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2nd Edition

The Green Future Index 2022

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 Morgan Stanley, Citrix, and Iris Ceramica Group. The research was conducted through in-depth secondary research and analysis along with interviews with global experts on climate change, green energy, and technologies that will drive decarbonization. It measures the extent to which 76 countries and territories are moving 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 writer of the report was Ross O'Brien, the editors were Francesca Fanshawe and Jenn Webb. Nicola Crepaldi was the producer and Natasha Conteh was the coordinator.

MIT Technology Review Insights would like to thank the following individuals for their time, perspective, and insights:

Inger Andersen, Executive Director, United Nations Environment Programme, Kenya

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Johanna Nalau, Adaptation Scientist, Griffith University, Australia

Dongjae Oh, Researcher, Solutions for Our Climate, South Korea

Eiji Ohira, Director, Fuel Cell and Hydrogen Technology Office, New Energy and Industrial Technology Development Organization, Japan

Bill Russo, Founder and CEO, Automobility Ltd, China

Thierry Senechal, Director, Finance for Impact, France

Rahul Shendure, CEO, CarbonBuilt, United States

Robert Stoner, Deputy Director for Science and Technology, MIT Energy Initiative, United States

Kevin Trenberth, Distinguished Scholar, National Centre of Atmospheric Research, United States

Hazel Tsui Wai Man, Officer, Hong Kong Environmental Protection Department, Hong Kong

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Executive summary

The Green Future Index 2022 is the second annual comparative ranking of 76 nations and territories on their ability to develop a sustainable, low-carbon future for their economies and societies. In this year's ranking, we have found that many countries may not be maintaining the rate of change first brought about by pandemic-related slowdowns and lockdowns. Moreover, faced with uncertainty as the pandemic drags on, many have reverted to old carbon-intensive habits to recharge their economies. Yet, there has also been an incredible ramp-up in the investment in renewable energy (accounting for more than 70% of all new power generation in 2021) and many of the world's leading nations – including some of its largest polluters – committed to firm dates to achieve carbon neutrality. Our collective efforts to establish a green future are inexorably (if perhaps more moderately than hoped for) gathering momentum.

The key findings of this year's report are as follows:

- **Europe's green leadership maintained for a second year.** In the 2022 rankings, 14 of the top 20 scorers have remained largely in place this year. Sixteen of the Green Leaders are from Europe: Iceland and Denmark still hold the number one and two spots, and third and fourth places are now held by the Netherlands and the UK, which have seen significant jumps due to their much-improved climate policy scores. The UK (ranked 17th last year) has become particularly aggressive in directing investment toward its clean energy transition: nearly 36% of the country's power came from clean sources toward the end of 2021, and Britain intends for that percentage to be 100% by 2035.

- **New leaders are innovators.** New entrants to the top-ranked cohort represent an additional cluster of European economies, as well as South Korea, Japan, and the United States; all three have seen significant rises in their innovation scores thanks to their world-beating green intellectual property contributions (South Korea leads the world in green patents) and notable increases in pivoting infrastructure spending toward clean and green projects.

In this year's index, many countries are not maintaining the rate of change first brought about by pandemic-related slowdowns and lockdowns. Faced with uncertainty as covid-19 drags on, many have reverted to old carbon-intensive habits to recharge their economies. Yet, there has also been an incredible ramp-up in the investment in renewable energy, which accounted for more than 70% of all new power generation in 2021.

- **Many move up to the Greening Middle.** The Greening Middle includes several European countries that have made significant policy and energy infrastructure investment gains, including Greece, which has earmarked 30% of its total EU recovery fund package for clean energy transition efforts. It also includes China (rising from 45th in 2021 to 26th in 2022), which continues to make significant gains in green society transitions (including purchasing more than half of the world's electric vehicles in 2021).

- **Mind the gap.** The steady rise of Green Leaders demonstrates the determination of economies with both committed policy infrastructure and mature green innovation ecosystems. It also, however, highlights a widening gap between leaders with strong scores in all pillars, and those where one or more pillars is weaker. Several previous Green Leaders appear to have lost some momentum, including Singapore, New Zealand, and Costa Rica, which fell from seventh in 2021 to 20th in 2022. Costa Rica's tumble has little to do with its aspirations – it remains Latin America's highest-ranked scorer – but it has had significant climate policy implementation challenges.

- **Sliders and risers.** The Climate Laggards cohort includes India, which has begun to make firmer policy commitments to decarbonization, but its green efforts are overshadowed by an ongoing pandemic recovery plan that continues to favor traditional industries. By contrast, a couple of economies (notably Pakistan and Hong Kong) have seen increased green infrastructure investment and firmer sustainable policy frameworks, raising their scores out of the lowest cohort.

- **Weighed down, way down.** Last-ranked Climate Abstainers have largely remained the same as 2021: economies that either lack political will to pursue green agendas (Russia, for example) or are even more weighed down by their existing resource-based economies to make any real headway, especially as the effects of the pandemic continue into a third year. These include two countries that have seen their green agendas far overshadowed by the detrimental effects of covid-19: Argentina (dropping from 59th to 68th this year) and Indonesia (falling from 57th to 70th).

The research for The Green Future Index 2022 concluded in January 2022, prior to the Russian invasion of Ukraine. That conflict is likely to have far-reaching and ongoing implications for the sustainability efforts of countries all around the world. While MIT Technology Review Insights has attempted to relay the most accurate information possible, we can expect the economic, social, and political climate to continue to shift.

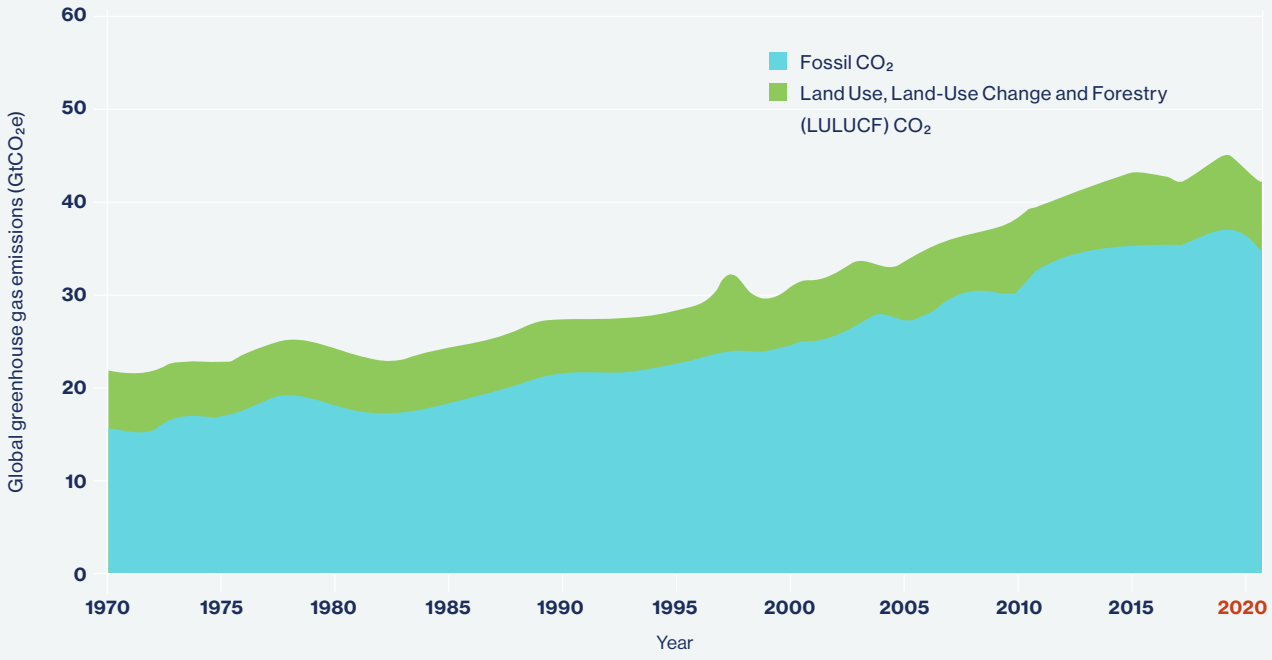
02 Introduction

Hitting the snooze button

The inaugural edition of our Green Future Index, published in January 2021, was developed in part to explore the root causes of a palpable sense of optimism in the global climate community that real progress on decarbonization was being made, not only in spite of the economic and societal devastation caused by covid-19, but in several ways because of it. A world in lockdown consumed less energy, and thus released less greenhouse gases (GHGs) into the atmosphere. The International Energy Agency (IEA) estimated that global energy demand dropped 4% in 2020, while the UN Environmental Program, in its 2021 Emissions Gap report, estimated that carbon dioxide levels dropped a record-breaking 5.4% in 2020[1] (see Figure 1). All this provided valuable lessons on the impact of shifts in human activities on carbon emissions, particularly important in a year beset by a series of floods, fires, and other catastrophic extreme weather events – a "year of wake-up calls," as we noted in the Green Future Index 2021 report.[2]

