investment. We can reuse this infrastructure, particularly pipelines and pipeline storage, in a green economy context." Hydrogen may be used this way in future. "You can't put hydrogen at 100% concentration into most existing gas pipelines, as it will either re-brittle the pipelines or seep out through the connection points, but you can put it in 10% or 15% concentrations."

But repurposing traditional infrastructure for variable, weather-dependent renewables is challenging, he says, because existing electric power systems are built around

routine, scheduled inputs. “Electricity grids have to accommodate numerous intermittent sources, as well as many diverse storage devices, and enable them to be connected with a diversity of lows in a different way than they have been in the past. We’re going from broadcast topologies where energy is produced in central plants and flows steadily from generation to load, to one where energy becomes more distributed throughout the system and more intermittent in character.”

This, Stoner says, will create an energy transformation process much more profound than simply switching from hydrocarbon sources to renewables—one where “new historically independent sectors” such as public transportation, logistics, real estate, and agriculture, “become coupled through the electricity system to a large degree.”

These newfound couplings could eventually create even more profound innovations and efficiencies in the ways that energy is produced, distributed, and managed. “What I do at home with my electric car suddenly affects what someone else will do in a factory with heating of a thermal process, because energy will start moving energy back and forth into the system, and this will require a deal of thinking about how to make use of storage optimally, or how to control the system differently.”

Stoner believes that some of the most important transition innovations will come from emerging economies. He points

Morocco: exporting renewables

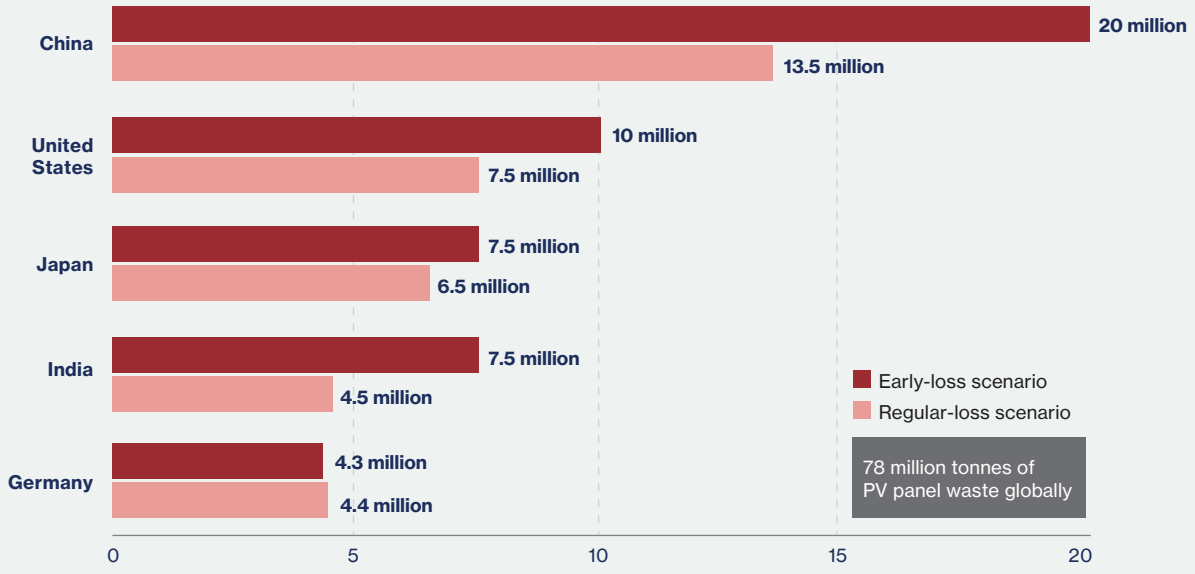
Over a decade ago, the King of Morocco began a national debate about the future of energy, resulting in a fundamental policy redesign and a goal that renewables would produce 42% of the country’s power by 2020—a target that has now been raised to 52% by 2030.

In addition to developing strong wind and solar sectors, says Said Mouline, CEO of the Morocco Agency for Energy Efficiency (AMEE), Morocco has also successfully driven down cost. “At less than $0.03 per kilowatt hour, renewables are now our cheapest way to produce electricity.” Fossil fuel subsidies have been eliminated and replaced with energy transition programs, for example to replace gas-fueled farm irrigation with solar-powered pumps. Nearly 40,000 pumps have been installed to date. Another program provides solar conversion incentives for steel and cement producers and mining companies.

Mouline envisions Morocco becoming a regional climate advocate within Africa. “Today in Africa we have 600 million people who don't have electricity, and we have the tools and capabilities to help leverage renewables to bridge that gap.” AMEE created a capacity-building center in Marrakesh to train Africans from other countries in areas like renewable electrification and sustainable pumping for agriculture.

Morocco is also looking north to Europe. Some 60% of wind turbine blades produced in a new Moroccan factory will be for the export market, mainly to Europe. Decarbonization will be essential to align with Europe’s New Green Deal, as well as capitalize on its opportunities. “Europe’s recovery plans will involve billions in hydrogen investment—we are now pushing to develop hydrogen resources, including storage technology and ammonia production to align with those aspirations. It is our new mission as an agency.”

Figure 6: Estimated solar panel waste (Tonnes)



Source: Compiled by MIT Technology Review Insights based on data from IRENA, 2016

to India's rapid transition to expanding wind and solar, with plans for 450 GW of clean power by 2030. The country has several of the world's largest solar plants (including the single largest in Bhadla, in Rajasthan). As India continues to rapidly urbanize, and gets hotter, the rising use of air conditioning will be a considerable challenge. To manage the transition, says Stoner, "India will have to mitigate the intermittency (of renewable generation) and shape the load to accord with emerging demand."

Increasing energy access, sustainably

For much of the developing world, the burning energy issues are overcoming supply deficits and increasing access. This gives governments the opportunity to build clean energy from the outset.