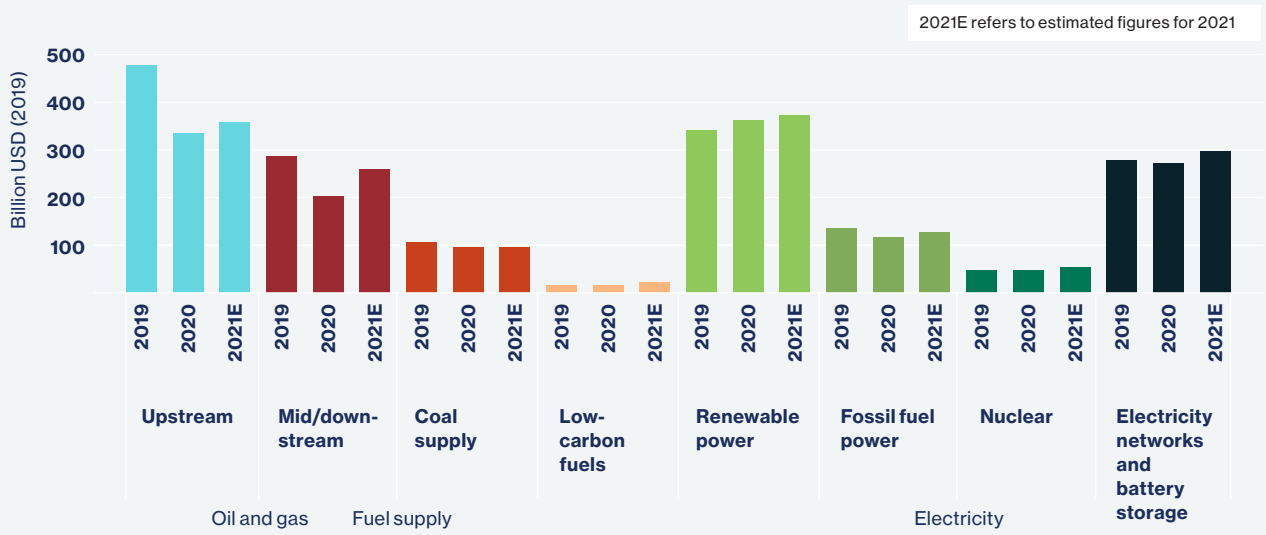
Initially, it seemed that the world was taking these lessons to heart. An incredible ramp-up in the investment in renewable power is underway; the IEA estimates that spending on clean energy power generation was 70% of the $530 billion spent in 2021 on all new electricity generation capacity globally[4] (see Figure 2). However, as

Figure 1: Global CO_2 emissions, 1970-2020



Source: Compiled by MIT Technology Review Insights based on data from the UNEP Emissions Gap Report 2021[3]

Figure 2: Global energy supply investment by sector, 2019-2021



Source: International Energy Agency, World Energy Investment 2021[5]

2021 unfolded, several signals indicated that, instead of heeding the wake-up calls and seizing the opportunities revealed by the pandemic, the world had collectively hit the snooze button. For one, a world desperate to get back on track economically quickly resumed "normal" modes of manufacturing and production. China, still the world's factory, saw its export values surge over 20% in 2021. And while China continues to lead the world in clean energy development and has committed to phase out coal-fired power generation as part of its 2060 carbon neutrality pledge, the manufacturing giant's energy needs continue to grow apace. The IEA saw global energy demand increase by 4.6% in 2021, more than offsetting the 4% drop in 2020.

Moreover, outside of the climate impact indicators directly affected by covid-induced swings in transport or factory output, most other measures of world economic activity over the last two years reveal that very little, if any, climate-friendly changes happened at all. These include evidence that the world's enduring (and carbon-intensive) love affair with meat consumption continued apace. The Brazilian Institute of Geography and Statistics reported that the cattle population within the Amazon basin grew 4.2% in 2020, and over 8% in the state of Acre, the Amazon's most densely forested state, which lost nearly 85,000 hectares of forest land to livestock grazing in 2020.[6]

Finally, signals from the global scientific community and the actions of global policy bodies in 2021 served to lessen collective confidence in our decarbonization progress, perhaps the most significant indication that the unique blend of urgency and optimism created by 2020's pandemic pivot is fizzling out. The loudest and most alarming of these signals came in August, when the United Nations Intergovernmental Panel on Climate Change (IPCC) released the Working Group I contribution to its sixth climate change report,[7] in which 234 authors across 66 countries unequivocally agreed that the 1.1 °C rise in the Earth's temperature since the Industrial Revolution is due to human activity, and warned that only tremendous changes in those activities can limit its continued rise to between 1.5 °C and 2 °C before the end of this century. Once past that threshold, the report argues, humanity is exposed to a greater risk of passing through "tipping points," thresholds beyond which certain impacts can no longer be avoided, even if temperatures are brought back down later on.[8]

Less than three months later, the United Nations Framework Convention on Climate Change 26th annual Conference of the Parties (COP) in Glasgow managed to keep the goals of the 2015 Paris Agreement meeting alive, and passed several important new agreements on areas such as sustainable agriculture and forestry. Forty countries signed an agreement to phase out coal from

Figure 3: Overall top 10 and bottom 10: The Green Future Index comparative rankings for 2021 and 2022

Overall top 10

RANK 2022		2021	COUNTRY	SCORE
1	—	1	Iceland	6.92
2	—	2	Denmark	6.55
3	↑	10	Netherlands	6.42
4	↑	17	United Kingdom	6.29
5	↓	3	Norway	6.21
6	—	6	Finland	6.21
7	↓	4	France	6.12
8	↑	11	Germany	6.12
9	↑	12	Sweden	6.07
10	↑	31	South Korea	6.03

Overall bottom 10

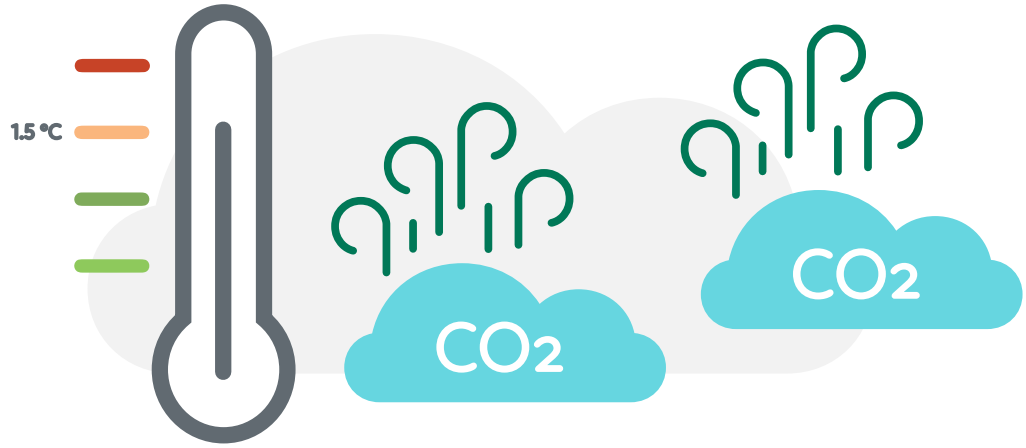
RANK 2022		2021	COUNTRY	SCORE
67	↓	66	Peru	3.86
68	↓	59	Argentina	3.78
69	↓	68	Turkey	3.71
70	↓	57	Indonesia	3.68
71	—	71	Ghana	3.63
72	↓	70	Guatemala	3.49
73	↑	76	Qatar	3.35
74	↑	75	Paraguay	3.34
75	↓	72	Algeria	3.16
76	↓	74	Iran	2.67

Source: MIT Technology Review Insights, 2022

their power grids by the 2030s (though neither the United States nor China were among the signatories). Some new national commitments were also made – most importantly India's pledge to join the growing club of countries with net-zero carbon emissions targets. India is committed to reaching net-zero carbon emissions by 2070, and to reduce its carbon dioxide emissions by a billion tons and generate half of its electricity through renewable sources by 2030.[9]