The government of Kenya (Africa's highest-ranked nation, in 23rd place) states that some 80% of the country's power supply comes from renewable resources—although an estimated quarter of the population still lacks access to the grid. M-Kopa Solar is a Nairobi-headquartered provider of off-grid solar power services, serving 800,000 customers in Kenya with a unique business model and generating $100 million across three African countries.

"We are not really an energy company in a traditional sense, in that we don't build big power-generating infrastructure," says founder and CEO Jesse Moore. He describes the business as a connected asset financing company that uses digital micropayments across "pay per use" models in solar panels, solar powered home appliances, and mobile phones. Home installed solar-powered generators are linked through SIM cards to a cloud platform, allowing consumers to pay for power as they use it—eventually owning the underlying asset.

The success of M-Kopa's service distribution model is partly due to Kenya's well-developed mobile and digital payments infrastructure. Moore considers user experience and health concerns to be more pressing than environmental factors in driving Africa's adoption of off-grid solar. "Burning kerosene in your home makes it difficult for your kids to read at night, or often even breathe. In Nigeria, it is about noise as well. The country is plagued by brownouts and blackouts, so many run small generators that generate a lot of noise eight hours a day. It also has to be affordable. If people can access renewable power that's better and cheaper, then the fact that it's also cleaner is just the cherry on top." Moore estimates M-Kopa's services have avoided 1.6 million tons of carbon emissions in Africa.

The trend for industrial companies, factories, airports, shopping malls, and universities to establish their own solar power generation capability and sell excess capacity back to the grid has led to thinning revenues for Kenya Power, the national utility. The 3.7% demand growth for grid electricity in 2020 was considerably lower than projected, with electricity surpluses adding cost pressure.[23] This private sector-led shift to solar could accelerate the decommissioning of coal-fired power, not just in Kenya but across Africa.

The solar lifecycle

With solar becoming widely and cheaply available, other voices are highlighting the need to prevent another environmental disaster. "Ecosystems take a long time to respond to human interventions," says Yifei Li, assistant professor of environmental studies at NYU Shanghai, and co-author of China Goes Green: Coercive Environmentalism for a Troubled Planet. "We know the positive benefits of harnessing solar power—but we have no idea what to do with decommissioned solar panels, which use heavy metals and rare earth elements which are difficult to recycle." Four years ago, IRENA forecasted that China's solar energy boom could result in 13 to 20 million tons of photovoltaic panel waste by 2050.[24]

"PV recycling is starting to be a big topic as it becomes a more mature industry and a lot of panels start to hit end of life," says Lindsey Wiedmann, chief legal officer and head of sustainability at Singapore-headquartered Maxeon Solar Technologies. "Governments are trying to figure out whose responsibility it is—the manufacturers? The developers? The owners? and how to ensure that less panels end up in landfills." Wiedmann notes that Maxeon's panels have a lifespan of nearly 40 years, and the company is focusing on sustainability by design. This includes reducing waste throughout the manufacturing process, sending less than 1% of its waste to landfill, and striving to reduce lead and other environmentally harmful materials from its panels.

Avoidance does not equal reduction

As energy systems transition toward cleaner sources of power, these investments will help to avoid carbon emissions, which, while valuable, cannot claim to actually reduce emissions, says Friedmann at Columbia University. "Economists view avoided emissions as the same as reduced emissions, because in their ledgers they look the same. It does not look the same to an atmospheric chemist. Avoided emissions are not reduced emissions." Far from being a terminology issue, this points to fundamentally divergent worldviews between the commercial and scientific lobbies, complicating how to guide industry and civil society toward activities that support "deep decarbonization." Meeting the goals of the Paris Agreement requires removing greenhouse gases from the atmosphere, not merely reducing the amount newly generated.

Latin America: a challenging transition

"Latin America neither has the world's highest emissions, nor its poorest countries—but it is a region quickly walking toward a high-carbon development trajectory," says Isabel Cavelier Adarve at Transforma, in Bogota, Colombia, as a result of persistent social inequality and high economic dependency on fossil fuels and resource extraction. "Latin America's four largest economies have large, nationally-owned fossil fuel companies, and direct cash subsidies to the poor are linked to their financial performance."

Colombia's 2016 carbon tax levied on fossil fuel purchases averaging $5 per ton of CO2, aimed at raising money for social programs, has an exemption for coal, the country's second-largest export by value. The covid pandemic lowered demand for fossil fuels, putting more pressure on tax revenues. "When you need to build housing for the poor, you're not thinking about cement emissions," she says. Having such a high percentage of the region's workforce in the informal economy compounds the problem, according to Maria Laura Rojas, Transforma's executive director. "It's very difficult to implement climate change-focused public policy objectives in the informal sectors, many of which are directly related to emission drivers," such as long-haul trucking, unlicensed logging, and farming.