Many climate professionals feel that the depth of these commitments, and the speed with which they are to be honored, is largely insufficient. "Awareness is broader, but action is lacking," says Inger Andersen, executive director of the United Nations Environment Programme (UNEP), headquartered in Nairobi. "If we want to stay at 1.5 °C, we have to remove between 400 and 500 tons of GHG, or roughly 55 tons a year through 2030. We absolutely need to speed up, and organizations in all our primary emitting sectors – energy, transport, buildings, and agriculture – really need to rev up their ambitions." The UNEP's Emissions Gap report noted that by the end of September 2021, 120 countries, accounting for just over half of global GHG emissions, updated their National Determined Contribution (NDC) commitments for reducing greenhouse gases – but only half of those NDCs resulted in lowered emissions by 2030, and the report concluded that their aggregate impact is insufficient.[10] Even COP26 President Alok Sharma, in his first speech since the conclusion of the Glasgow proceedings, expressed concern that agreements represented a "fragile win," which would be lost if pledges were not turned to concrete action this year.[11]

Despite the quick reversal of carbon fortune, and the relatively lackluster impact that COP26 seems to have had, there is still real room for optimism, says Robert Stoner, deputy director for science and technology at the MIT Energy Initiative. "While emissions fell remarkably little during the covid-19 shutdown, this only reflects our current technology adoption levels. It has nothing to do with our carbon future – what's being implemented now won't have an impact until later. I'm not going to argue that the rate of low-carbon technology adoption is impressive



"Awareness is broader, but action is lacking. If we want to stay at 1.5 °C, we have to remove between 400 and 500 tons of greenhouse gases, or roughly 55 tons a year through 2030. We absolutely need to speed up, and organizations in all our primary emitting sectors – energy, transport, buildings, and agriculture – really need to rev up their ambitions."

Inger Andersen
Executive Director, United Nations Environment Programme

or satisfactory, but we live in a world full of engineers who are actually doing stuff and not waiting for policymakers to give us a green light. At COP26, I felt that the innovators and private sector stepped up." Stoner refers to advances in the development of nuclear fusion as an example. "If we make fusion work, and [make it] commercially viable within the next couple of decades, this will provide the energy that humanity needs to get to the stars and continue to thrive. I think what's happening with fusion here [at MIT] and around the world is remarkable. Every time I try to cite the number of fusion startups, I underestimate by another few. I think we're going to have demonstrated fusion within four or five years, and we will have working fusion power reactors within the decade. That's very exciting and potentially transformative."

There are many other important societal shifts taking place. Stoner also sees immense progress in many aspects of consumer adoption of low-carbon solutions, such as electric vehicles (EVs). "EV sales are now 9% of global car sales, and that will only increase. We're going to see a faster-than-anticipated electrification of the automotive sector." Additionally, environmental, social, and governance (ESG) requirements are quickly becoming baked into the firmament of global capital markets. The value of ESG-labeled bonds grew to over $1 trillion in 2021,[12] and are estimated to more than quadruple in value to $4.5 trillion by 2025, according to a report released by Pictet Asset Management and the Institute of International Finance in January 2022.[13]

In the 2022 Green Future Index, we explore how much progress countries and territories have made toward their sustainability goals by leveraging this wealth of innovation, investment, and policy action. The nations of the world may not be maintaining the rate of change first imagined at the beginning of the pandemic and have shown a worrisome willingness to revert to old carbon-intensive habits when faced with the risk of economic uncertainty. But there is no doubt that our efforts are gathering momentum.

Methodology: The Green Future Index in 2022

The Green Future Index 2022 is the second annual comparative ranking of 76 nations and territories (representing about 95% of global GDP) on their ability to develop a sustainable, low-carbon future for their economies and societies. As it was in its inaugural year, the index was developed through in-depth primary and secondary research processes. Secondary research included the review of several hundred articles, research reports and papers in scientific literature, and news and legal analysis journals. Primary research was conducted through more than 20 in-depth interviews with global experts on climate change, green energy, and decarbonization technologies.

This research process informed our evaluation and selection of 22 distinct sets of country-level data to comprise the indicators of the index. The data came from a wide range of publicly available sources, including the International Energy Agency (IEA), the International Renewable Energy Agency, the World Bank, the United Nations Food and Agriculture Association (FAO), the World Intellectual Property Organization, and the Climate Action Tracker (CAT).

Where it was necessary to fill in gaps, we expanded and refined existing datasets by conducting additional detailed research on selected countries and consulted with global experts. This was done in the climate policy and carbon finance initiatives indicators, and in new indicators added to this year's index, specifically in defining carbon capture and sequestration "readiness" and in developing estimates for the penetration of electric vehicles (see the section "What is different in the 2022 Green Future Index?").

The indicator datasets were turned into ranked scores in one of two ways. For quantitative metrics, such as growth rates or values, each data point for each country was scaled up or down using minimum-maximum normalization to develop a range of scores across all countries for that indicator. For data that was largely qualitative or non-standard, a ranking categorization system was developed, and each country was assigned a score. Once all 22 indicators were scored, they were organized into five separate pillars. The structure of this second edition of the Green Future Index remains largely the same as the 2021 edition, with a few indicators added to augment its coverage of sustainable activities (see the section "What is different in the 2022 Green Future Index?").

Pillar 1: Carbon emissions - This pillar measures how effectively countries are curbing carbon dioxide emissions overall, as well as in key sectors. The indicators within this pillar are:

- Total carbon dioxide emissions in 2019, in millions of tons, relative to GDP
- Average annual change in carbon dioxide emissions between 2014 and 2019, both in total, and for each of the industry, transportation, and agriculture sectors

Pillar 2: Energy transition - This pillar assesses the contribution and growth rate of renewable energy sources, and now includes nuclear power. The indicators within this pillar are:

- The growth of renewable energy production in giga-watt-hours between 2014 and 2019
- The percentage that energy from renewable sources

made up in final energy consumption in 2018

- The growth of nuclear energy production in giga-watt-hours between 2014 and 2019
- The percentage that energy from nuclear generation made up in final energy consumption in 2018

Pillar 3: 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
- 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
- The stock electric passenger vehicles per million urban population in 2020

Pillar 4: Clean innovation - This pillar measures the innovation environment for building a low-carbon future, such as the relative penetration of green patents, investment in cross-border clean energy, and investment in food technology. 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 efforts between 2014 and 2018, as a percentage of GDP
- The number of food technology ("foodtech") startups per million of urban population

Pillar 5: Climate policy - This pillar measures the ambition and effectiveness of climate policy, including carbon financing initiatives, sustainable agriculture policy, and the use of pandemic recovery spending to achieve a green economic recovery. The indicators include:

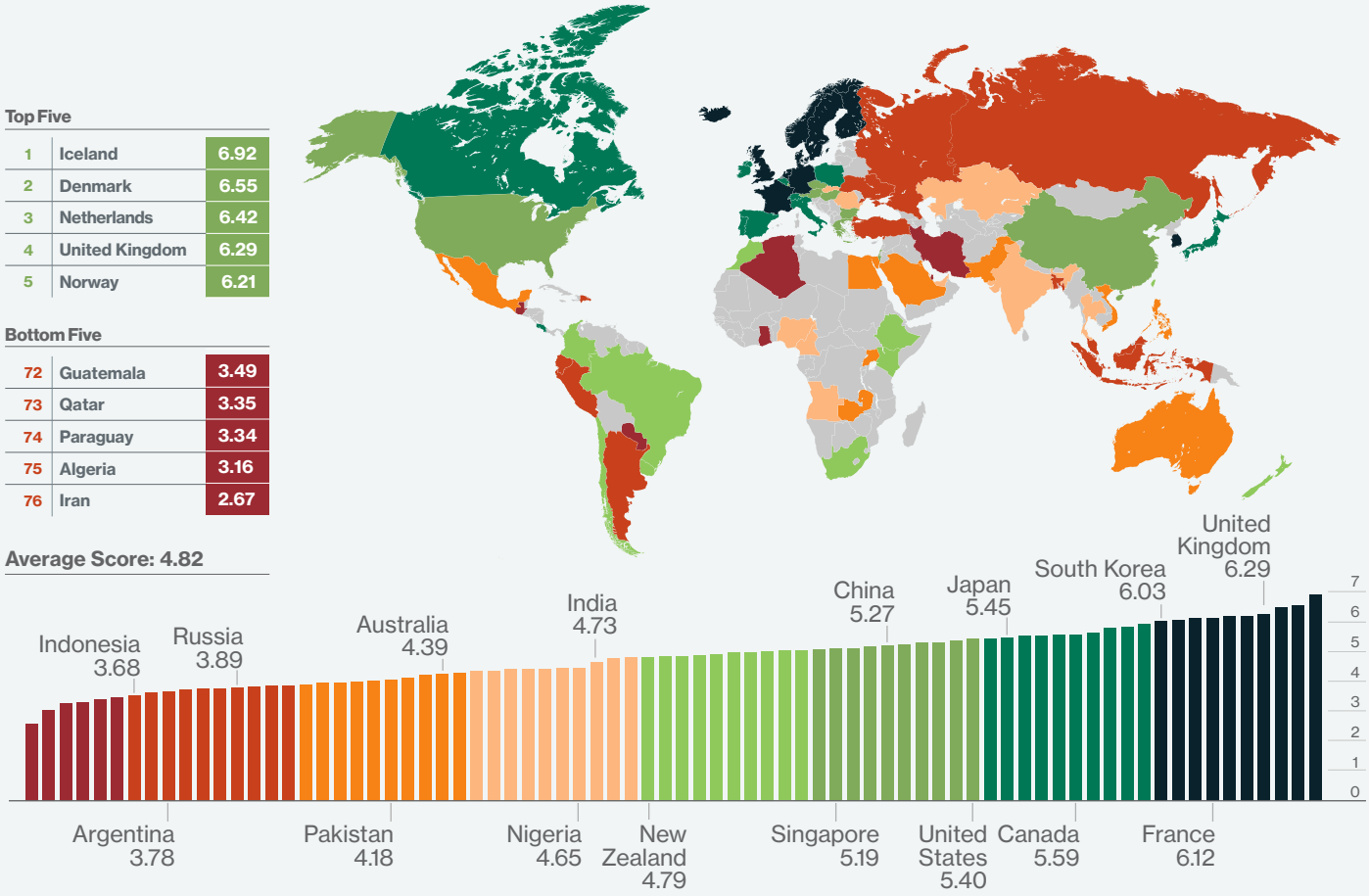
- A qualitative evaluation of policy action to reach stated climate goals in compliance with the Paris Agreement and Nationally Determined Contributions (NDCs)
- A qualitative evaluation of policy and regulatory frameworks to promote carbon capture and sequestration efforts (CCS)
- A qualitative assessment 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 market for carbon bonds and emissions trading systems
- 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:

1. Energy transition impact – Scoring countries by the proportion of stimulus spending directed at new energy initiatives versus fossil fuel projects

2. Green stimulus initiatives – Scoring countries by the percentage of total stimulus spending allocated to sustainable, low-carbon key public infrastructure projects (such as transport, water, public spaces, and information)

These pillars are constructed to comprehensively evaluate each country's green future across two dimensions: the progress they have made on achieving carbon reduction goals and other climate-friendly societal activities, and the ambitions that the country must achieve to maintain a carbon-neutral economy. The first four "progress pillars" account for 60% of the weighting in the index. The fifth pillar – climate policy – measures the extent to which investment and policy activities are channeled into green infrastructure initiatives and legislation frameworks. These factors, we believe, collectively provide the primary impetus toward establishing and sustaining a country's green future, and thus this pillar accounts for 40% of the Index weighting.

Figure 4: The Green Future Index 2022 rankings world map



Source: MIT Technology Review Insights, 2022

What is different in the 2022 Green Future Index?

In our review of scientific climate change research and policy developments since the 2021 edition of the Green Future Index,[14] we determined that we needed to expand the indicators assessing a country's progress on green future goals. These include:

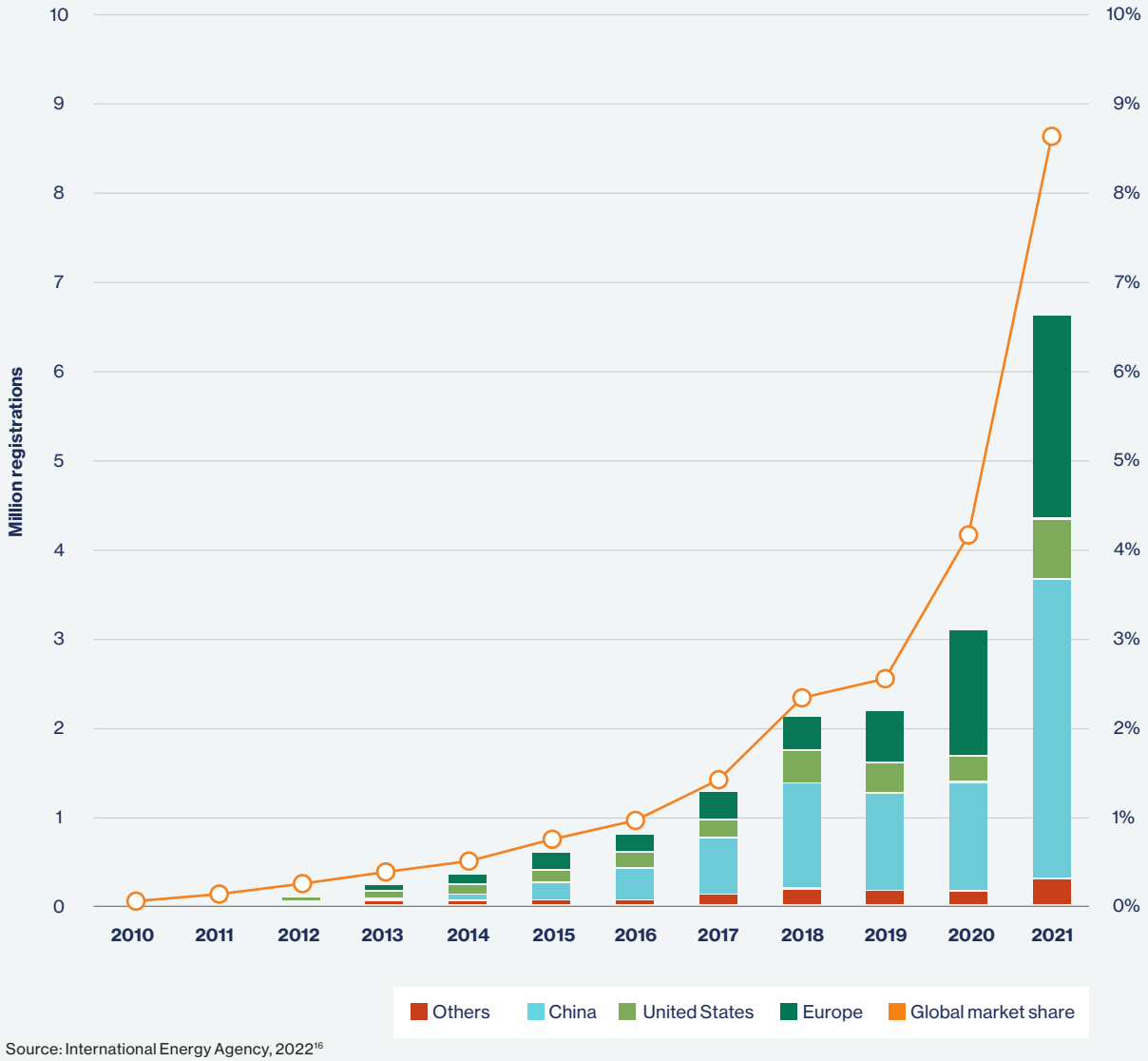
- **Pillar 2: Energy transition now includes nuclear energy – its growth in production and the amount it contributes to a country's overall energy requirements.**
  Most established measures of energy transition only include contributions from renewable sources. But nuclear power is still a factor in many countries' low-carbon energy production efforts, and therefore provides a fuller picture of each country's green future.

- **Pillar 3: Green society now includes the penetration of electric vehicles (EVs) as a percentage of urban population.**
  Electrification of transportation is increasingly regarded as a key element in shifting societal and economic norms toward long-term sustainable outcomes. The International Energy Agency reported that over 6.6 million EVs were sold in 2021, close to 9% of total new vehicles – more than triple the volume in 2019 (see Figure 5).[15] Moreover, increased EV adoption not only offers immediate transport sector decarbonization benefits, but it can also signal broader consumer willingness to adopt new modes of mobility less linked to personal vehicle ownership.

- **Pillar 4: Clean innovation – updated methodology for evaluating "green" patents .**
  To more accurately reflect the level of climate-friendly innovation in each country's economy, we have revised the indicator 4.1 to reflect the accumulation of total environmental and climate patents registered between 2016 and 2020 as a percentage of GDP.