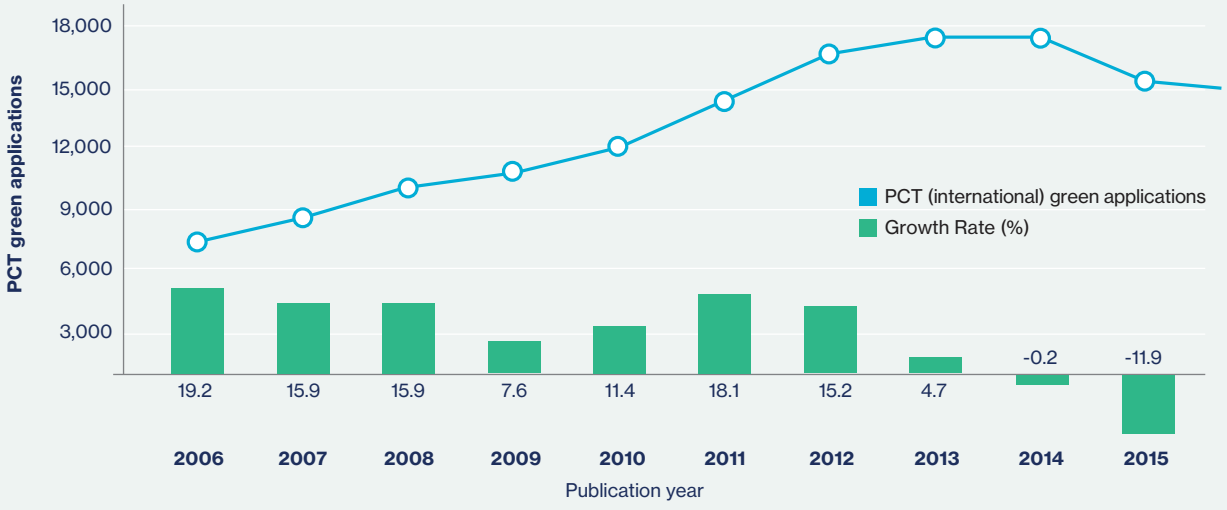
04 Industry, investment, and innovation

Compared to the energy sector where the transition to clean power is already gathering pace, the next frontier, says Jos Delbeke, chair of climate change policy at the European Investment Bank, is manufacturing. "In the energy sector, the technologies are there. It is about rolling out massive investment in the low-carbon solutions. In the manufacturing industry in contrast, for the coming decade, it's all going to be innovation funding." Delbeke envisions a decade of massive investment in the hydrogen economy and carbon capture and storage technologies, including areas such as biochemistry and biomass R&D. The broad roll out, he expects, will occur across industry from 2030 onward.

Clean innovation

Countries that foster cleantech—creating new technologies and solutions that generate clean energy, for instance, or transportation and heating processes that use less power—add to the stock of global intellectual property and help all nations decarbonize. Ironically, this stock is not growing particularly fast. The World Intellectual Property Organization (WIPO) reports that global applications for green energy patents were just under 17,000 in 2019, only 1.3% greater than 2018[26] (see Figure 7). According to WIPO, while five countries—China, the US, Japan, Germany, and South Korea—account for over three-quarters of the world's green patents, only China and Korea registered growth last year. Other growth leaders are actually small economies that have

Figure 7: Green energy patent applications filed under the Patent Cooperation Treaty, 2006-19



Source: Compiled by MIT Technology Review Insights based on data from the World World Intellectual Property Organization, 2020[27]

Figure 8: Highest and lowest performers in the clean innovation pillar

A high score means a higher relative number of green patents, investment in cross-border clean energy initiatives, and investment in foodtech.

RANK	COUNTRY	SCORE
1	Singapore	7.6
2	Finland	7.4
3	Chile	7.2
4	Luxembourg	7.0
5	Morocco	7.0
6	Denmark	6.9
7	Kenya	6.8
8	Egypt	6.7
9	France	6.6
10	Uruguay	6.5

RANK	COUNTRY	SCORE
67	Poland	3.6
68	Hungary	3.4
69	Romania	3.3
70	Angola	3.0
71	Bulgaria	3.0
72	Iran	2.2
73	Bangladesh	2.0
74	Qatar	2.0
75	Algeria	1.3
76	Paraguay	1.0

Source: MIT Technology Review Insights, 2021

managed to attract venture capital or have fostered technology clusters. Luxembourg, which after China has the second-fastest patent growth, is a popular cleantech investment hub, attracting innovative startups such as Clariter, a developer of chemical solutions for recycling plastic waste into industrial ingredients.

The prospect for investment and innovation to build a green future is reflected in the index. The clean innovation pillar measures each country's relative number of green patents, cross-border investment in clean energy, and private investment in foodtech. Many of the leaders in this pillar have made sizeable commitments to energy transformation, including Chile, Kenya, and Morocco. The leaders also include countries such as Finland that have directed R&D and venture capital toward building vibrant cleantech clusters. The laggards have demonstrated very little appetite for issuing, or deploying, cross-border clean energy investment capital, or, like Iran, not been able to access foreign sources of capital for their transition.

Follow the money

Claire Healy, program director at climate advocacy group E3G, agrees that the next decade will be critical. "If countries and businesses claim they want to achieve net zero emission by 2050, then we need to halve total global emissions in the next 10 years. That's what scientists say is necessary, and nobody knows how we'll do that yet. But the future is unquestionably is going to be low carbon, and we will get there much faster if countries cooperate."

That belief, Healy says, stems from the growing momentum for green investments in the financial community. "We were not long ago struggling to cobble together a couple of billion in investment for clean infrastructure or technology R&D—now, there are billions and trillions being thrown around. Investors are walking away from oil and gas, and particularly coal, where I think the argument's been won in most markets." Development banks have to decouple themselves as well, says Healy, such as enacting exclusion policies for financing or providing export credits for fossil fuels.

A decade ago, less than 10% of assets under management were aligned to sustainability objectives, estimates Audrey Choi, Morgan Stanley's chief marketing officer and chief sustainability officer. Now, that figure is close to a third of the $17 trillion in managed assets globally, a portfolio that significantly outperformed the rest in 2019.

Sustainable business practices

While decarbonizing industry might seem a Herculean task, Friedmann argues there is actually a fairly short list of actions for industry leaders and policymakers. "There

Beyond keeping transport down, reduced footprints in offices mean fewer industrially climate-controlled buildings, and increasingly, less reliance on energy-intensive workstations and monitors.

are only three things that reduce emissions. Efficiency and conservation—this works, is easy to measure, and non-ambiguous. Second, carbon capture and storage. You have a power plant that's emitting a million tons of CO2 a year, you slap a device on it, now it doesn't. Three, shutting things down—not just building renewable power capacity, but using renewable capacity to displace power dispatch from a fossil fuel plant."

Most industrial policy runs counter to these three actions, he says, particularly in industrialized nations. Friedmann points to Germany as an example, "betting on a solar industry that they can sell to the world, but they need an overall energy export economy as well, so they still sell gas turbines and coal boilers and gasifiers."