- **Pillar 5: Climate policy now includes carbon capture and sequestration (CCS) "readiness."**
  As the world continues its pursuit of lower GHG levels, the emerging consensus within the scientific community is that emission reductions can only be part of the sustainability equation. "The reality is we do actually need to capture or sequester carbon rather than just offset it," observes Michael Manion, CEO of Seattle-based innovation consultancy Keon Research. The 2022 edition of the Green Future Index incorporates scoring and measurements primarily from the Global CCS Institute to evaluate each country's policy and regulatory environment as it relates to CCS, and the definitive plans in place to develop relevant infrastructure.

Figure 5: Global sales and sales market share of electric cars, 2010-2021



Source: International Energy Agency, 2022[16]

Morgan Stanley

Supporting pioneering sustainable solutions

Climate change remains one of the great challenges of our time, and as the past two years have revealed, the intersection between the global health crisis, the climate crisis, and systemic social injustice has only made solving these challenges more complex.

That is why, in the race to net zero carbon emissions, it is imperative that we work together to support pioneering solutions that facilitate cross-sector approaches and drive systems-level changes at scale.

In 2020, Morgan Stanley launched the Sustainable Solutions Collaborative[1] to boost early-stage sustainability initiatives that will benefit from partnerships across private and public industries, and in October 2021 the first cohort of five winning teams was announced[2]. They are a group of innovators focused on tackling distinct global problems by bringing forth new ways of thinking about health care, climate solutions, plastic waste reduction, and ecosystem services through re-engineered distribution methods, technology platforms, and a new perspective on the importance of nature.

One first-year collaborative member is SunCulture, a Kenya-based company working hand-in-hand with local and national governments on innovations in solar technology, sustainable agriculture practices, and to provide access to inclusive finance that will help farmers in sub-Saharan Africa address their biggest challenges. These include finding affordable, accessible, clean energy to electrify their homes and power irrigation to their farmland. By solving these problems in tandem, SunCulture is helping farmers boost their crop yields and increase their incomes at a time when the global food crisis has been exacerbated by the pandemic and climate change.[3]

Another member is the nonprofit The Soil Inventory Project (formerly MySOC), a project out of Skidmore College and Michigan State University focused on soils, where scientists say more carbon resides than in the atmosphere and all plant life combined. Yet forested lands remain the source of far more carbon credit sales than do agricultural fields. The Soil Inventory Project is using data to answer foundational questions about soil carbon to create a new market, in partnership with farmers. A database of soil carbon levels will help to inform farmers in making decisions on sustainable agricultural practices. This will open the possibility of selling carbon credits by measuring soil carbon through app-led field methods, remote sensing technology, and biophysical modeling. The samples they collect will also help to establish the first national soil carbon inventory.[4]

Rounding out the group are mPharma, a health tech startup that aims to make health care accessible and more affordable in Africa by revolutionizing the drug supply chain; Siklus, which is tackling the nexus of poverty and plastic waste in Indonesia; and Trees As Infrastructure, an open-source platform that is operating across Europe to establish nature as a critical part of the urban infrastructure.[5]

The members come from across industry, nonprofits, and academia, and each of them, with the proper support and guidance, has the potential to scale and contribute to creating the type of systemic change needed to achieve a more sustainable future.

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

Disclosures

1. "Morgan Stanley Launches Sustainable Solutions Accelerator to Address Global Sustainability Challenges," (press release) Morgan Stanley, Aug. 12, 2020
2. "Inaugural Morgan Stanley Sustainable Solutions Collaborative Cohort," Morgan Stanley, June 9, 2021
3. Audrey Choi, "When It Comes to Saving the Planet, Innovation Has To Be a Team Effort," Fast Company, July 10, 2021
4. "Inaugural Morgan Stanley Sustainable Solutions Collaborative Cohort," Morgan Stanley, June 9, 2021
5. "Inaugural Morgan Stanley Sustainable Solutions Collaborative Cohort," Morgan Stanley, June 9, 2021

03 Mind the gap: Changes in this year's rankings

There have been several shifts in the rankings this year, although 14 of the top 20 scorers—a cohort we refer to as the "Green Leaders"—have remained largely in place. Iceland and Denmark still hold the number one and two spots, with moderately improved scores (6.92 and 6.55, respectively). The third and fourth place are now occupied by the Netherlands and the United Kingdom, both of which have seen significant jumps due to their improved climate policy scores. The UK (ranked 17th last year) has become particularly aggressive in directing investment toward its clean energy transition: nearly 36% of the country's power came from clean sources in the third quarter of 2021,[17] and in October 2021 Prime Minister Boris Johnson indicated that that figure will be 100% by 2035, when Britain also plans to reduce its net emissions levels by an ambitious 78%.[18] Increases in policy and investment over the last year have also allowed Finland to remain even year-on-year in sixth place. In January 2022, Finland took on €217 million in pre-financing allocated under the European Commission's Recovery and Resilience Facility, which will partially go to efforts to decarbonize the energy sector, such as building hydrogen and CCS infrastructure,[19] as it works to meet 2035 carbon neutrality goals.

With the exception of Ireland, all of the previous year's Green Leaders saw their scores increase, on average over a third of a point. The new entrants to the top cohort

The UK has become particularly aggressive in directing investment toward its clean energy transition: nearly 36% of the country's power came from clean sources in the third quarter of 2021 with the ambition to make it 100% by 2035, when Britain also plans to reduce its net emissions levels by an ambitious 78%.

Figure 6: The Green Future Index country rankings, 2021-2022

		RANK 2022		RANK 2021			RANK 2022		RANK 2021			RANK 2022		RANK 2021		
Green leaders	The 20 countries making the greatest progress and commitment toward building a low carbon future.	1	—	1	Iceland	6.92	8	↑	11	Germany	6.12	15	↓	14	Canada	5.59
		2	—	2	Denmark	6.55	9	↑	12	Sweden	6.07	16	↑	34	Poland	5.59
		3	↑	10	Netherlands	6.42	10	↑	31	South Korea	6.03	17	↑	22	Italy	5.53
		4	↑	17	United Kingdom	6.29	11	↓	9	Belgium	5.95	18	↑	30	Portugal	5.51
		5	↓	3	Norway	6.21	12	↓	5	Ireland	5.85	19	↑	60	Japan	5.45
		6	—	6	Finland	6.21	13	↑	18	Spain	5.83	20	↓	7	Costa Rica	5.42
		7	↓	4	France	6.12	14	↑	19	Switzerland	5.63					
The greening middle	The 20 countries that are making progress or commitment toward building a green future.	21	↑	40	United States	5.40	28	↓	13	Luxembourg	5.19	35	↓	27	Ethiopia	4.96
		22	↑	37	Greece	5.33	29	↓	16	Singapore	5.19	36	↓	26	Morocco	4.83
		23	↓	15	Austria	5.31	30	↑	38	Israel	5.00	37	↑	46	Taiwan	4.81
		24	↑	39	Hungary	5.31	31	↑	47	South Africa	4.98	38	↓	20	Uruguay	4.80
		25	↑	44	Bulgaria	5.28	32	↓	25	Colombia	4.98	39	↓	8	New Zealand	4.79
		26	↑	45	China	5.27	33	↓	24	Chile	4.97	40	↓	23	Kenya	4.76
		27	↑	28	Czech Republic	5.21	34	↓	32	Brazil	4.96					
Climate laggards	The 20 countries that are making slow and uneven progress or commitment toward building a green future.	41	↑	42	United Arab Emirates	4.76	48	↓	29	Thailand	4.50	55	↑	67	Pakistan	4.18
		42	↓	21	India	4.73	49	↓	33	Kazakhstan	4.48	56	↓	49	Vietnam	4.17
		43	↑	53	Nigeria	4.65	50	↑	52	Angola	4.47	57	↓	54	Uganda	4.15
		44	↓	41	Cameroon	4.55	51	↑	61	Saudi Arabia	4.42	58	↑	65	Kuwait	4.09
		45	↑	64	Hong Kong, China	4.54	52	↓	35	Australia	4.39	59	↓	58	Egypt	4.03
		46	↑	50	Slovakia	4.52	53	↓	43	Philippines	4.37	60	↓	51	Zambia	3.99
		47	↑	48	Romania	4.52	54	↓	36	Mexico	4.23					
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	↑	63	Ukraine	3.95	68	↓	59	Argentina	3.78	75	↓	72	Algeria	3.16
		62	↑	69	Bangladesh	3.94	69	↓	68	Turkey	3.71	76	↓	74	Iran	2.67
		63	↓	62	Ecuador	3.91	70	↓	57	Indonesia	3.68					
		64	↑	73	Russia	3.89	71	—	71	Ghana	3.63					
		65	↓	56	Malaysia	3.87	72	↓	70	Guatemala	3.49					
		66	↓	55	Dominican Republic	3.87	73	↑	76	Qatar	3.35					
		67	↓	66	Peru	3.86	74	↑	75	Paraguay	3.34					

Source: MIT Technology Review Insights, 2022

represent an additional cluster of European economies (Italy, Portugal, and Poland), as well as South Korea, Japan, and the United States. All three of these economies have seen significant rises in their innovation scores thanks to their world-beating green intellectual property contributions (South Korea leads the world in green patents) and notable increases in pivoting infrastructure spending toward clean and green projects.