Despite the tensions, there is plenty of evidence that Europe will play a leadership role in developing decarbonization technologies. French cement producer Lafarge has formed an industrial consortium to develop Carbon2ProductAustria—a vertical carbon capture chain aiming to convert all of the 700,000 tons of CO2 produced by its cement facility in Mannersdorf, Austria, into hydrogen and other renewable-based hydrocarbons.[28]

Additionally, there are growing efforts by governments and industry to develop green hydrogen—produced through the electrolysis of water, rather than gray hydrogen produced or recycled from carbon-emitting processes. The UK (17th overall in the index) has announced plans to introduce green hydrogen into its cement industry as well as develop world-first experiments to use clean hydrogen to power towns in Scotland.

Efficiency at work

As the private sector, and particularly services sector, looks at how it can do its part, covid has also shown that big changes are possible. The shift to home and remote working are likely to result in some permanent changes to workforce habits and locations. Commuting to work is a significant driver of carbon emissions and is estimated to account for more than a quarter of transportation emissions in the UK.[29] Beyond keeping transport down, reduced footprints in offices mean fewer industrially climate-controlled buildings, and increasingly, less reliance on energy-intensive workstations and monitors.

To make devices and working environments more energy efficient, new chipsets are being designed to lower power consumption. Gowrishankar Chindalore, head of strategy for edge processing at NXP Semiconductors, says that AI will increasingly play a role, by boosting device power conservation and managing information more efficiently over distributed environments. "Transferring data over a wireless network requires up to a thousand times more energy than processing it locally using CPU or dedicated hardware," he says. This will be increasingly important in the IoT era where devices installed throughout homes, offices, and vehicles will generate terabytes of data. Innovation will be needed to lessen "energy wastage that occurs when devices are plugged-in but idle—aka "vampire power"—which is fast becoming a noticeable portion of the total energy consumption ."

Partner perspective

Citrix

As a company headquartered on the Florida coast, we are acutely aware of the consequences of the climate crisis, and we are committed to decreasing our environmental impact, and crucially, the impact of our customers. And with 100 million Citrix users in more than 100 countries, we have the scale needed to make a positive climate impact.

At Citrix, we understand that our role in reducing energy consumption starts with our products, which enable anyone to work from anywhere—reducing transportation emissions from commuting and enabling a shift to more energy-efficient devices. For example, Citrix Workspace eliminates the need for applications and data to reside on endpoint devices. This puts product sustainability into practice, allowing customers to transition away from more energy-intensive desktops with large screen displays and high-performance processors toward more energy-efficient laptops. And because no data is required to live on these devices, it can extend the useful life of an individual device by up to 40%. This can significantly decrease an organization's energy demand and reduce waste.

Citrix Workspace—combined with flexible remote work policies—can drive down corporate office space needs and reduce employee commuting, further reducing a company's carbon footprint. According to a recent PwC survey,[1] the majority of CEOs believe that covid-19 pandemic-driven shifts toward remote collaboration and fewer people working from offices are likely to stay.

When organizations deploy Citrix Workspace and manage client devices to optimize for energy efficiency, they can—depending on the size of their employee base—dramatically decrease the GHG emissions associated with client computing. That's because giving employees the ability to work on any device, on any network anywhere, can decrease reliance on fossil fuels and lessen the burden of traffic congestion. As an example, emissions from transportation account for 14% of global GHGs and 28% of GHGs in the United States.[2] In the US, transportation is the largest contributor to GHG emissions,[3] and prior to the pandemic, over 75%[4] of Americans commuted to work by private car. Work from home employees in the US avoid emitting 3.6 million tons of transport-related emissions, which is the equivalent of 91 million trees planted.

Working together, Citrix is able to meet the needs of our customers, employees, communities, and the environment. Our scale provides us a unique opportunity to enable this change, contributing to better air quality, a reduction in chronic health issues, less dependency on fossil fuels, a healthier natural environment, and more-livable cities.

Tim Minahan
EVP, Business Strategy and Chief Marketing Officer
Citrix

75% of Americans commuted to work by private car prior to covid-19.

1. "CEOs: Post-Covid changes are permanent and there are more to come, " PwC, November 11, 2020.

2. 3. U.S. Environmental Protection Agency Carbon Pollution from Transportation, US Environmental Protection Agency.

4. U.S. Census "America's commuting choices: 5 major takeaways from 2016 census data," Brookings Institution, October 3, 2020.

05 Green society

The green society pillar of the index measures how countries are preserving their environment and adopting sustainable practices. The indicators in this pillar include the relative number of green buildings, the proportion of waste that is recycled, efforts to increase forested land, and per capita meat and dairy consumption. This last indicator is largely culture- and income-driven; however, the UN Intergovernmental Panel on Climate Change estimates that reducing meat consumption could avoid up to 8 billion tons of CO2 annually by 2050.[30]

Singapore, the leader in the green society category, has the highest rate of non-domestic recycling in the world at 73% in 2019. South Korea, Taiwan, and Germany also score well on this measure. Ireland and the Czech Republic are among the global leaders in reforestation efforts (although tree planting in no way mitigates the damage caused to ecosystems and biodiversity by deforestation). The United States has the largest number of green buildings relative to its urban population. Ireland also scores well on this measure. Meat and dairy consumption in the Philippines, Thailand, and Singapore remain low.

Figure 9: Highest and lowest performers in the green society pillar

A high score means a better overall performance in the indicators covering green buildings, recycling, forestation, and low meat and dairy consumption.

RANK	COUNTRY	SCORE	RANK	COUNTRY	SCORE
1	Singapore	6.9	67	Algeria	4.1
2	Ireland	6.9	68	Nigeria	4.1
3	South Korea	6.8	69	Qatar	4.1
4	Taiwan	6.7	70	Kazakhstan	4.1
5	Philippines	6.6	71	Brazil	4.0
6	Czech Republic	6.4	72	Ukraine	3.9
7	United States	6.1	73	Pakistan	3.9
8	Germany	5.9	74	Argentina	3.8
9	UAE	5.9	75	Russia	3.7
10	Thailand	5.8	76	New Zealand	3.2

Source: MIT Technology Review Insights, 2021

New Zealand, which scores eighth in the index overall, has a particular lag in the green society pillar, coming last of all 76 countries measured. The country has a particularly low recycling rate; advocacy group WasteMINZ estimates each year 750 million plastic containers end up in landfills that could have been recycled.[31] The country also has a high consumption rate of meat and dairy products and has few green buildings.

Reducing meat and dairy consumption

Global growth in vegetarian and vegan food categories provides hope that more sustainable, plant-based lifestyles will continue to gain popularity. Latin America has a food culture that centers on meat and is home to several of the world's largest meat exporters. Yet the region has several foodtech startups, including Chile's NotCo, which produces milk substitutes, and Fazenda Futuro, from Brazil, which develops meat substitutes made from soy, peas, and chickpeas. The two startups attracted almost $40 million in venture capital in 2020.[32] Yet attempts by the city government of Bogota, Colombia, to promote a city-wide volunteer *dia sin carne* (meatless day) sparked social media outrage—including from the country's president—over perceived encroachment on civil rights and slights to Colombia's cattle industry.

Elsewhere, Singapore startup Eat Just has received regulatory approval to commercialize cell-cultured chicken. And the Netherlands has a cluster of R&D research centers in its so-called Food Valley, including a $94 million facility being built by Unilever. Yet these innovations will take time to be adopted. The Netherlands' per capita meat and dairy consumption ranks in the global top 10, and at 39 kilograms per person in 2019, Dutch consumption of meat grew by 500 grams over 2018 levels.[33]

While reducing consumption of meat and dairy is important, there is also plenty of scope to explore practices within those industries, says Friedmann, pointing to experimentation with seaweed-based feeds for reducing methane from livestock. Contained farming (largely pioneered in the Netherlands' Food Valley) and vertical farming are other foodtech innovations that will shift food production and consumption toward sustainability, observes King Lai, head of HK Eco Foods, a Hong Kong-based developer of vertical growing systems for urban environments. "Controlled environments produce 10 times the volume of broad-field growing," and can create what he refers to as "distributed abundance"—growing food widely and locally, as close to population centers as possible.

Natural forest and biodiversity

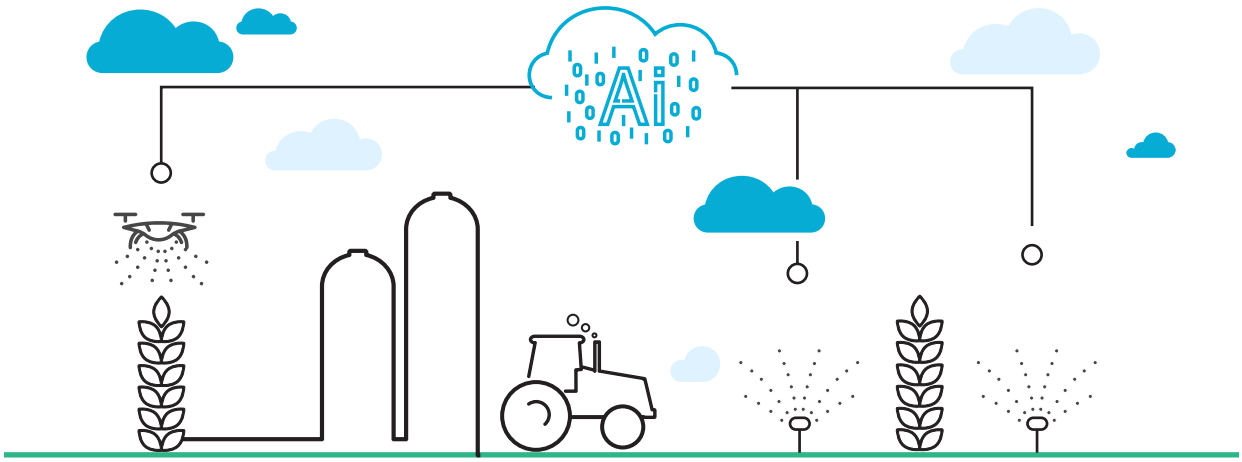
The index measures net change in forestation, capturing how countries are replacing tree cover as well as planting seedlings in areas that were not previously forested. "It's crucial to restore and plant forests on deforested areas, but probably more important not to degrade them in the first place, says Alistair Monument, conservation impact director, Asia Pacific, at the World Wildlife Fund for Nature. "We are realizing that many forests should be kept intact as it is just not possible to replace their unique ecosystems."

Tree planting has gained popularity in recent years as a strategy for capturing carbon, yet the impact is "mixed," says Monument. "Most of the observable carbon capture occurs in the cycle of forest planting, which is used to justify expansion of forested land." This ignores the impact of the planting on biodiversity, soil depletion, or the carbon impact of timber use in fast furniture or biofuel.

Reforestation plans must consider long-term effects, says Li at NYU Shanghai. "Poplar tree planting projects can grow into great 'forests' in only a year or two. However, they are not only less diverse than original primary growth forests, but they're also made up of trees with very deep root systems, which suck up so much water they cause irreversible damage to the underlying aquifers."

Tree planting has gained popularity in recent years as a strategy for capturing carbon, yet the impact is mixed. Most projects ignore the impact of forest planting on biodiversity, soil depletion, or the carbon impact of timber use in fast furniture or biofuel.

Food, agriculture, and deforestation



Land use, food production, packaging, and distribution are estimated to account for a quarter of global greenhouse gas emissions. Concerns about food security continue to drive agricultural industrialization in many low-income countries. Indonesia (57th) has recently been criticized for using its Ministry of Defense to quell opposition to the planting of 30,000 hectares of rice in central Kalimantan this year (an area the size of Bali).

Yet technology is rapidly making farming more efficient, productive, and sustainable. Ipos Consulting estimates China has more than 13,000 drones in service, delivering pesticides and fertilizer to over 7 million hectares of farmland. While this has transformed productivity, China now uses three times more agriculture-enhancing products per hectare of land than the US, degrading the country's land and water supplies.