The steady rise of the Green Leaders demonstrates the determination of economies to establish committed policy infrastructures and mature green innovation ecosystems.

Several European countries have made significant policy and energy infrastructure investment gains including Greece, which has earmarked more than 30% of its €18 billion EU recovery fund package for clean energy transition efforts.

It also, however, highlights a potentially worrisome trend in this year's scores: a widening gap between the leaders and those without a decent showing across all pillars, where their scores remain flat or begin to decrease. In the second cohort of scores, which we have labeled the "Greening Middle," there are several European countries that have made significant policy and energy infrastructure investment gains. This includes Greece, which has earmarked more than 30% of its total EU recovery fund package (€18 billion) specifically for clean energy transition efforts.[20] The Greening Middle also includes China (rising from a ranking of 45 in the 2021 Green Future Index to 26 this year), which continues to make significant gains in green society transitions (including purchasing more than half of the world's EVs last year), innovations, and policy formation.

In 2022, however, the Greening Middle also saw the entry of several countries that had previously been Green Future Index leaders but appear to have lost some momentum in the last year. This includes countries such as Singapore, New Zealand, and Costa Rica, which has fallen from a ranking of 7 last year to 20 in 2022. Costa Rica's tumble has little to do with its aspirations – it remains Latin America's highest-ranked economy and is widely regarded as having solid policy outlooks with regard to green economic recovery and decarbonization. However, Costa Rica is having implementation challenges. According to research group Climate Action Tracker, which monitors government action to reduce GHG emissions: "While Costa Rica's target meets its fair-share contribution to limiting warming to 1.5 °C, it needs additional support to implement additional policies and to strengthen its reduction target in order to get national emissions on a pathway compatible with 1.5 °C."[21]

The countries in the third tier of the rankings we have named the "Climate Laggards." As with the 2021 edition, many of the Climate Laggards have economies anchored to fossil fuel or resource extraction industries. These include countries that have been actively investing in technologies and industrial transition programs to move away from hydrocarbon businesses (such as the United Arab Emirates or Saudi Arabia) as well as others that remain committed to extractive industries as part of their economic development (Mexico and Australia).

The Climate Laggards also include some notable slides. India has begun to make firmer policy commitments to decarbonization and remains one of the world's most active investors in renewable power generation (solar, most of all), including plans for India's state coal companies to install 5.56 gigawatts of renewable power generation capacity by 2030.[22] But such green efforts are overshadowed by an ongoing pandemic recovery plan which continues to favor traditional industries. In its 2022 budget, India's Ministry of Coal will receive more funding ($2.5 billion) than its Ministry of New and Renewable Energy and its Ministry of Environment, Forests, and Climate Change combined.[23] By contrast, a couple of economies (notably Pakistan and Hong Kong) have seen increased green infrastructure investment and firmer sustainable policy frameworks, raising their scores out of the lowest cohort – the "Climate Abstainers."

The last grouping in the Green Future Index, the Climate Abstainers, has largely remained the same as 2021. They are a collection of economies that either lack political will to pursue green agendas (Russia, for example) or are even more weighed down by their existing resource-based economies to make any real headway, especially as the effects of the pandemic continue into a third year. These include two countries that have seen their green agendas far overshadowed by the detrimental effects of covid-19, lowering their scores: Argentina has dropped from 59th position in the 2021 Green Future Index to 68th this year, and Indonesia has fallen from 57th to 70th.

04 Developing a sustainable future: Carbon emissions and energy transition

The first two pillars of the index – carbon emissions and energy transition – represent the activities that form the cornerstones of each country's efforts to develop a sustainable future. They measure the extent to which a country is successfully reducing carbon dioxide emissions from its economic activities and how much it has converted its power infrastructure to generate electricity from clean sources. On both measures, there is clear evidence that the world is building on its sustainable foundations, although less than the year before and more slowly than the climate action community has hoped.

In the carbon emissions pillar, there were slight but appreciable gains in the scores, reflecting overall global efforts to cut emissions levels: the median score in the pillar has edged up slightly from 5.63 in the 2021 edition of the Green Future Index to 5.67 in 2022. As mentioned, the beginning of the pandemic saw radical shifts in mobility and overall economic activity globally, resulting in swift but temporary falls in emissions. The UNEP estimates that in the United States and Europe, countries' 2020 carbon dioxide emission levels have dropped 10% compared to pre-pandemic levels in 2019, but 2021 decreases were half that (see Figure 7).[24] Emerging economies, including China, Brazil, and Russia, actually saw their emission levels increase last year.

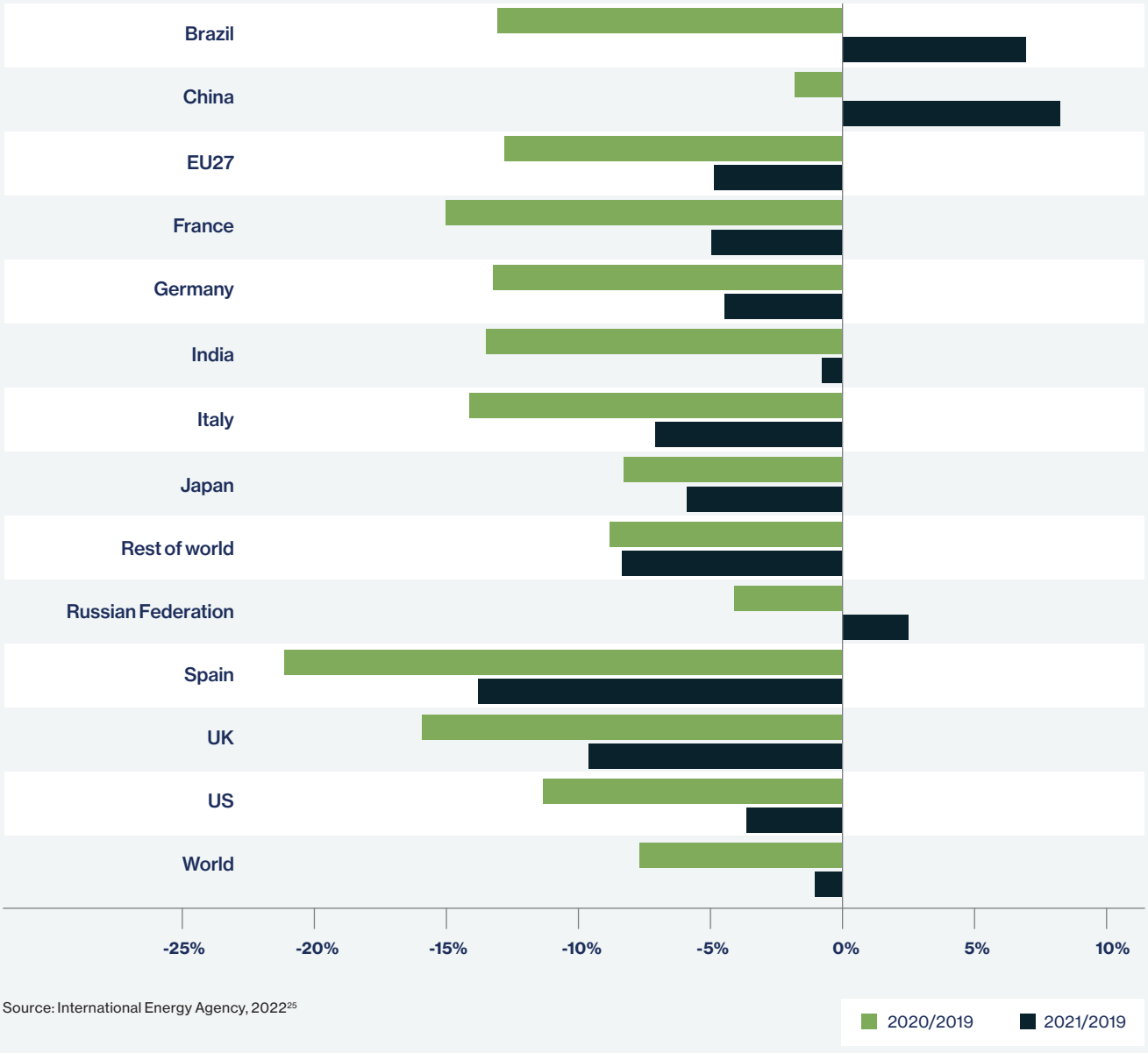
In terms of global energy transition, there has been a tremendous amount of progress in decarbonizing power grids in recent years, as growing production scale and technological maturity have made renewable energy generation much more affordable and reliable. In the decade prior to 2020, nearly 3,700 terawatt hours of electricity were generated from new renewable energy facilities, outstripping the amount of new hydrocarbon-fueled power by nearly 29% (see Figure 8). However, continued increases in clean power generation are not guaranteed, as they are susceptible to disruptions in the commissioning of new facilities, such as pandemic-related slowdowns and weather changes lessening the supply of wind and sunlight. The latter caused renewable power generation in the UK to drop 17% in the third quarter of 2021 to a four-year low.[26]