AI can provide a solution to that, with models that can increase precision in planting and fertilizer and water use, significantly decreasing the CO2 per unit being produced, says Chris Seifert, VP of data science at Granular, a San Francisco-based agritech analytics company. Granular also runs AI models which optimize nitrogen use—N2O has a global warming potential of hundreds of times that of carbon.

The US Department of Agriculture is promoting AI development around "prescriptive interventions," modeling techniques that help farmers increase the complexity of their operations—such as adding more passes of fertilizing equipment, or managing fields non-uniformly with a mix of crops, to expand crop yields or better manage cost. Despite the benefits AI brings to agricultural efficiency, there is resistance to change, says Siefert. "It's hard to sell complexity to a grower who manages thousands of acres, to ask them to intercrop 200 species of different fruits and vegetables."

In the future, AI will drive industry standards for measuring carbon sequestering, giving weight to the emerging carbon offset market where farms can sell carbon credits for leaving fields untilled between plantings. There are several models and tools currently available, says Seifert, but lack of common cross-industry carbon verification processes has created a fragmented service market for validating carbon credits for farmers, which often makes certification costs much higher than the value of the carbon captured. "Figuring out which one of those the industry might standardize on provides a great opportunity to create a carbon marketplace for sequestration at a relatively low cost."

Partner perspective

Morgan Stanley

In the half-century since the first plastic products hit the market, the global economy—and no doubt each of us—has reaped the benefits of this innovation and the products it has enabled.

From our smartphones and laptops to vital diagnostic and life-saving equipment—plastic has become a critical component of the modern word.

But we also face a growing, and global, plastic waste problem—with 44 tons of plastic waste every minute now dumped into landfills or the environment.[1] It's a pressing economic, environmental, and health issue that no company, industry, country, or alliance can address alone. In fact, it will take a systemic approach that covers the entire plastic value chain from industrial design to disposal and involves close collaboration among government, philanthropy, manufacturing, finance, and consumers.

That's why Morgan Stanley launched its Plastic Waste Resolution to facilitate the prevention, reduction, and removal of 50 million metric tons of plastic waste in rivers, oceans, landscapes, and landfills by 2030. Delivering on this requires a set of integrated solutions, a holistic approach that leverages every part of the firm—from institutional securities, wealth management, and asset management, to our ability to fund cutting-edge research and public involvement.

Already, we've made progress. The firm's Global Capital Markets is underwriting bonds to address plastic waste, including Pepsi's $1 billion green bond, used in part to reduce virgin plastic across its beverage portfolio. Our Investment Management business is creating products that consider plastic waste reduction a core part of the underlying investment strategy, and the Institutional Equities Division is exploring the creation of structured financial instruments and other products to help investors address the plastic waste challenge.

Over the past decade, Morgan Stanley and its Institute for Sustainable Investing have focused on harnessing the power of the capital markets to protect the environment and strengthen communities as an integral part of how we do business. The Plastic Waste Resolution continues that commitment by supporting the research and new thinking that will help us better understand the challenges of plastic waste, develop and fund viable solutions, and encourage capacity building among the entrepreneurs, innovators, and a new generation of finance professionals who can address this issue together.

For a complete list of the actions that the firm is taking, and to follow our updates, please visit: www.morganstanley.com/PlasticWasteResolution.

Audrey Choi
Chief Sustainability Officer and CEO
Morgan Stanley Institute for Sustainable Investing

50 million

metric tons of plastic waste will be removed from rivers, oceans, and landfill by the Morgan Stanley Plastic Waste Resolution by 2030.

1. Borrell, et. Al. "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution," Science, September 2020

06 Climate policy and the path ahead

The climate policy pillar, which accounts for 40% of the weighting in each country's score, measures:

- **Climate action:** The level of ambition each country is setting out in its Nationally Determined Contributions (NDCs) toward meeting the goals of the Paris Agreement, and the effectiveness of policy frameworks being used to achieve them
- **Carbon pricing initiatives:** The level of development and implementation of carbon taxes or carbon trading markets
- **Sustainable agriculture policy:** The robustness of sustainable agriculture policies and degree to which they promote private sector investment in sustainable farming
- **Pandemic pivot:** An assessment of how covid-19 recovery stimulus packages will accelerate each country's decarbonization through investments in energy transition and low-carbon infrastructure

New Zealand, Denmark, and France lead the climate policy pillar. In all three countries, well-honed existing climate action policy frameworks have been bolstered by new green stimulus spending and accelerated infrastructure investments, such as France's hydrogen strategy and government plans to provide Air France with a €10 billion ($12.3 billion) bailout with green strings attached, including introducing sustainable fuel and reducing domestic routes.[34] Denmark's recovery programs include $5 billion for energy efficiency renovations to some 72,000 public housing residences.[35]

> Europe's greatest innovation in promoting climate action, just as in the introduction of the General Data Protection Regulation for protecting private data, might be in creating and promoting a framework that will set the standard globally.

Unsurprisingly, the poorest performers in this pillar are hydrocarbon-dominant economies. Many, particularly those in the Middle East, have recognized the need to decarbonize and have made attempts to develop renewables and cultivate green industries. But in the main, low scorers on the policy pillar have either leaned into traditional (carbon-intensive) drivers of growth, or seen key firms and institutions crippled by covid-19. In South Africa's case, recent stimulus investments have favored coal and other resource sectors, and while the country implemented a renewables-focused Integrated Resource Plan in October 2019, the precarious finances of state electricity provider Eskom cast doubt on its ability to implement it.

Figure 10: Highest and lowest performers in the climate policy pillar

A high score means a stronger relative performance in the climate policy, carbon pricing, suitable agriculture, and pandemic pivot indicators.