Seven of the top 10 leaders in this year's carbon emissions pillar – who were also leaders in the 2021 rankings (see Figure 9) – are European nations that continue to implement strong energy and industry transition programs and hold fast to their low-carbon economic development goals. That said, strong commitment to decarbonization does not guarantee steady progress. This pillar ranks relative increase in emissions over a rolling five-year period as well as overall emission decreases. In several cases, the scores of mature leaders have gone down as the rate of their emissions reduction has slowed. New entrants to the leaders in this pillar include several countries that have redoubled emissions reduction efforts, including the United Arab Emirates, where for several years the Supreme Council of Energy has been coordinating cross-sectoral efforts to lower emissions in its water, waste management, and power sectors, and in 2022 has reset a goal of a further 30% carbon dioxide reduction by 2030.[31]

Most of the lowest scoring performers in the carbon emissions pillar (in both 2021 and 2022) were emerging economies, many in Africa that are struggling with the implications of their carbon-intensive economies.

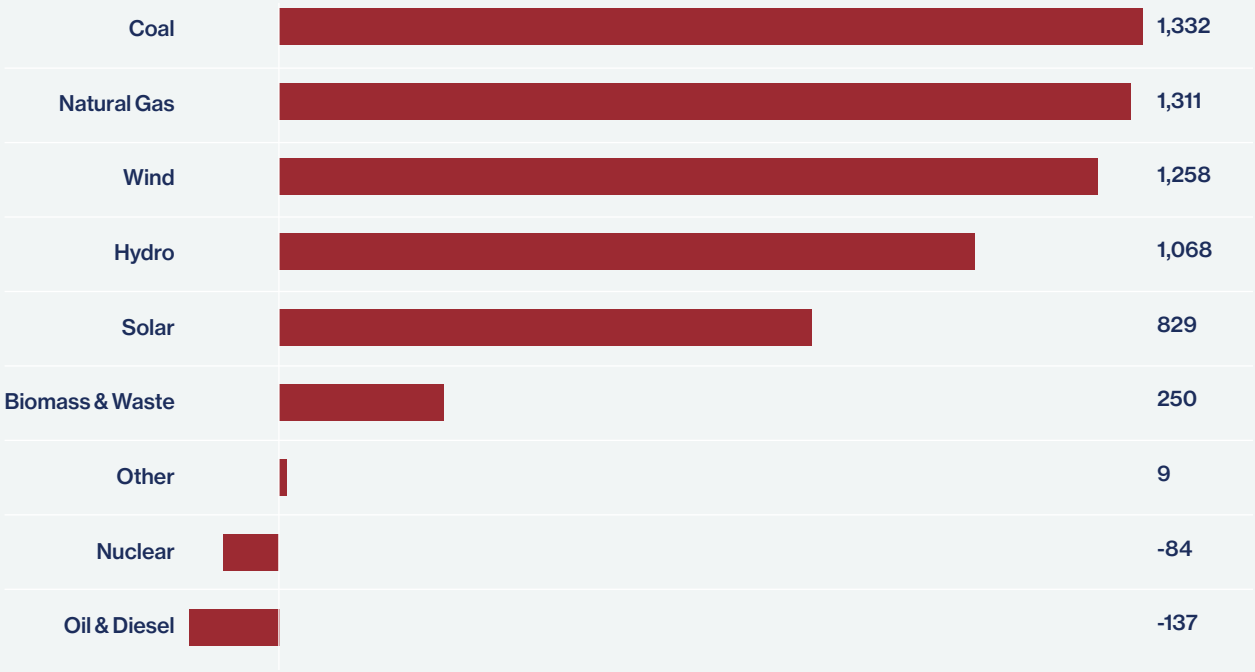
Interestingly, these same emissions laggards are energy transmission leaders. Four African nations (Nigeria, Ethiopia, Kenya, and Zambia) have some of the highest scores in the energy transition pillar, and at the same time, among the lowest scores in the carbon emissions pillar. Electricity and heat generation accounts for an estimated quarter of global carbon emissions, so efforts to transition power grids to clean energy feedstocks is an important precedent to decarbonization. Nigeria is ranked last (76th) in the carbon emissions pillar, but it ranks fourth in the energy transition pillar, thanks in large part to a vast hydroelectric power network that constitutes the majority of its energy generation. In December 2021, Nigeria's Ministry of the Environment launched a "Deep Decarbonization" initiative in collaboration with the support of the French Development Agency, which includes investments to broaden its renewable power resources.[32]

Figure 7: Change in CO_2 emissions in 2020 and 2021 relative to 2019 levels



Source: International Energy Agency, 2022[25]

Figure 8: Growth in global power generation 2011-2020, terawatt-hours



Source: BloombergNEF, 2021[27]

Collaboration is key to decarbonization

Many climate observers feel that transnational collaborations are increasingly vital in the global effort to combat emissions. Unfortunately, many also find these efforts lacking. "At the Glasgow summit, there were many important state-level initiatives around stopping deforestation and other nature-based solutions, but they all failed to establish any means of North-South collaboration," observes Naoko Ishii, the director for the Center for Global Commons at the University of Tokyo, an initiative that works to create frameworks to govern global commons such as biodiversity and climate systems. Ishii says it is critical for the world's decarbonization leaders, which are largely advanced economies, "to recognize that the green lives they lead are realized by importing goods and foods unsustainably produced in the Global South. If we are all serious about reaching net zero by 2050, we need to find a way to address the disproportionate burden borne by the South and to create mechanisms to recognize their contributions through nature-based solutions."

There are many avenues to facilitate more international cooperation on energy transition and decarbonization, such as expanding the use of sustainable development goal (SDG) bonds to finance projects. Morocco aims to generate 52% of its electricity from green sources by 2025, and 80% by 2050,[33] aided by an EU loan worth €1.6 billion to accelerate energy transition efforts over the next five years.[34] Indonesia has become a Southeast Asia regional pioneer in the use of SDG bonds, including a $584 UN sovereign SDG bond[35] and a $150 million loan to fund the Sustainable Development Goals Indonesia One–Green Finance Facility from the Asian Development Bank.[36] But Ishii says that in order to deepen transnational collaboration, there must be broader, more integrated efforts, similar to the way Europe's attempts to introduce carbon border adjustment mechanisms could create a global market for carbon. She suggests that creating globally recognized biodiverse regions is another such tool.

William Collins, director of the climate and ecosystem sciences division for the Earth and environmental sciences area at the Lawrence Berkeley National Laboratory in California, agrees that more international recognition – and formalization – of biodiversity's contributions need to happen to speed up the pace of

Nigeria is ranked fourth in the energy transition pillar, thanks in large part to a vast hydroelectric power network that constitutes the majority of its energy generation.

Figure 9: Highest and lowest performers in the carbon emissions and energy transition pillars: The Green Future Index 2021 and 2022

PILLAR 1: Carbon emissions

A high score means a low emissions growth rate.