RANK	COUNTRY	SCORE
1	New Zealand	7.8
2	Denmark	7.3
2	France	7.3
4	Netherlands	6.7
5	Iceland	6.7
6	Costa Rica	6.6
7	Ireland	6.4
7	Norway	6.4
9	Spain	6.2
10	Belgium	6.1

RANK	COUNTRY	SCORE
66=	South Africa	2.5
68	Peru	2.4
69=	Ghana	2.1
69=	Saudi Arabia	2.1
71	Qatar	1.8
72	Uganda	1.6
73	Iran	1.5
74	Guatemala	1.5
75	Paraguay	1.3
76	Russia	1.2

Source: MIT Technology Review Insights, 2021

Carbon tax and trading

Creating an effective market structure for pricing and trading carbon credits is a foundational component of climate action policy, and just over half of the countries and territories ranked in the Green Future Index have implemented either a system of tradable emission-based financial products or some form of tax on corporate carbon emissions.

However, while a dozen green leaders have both an emissions trading system (ETS) market and comprehensive national carbon taxes, no country yet has managed to explicitly link their tax schemes or dispersion of "allowances" (emission credits granted to firms) to their national targets for decarbonization.

This has meant that there are too many allowances, depressing the price of carbon, even in the most (relatively) mature ETS markets, like the EU. Added to this, the impact of covid could further threaten attempts to build more effective carbon markets. The French government recently pressed EU peers for a floor price on carbon, since the weak fossil fuel demand and energy prices have also lowered the cost of trading carbon credits.[36] Of the major economies with national carbon trading schemes today, only the UK has managed to implement a floor price, although in March 2020 the treasury failed to raise that to £30 ($41) per metric ton as originally planned, opting to keep it at £18 ($25).[37]

The EU: tackling structural reform

The world's ability to contain the climate emergency will largely be determined by China, the United States, and the 27 countries of the European Union. Based on data from the EU and the International Energy Agency, these countries together account for more than 56% of CO2 emissions measured in the carbon emissions pillar of the index.

The EU has had climate policies in place for more than decade, but covid-19 provided the impetus for a region-wide transition to green energy, infrastructure, and industry. The EU's Recovery and Resilience Facility includes over €200 billion ($245 billion) for innovation in industries and technologies that will reduce emissions. EU leaders have promised this funding will contribute to a "green and digital transition."

The European Investment Bank (EIB) will have a central role in dispatching these funds, and in September 2020, appointed Jos Delbeke as its first chair on climate change policy and international carbon markets. The appointment signals "a change of policy by the EIB," he says, to be "not only the European public bank, but also a climate bank."

> “China can accomplish amazing environmental goals, its ambitions are genuine, and the state has a proven track record in some areas.”
>
> **Yifei Li**
> Assistant Professor of Environmental Studies
> New York University Shanghai

A central plank of the strategy is to formalize financial mechanisms for valuing carbon emissions. The EIB, he says, is already the biggest issuer of green bonds in the world, but there is still much policy work required for changing market behavior. “Do we achieve this through carbon taxes? Or through emissions trading systems? I am a strong believer in both. I think what we are going to see in the future will be a blended system, with characteristics partly of an emissions trading system, partly a tax system.”

In 2021, the European Commission is likely to introduce a bill for a Carbon Border Adjustment Mechanism, or CBAM, which by 2023 will implement a transfer price on the estimated carbon content of imports into the EU. This represents the EU’s next phase in articulating the cost of carbon and may be the first substantive attempt to set climate standards to which both member states and their trading partners must adhere. “I expect this instrument will primarily be a climate policy instrument–not a tax, not a trade instrument,” says Delbeke, although he adds that the introduction of CBAMs must be carefully managed so as to avoid unnecessary impacts on international trade, particularly for member states with carbon intensive industries, or between the EU and its emerging market trading partners. “The purpose is to address carbon leakage that carbon prices may have on the competitiveness of countries’ manufacturing industries.” Europe’s potentially greatest innovation in promoting climate action, just as in the introduction of the General Data Protection Regulation for protecting private data, might be in creating and promoting a framework that will set the standard globally.

China’s green growth

Experts familiar with China’s singular determination to achieve national goals are relatively confident it will be net carbon zero by 2060. According to Yingxia Yang, senior fellow at the Boston University Institute for Sustainable Energy, “China has been very successful long-term strategic planning and fostering emerging clean energy technologies through government policies and subsidies.” But to galvanize the whole economy, the government should think beyond policies and subsidies. “China needs to set up the market infrastructure that incentivizes investment, innovation, and competition,” she says.

“China can accomplish amazing environmental goals, its ambitions are genuine, and the state has a proven track record in some areas,” says Li at NYU, citing China’s 2018 National Sword waste import ban that virtually eliminated imports of recyclable plastics within a single year, throwing international recycling supply chains into disarray. “But I am concerned about the cost,” he adds, describing how China’s top-down environmental policies have had damaging consequences. These include a 2017 initiative in northern China to transition communities from coal-fired to natural gas central heating. Local authorities vastly exceeded a government mandate to convert an estimated 10% of households, says Li, straining natural gas supplies and leaving many citizens without heating during the cold winter months.

Li believes the government has to stop trying to be the sole player in China’s environmental governance. “The state has been trying to marginalize non-state actors, but this is an all-hands-on-deck moment: China needs its

students, filmmakers, journalists, scientists, and environmental lawyers." That said, there are successful examples of Chinese authorities seeking non-state inputs. Li points to community engagement efforts, such as a mobile app developed by Jiangsu Province's government called Black and Smelly Water, for reporting water pollution.

The US: out of the wilderness

During the Trump administration, the United States (ranked 40th overall) could have been described as a climate abstainer. But President Biden has pledged to bring the world's largest economy back into the Paris Agreement on his first day in office and says that the "existential" climate crisis demands a coordinated, whole-of-government response.

There are still challenges. US stimulus spending on energy infrastructure post-pandemic is still weighted toward fossil fuels and carbon-intensive industries. According to Vivid Economics, nearly $100 billion in stimulus funds have been given to the aviation, transport, and shipping industries (without conditions for cleaning up).[38] Another complicating factor is the composition of the country's energy industry. The shale oil boom of the last two decades contributed 10% to the country's GDP growth between 2010 and 2015,[39] which makes a transition to clean energy harder for the Biden administration to sell.

On the bright side, the US (particularly California) is a major innovation hub with plenty of technology that can be deployed at home or exported for tackling climate change. Indeed, the US is the world's most attractive market for investment in renewables, according to Ernst & Young.[40] Major investments include a $3 billion Mitsubishi project to develop three green hydrogen power plants in New York, Virginia, and Ohio. Initially operating on 30% hydrogen and 70% natural gas, reports suggest this could reach 100% green hydrogen over time. Projects such as these could represent the start of the US journey toward leadership in a future hydrogen economy. A recent report issued by the National Fuel Cell Research Center claims that the last decade's funding into hydrogen and fuel cell development has laid the foundations for new businesses and industries that could generate $140 billion in revenues for the country's energy, industry, and transportation sectors by 2030.[41]

07 Conclusion

In its first year, the Green Future Index has highlighted the countries that are taking the most direct action for tackling humanity's gravest threat, the global climate emergency. Yet global heating is not a localized issue; the burden is unequal, unfair, and must be contained and managed by all nations, businesses, and citizens working as quickly as they can to conserve energy and resources, reduce emissions, and shut down sources of pollution.

In 2020, 83 countries indicated they would increase their NDCs, which account for one-third of global emissions.[42] That said, fewer than half of those actually formally updated them, and most of those were the 27 member states of the EU. Clearly, more action is needed. Healy at E3G notes that the 2030 NDC targets "are really only two business cycles, or two elections, away."

This decade will be marked by several transitions, toward clean energy, decarbonizing industry, maturing of carbon tax systems, and other shifts in transportation, agriculture, food culture, and social norms. It will also see the development of comprehensive, standardized tools for evaluating carbon storage efforts cost-effectively to motivate farmers, loggers, or other emitters to sequester carbon at scale.

But these transitions have to happen equitably. Countries have to lift up their neighbors, share technology and best practices. The number of cross-border investments in renewable energy projects prove the compelling economic opportunities that stem from such international efforts—even for climate laggards. Witness Egypt's leading participation in such schemes as the $2 billion Benban Solar Park, a 32-station, 1.5 GW project with investment from both Saudi Arabia and the United Arab Emirates.

A green future must also deliver on a stronger human rights agenda, create high-quality jobs and livelihoods, and foster new industries, rather than just shutting down old ones. Additionally, policymakers must foster new jobs and new industries in socially responsible ways. For example, by balancing high-tech new energy and transportation with efforts to increase small-holding green agriculture or replace tree-felling jobs in the Amazon with bioprospecting.

While economists point to the difficulty of maintaining the traditional capitalist system while shifting to a sustainable global model that reduces rather than increases consumption, optimists focus on the competitive advantage that will be gained by those economies that can transition the fastest. Their companies will be the most modern and technologically advanced, best placed to navigate a new and evolving regulatory landscape, and attracting investment and top talent globally. In the future, green will be synonymous with competitiveness.

Appendix: methodology and definitions

The Green Future Index, developed by MIT Technology Review Insights, benchmarks 76 countries and territories on the progress and commitment they are making toward building a low-carbon future, across five pillars that combine to form the index:

- **Carbon emissions**: Total emissions as well as the degree of change in emissions in industry, transportation, and agriculture
- **Energy transition**: The contribution of renewables to the overall energy mix and its recent historical rate of change
- **Green society**: A range of indicators covering net forestation, development of green buildings, recycling, and consumption of meat and dairy
- **Clean innovation**: The relative number of green patents, investment in cross-border clean energy, investment in food technology
- **Climate policy**: Policy commitment toward climate targets, carbon finance programs, sustainable agriculture, and the use of covid stimulus for a green recovery

Carbon emissions

This pillar measures how effectively countries are curbing CO2 emissions overall as well as in key sectors. The indicators within this pillar are:

- Total C02 emissions in 2018, in millions of tons, relative to GDP
- Absolute average change in C02 emissions between 2013 and 2018, both in total, and for each of the industry, transportation, and agriculture sectors

Energy transition

This pillar measures the degree to which each country or territory is promoting renewable energy. The indicators measure:

- The growth of renewable energy production in gigawatt-hours between 2013 and 2018
- The percentage of energy from renewable sources comprised of final energy consumption in 2017

Green society

This pillar measures the efforts made by government, industry, and society to promote green practices. The indicators measure:

- The number of LEED-certified green buildings in 2020, per million urban population
- The percentage of solid waste that is recycled as a percentage of total waste managed in 2016
- The net change in forestation between 2015 and 2020: an indicator that combines the change in acreage of forested land through naturally regenerated primary growth, and changes through planned afforestation projects

Clean innovation

This pillar measures the innovation environment for building a low-carbon future. The indicators measure:

- Growth in green intellectual property, measured by the increase in patents registered for sustainable technologies or processes and solutions between 2013 and 2018, relative to GDP
- The amount of investment a country received and provided for clean energy investments between 2014 and 2018, as a percentage of GDP
- The number of foodtech startups per million of urban population

Climate policy

This pillar measures the ambition and effectiveness of climate policy, including carbon financing initiatives, sustainable agriculture policy, and the degree to which countries are using covid stimulus packages to accelerate a green recovery. The indicators include:

- A qualitative evaluation of policy action to reach stated climate goals in compliance with the Paris Agreement and Nationally Determined Contributions (NDCs)
- A qualitative assessment of measures taken by each country to create financial incentives for firms and investors to assign a cost to carbon emissions, through the levying of carbon taxes and the creation of a markets for carbon bonds and emissions trading systems (ETS)
- A qualitative assessment of sustainable agriculture policies, assessing for comprehensiveness and effectiveness of implementation
- An assessment of the degree to which covid-19 recovery stimulus packages will accelerate decarbonization, resulting in a "pandemic pivot" along two measures:
  - Energy transition impact–scoring countries by the proportion of stimulus spending directed at new energy initiatives versus fossil-fuel projects
  - Green stimulus initiatives–Scoring countries by the percentage of total stimulus spending allocated to sustainable, low-carbon key public infrastructure projects (transport, water, public spaces, information)

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