RANK 2022		2021	COUNTRY	SCORE
1	↑	14	Iceland	8.06
2	↑	10	Finland	7.32
3	↑	51	United Arab Emirates	7.07
4	↓	2	Norway	6.81
5	↓	3	Sweden	6.78
6	↑	32	Argentina	6.77
7	↓	1	Ukraine	6.73
8	↓	7	Greece	6.61
9	↑	66	Guatemala	6.61
10	↓	5	Switzerland	6.52

RANK 2022		2021	COUNTRY	SCORE
67	↓	54	Russia	4.60
68	↓	50	Egypt	4.58
69	↓	47	Dominican Republic	4.54
70	↑	71	Bangladesh	4.48
71	↓	57	Zambia	4.44
72	↑	76	Pakistan	4.32
73	↓	70	Vietnam	4.20
74	↓	60	Kenya	4.15
75	—	75	Ethiopia	3.44
76	↓	72	Nigeria	3.00

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 2022		2021	COUNTRY	SCORE
1	—	1	Ethiopia	7.18
2	—	2	Angola	6.39
3	—	3	Uganda	5.97
4	↑	5	Nigeria	5.73
5	↑	14	South Africa	5.55
6	↓	4	Cameroon	5.36
7	↓	6	Kenya	5.30
8	↑	30	South Korea	5.10
9	↑	22	Israel	5.07
10	↑	23	United Arab Emirates	5.06

RANK 2022		2021	COUNTRY	SCORE
67	↓	65	Kazakhstan	2.28
68	↓	67	Spain	2.25
69	↓	50	Portugal	2.24
70	↓	57	Mexico	2.11
71	↑	74	Russia	2.11
72	↑	73	Iran	2.09
73	↓	64	Italy	2.01
74	↓	69	Egypt	1.98
75	↓	71	Singapore	1.69
76	—	76	Qatar	1.38

Source: MIT Technology Review Insights, 2022

decarbonization, noting that the collective promises made will only lower global temperatures one- to two-tenths of a degree Celsius by 2100. "Many countries in the Paris accords use the preservation of natural lands to contribute to their carbon emissions reductions, utilizing direct air capture technologies which draw down carbon into trees and into soils. But it's become clear that we need international scientific standards, because individual countries are quite demonstrably using very different estimates for the amount of carbon that can be stored per hectare." Collins notes that, unlike measuring the carbon impact of burning oil or other hydrocarbons, developing standard scientific metrics for carbon capture is tricky, as the amount of carbon a forest can store is variable: "It really depends on the type and age of the trees, and how recently the forest was disturbed." Ishii agrees and adds that there is further complication because a forest has significant value not only as carbon sink, but also as home to biodiversity: "We should aim at creating a global carbon market for sequestration. It is more challenging to create a market mechanism to measure significance of biodiversity. Biodiversity in Indonesia or the Amazon has a global significance, whereas biodiversity in Japan does not."

Collins notes that while many direct air capture technologies are very mature, they may prove difficult to scale: "We've used scrubbers on coal-fired power plants for decades, but these technologies are very energy intensive, and while they work well to clean smokestacks that emit 10% CO2, they aren't efficient when we are dealing with atmospheric CO2 at 400 parts per million, which is essentially like asking someone to remove an

Nuclear power's new, clearer future?

Nuclear remains contentious in climate action circles, creating divergent opinions even among generally well-aligned European Union nations, where a recent proposal to categorize nuclear projects as green infrastructure has incited outcry from such member states as Germany, Luxembourg, and Austria.[28] Outside of France, Europe's ambivalence toward nuclear energy is even, in some instances, slowing its energy transition efforts: Belgium is actively working to completely decommission its nuclear energy infrastructure by 2025,[29] but because it has not been replacing nuclear capacity with other clean energy quickly enough, it has had the EU's slowest rate of decrease of fossil fuels in its energy mix over the last decade (from 78% to 76%).[30]

Nuclear energy thus presents a conundrum for our green future: it is a viable clean energy source, but a problematic one. Fortunately, however, current technology and adoption trends may soon change this. MIT Energy Initiative's Robert Stoner points out that the current generation of nuclear solutions continues to have two key challenges accelerating its obsolescence: "Firstly, nuclear is expensive and increasingly uncompetitive with cheaper and cheaper renewables. Secondly, we have never honestly dealt with nuclear waste – there are no adequate repositories, and we don't have the ability to move nuclear waste safely from one place to another." Therefore, it is likely that "old" nuclear technology may naturally sunset itself as long-anticipated nuclear fusion solutions emerge.

Nuclear fusion – the combining of atoms, rather than splitting them – is a century-old technology goal, in which fusion generators will produce much more energy (and, importantly, much more energy than they consume) and with much less nuclear waste than today's fission-powered energy generation. One promising example of this is SPARC, a prototype fusion reactor developed by Commonwealth Fusion Systems (CFS), a US-based, MIT-backed startup. SPARC uses high-temperature superconducting electromagnets, the most powerful magnetic field ever created, which CFS believes will become a fusion electricity plant that produces 10 times the power it consumes by the 2030s. Moreover, if successful, SPARC's energy generation methods will allow for the creation of much smaller, much cheaper fusion machines than most current technologies under development.

"Many countries in the Paris accords use the preservation of natural lands to contribute to their carbon emissions reductions, utilizing direct air capture technologies which draw down carbon into trees and soils. But it's become clear that we need international scientific standards, because countries are using very different estimates for how much carbon can be stored per hectare."

William Collins
Director of the Climate and Ecosystem Sciences Division for the Earth and Environmental Sciences Area, Lawrence Berkeley National Laboratory

eye-dropper of food dye mixed into a full swimming pool." Even more problematic, he says, it that the world's current collective air capture capacity "in the range of a few tens of thousands of metric tons per year" is woefully insufficient to meet the task at hand. "The IPCC emissions reduction target is 10 to 20 billion metric tons per year, so we can only deal with one-millionth of that," says Collins.

Long shot or moon shot? Hydrogen's long-term potential

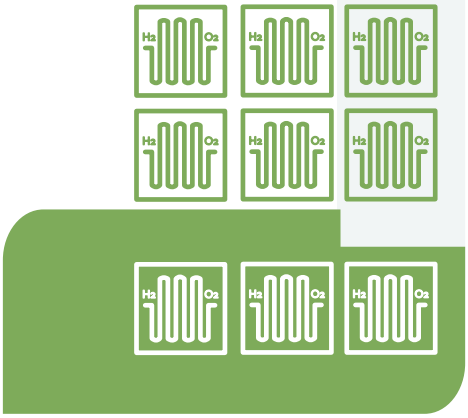
The growing scale of renewable energy technology has brought with it rising productivity and lowered costs. The IEA estimates that in 2020, investments in renewable power generation capacity are four times more productive than they were in 2010. This is because the unit cost of solar energy generation in 2020 was 10% less than in 2019, and 5% less for wind generation.[37] This is making the steady ramp-up of green electricity in the world's power grids, if not inevitable, then a far more reliable occurrence. In 2021, China more than doubled its offshore wind generation capacity to 26 gigawatts, knocking the UK off its top spot, and is now producing nearly half of all the offshore wind electricity in the world.[38]

However, while it is more present and effective, renewable energy generation remains a variable, and therefore undependable, source of electricity – solar and wind sources are unpredictable, and geothermal sources don't exist everywhere, for instance. Clean energy needs to be produced and stored in more stable supply chains, which is one of the compelling reasons that many of the world's energy innovation leaders are ramping up their hydrogen energy production efforts. "Green" hydrogen fuel (produced through electrolyzers – systems that use electricity to break down water into hydrogen and oxygen in a process called electrolysis – powered by renewable energy) is a highly efficient energy source: it's much more productive than fossil fuels and can be quickly produced and effectively stored indefinitely. It thus represents the ultimate potential of clean energy – the ability to create virtually unlimited amounts of clean energy that can be stored in fuel cells and integrated into transportation, manufacturing, and other off-grid energy supply chains.

Unfortunately, scale-intensive and cost-effective hydrogen production technology is still a long way off. Currently, electrolyzers are almost exclusively small capacity, and their costs are estimated to halve only by 2030.[39] As such, hydrogen power is currently unlikely to help any country to meet its Paris Agreement commitments. But the potential for hydrogen to spark a virtuous cycle of carbon-free energy, and with it the hopes of a truly sustainable economy, have compelled many countries to align public infrastructure and scientific resources to take this long shot. In the United States, the Biden administration's Infrastructure Investment and Jobs Act, signed into law last November, has earmarked $8 billion in funding to establish multiple regional hydrogen production hubs, and another $1.5 billion to seed showcase projects which will "develop a clean hydrogen supply chain and workforce."[40]

Japan is another country looking at achieving leadership in hydrogen technology and production capabilities as a

"Green" hydrogen fuel represents the ultimate potential of clean energy—the ability to create virtually unlimited amounts of clean energy that can be stored in fuel cells and integrated into transportation, manufacturing, and other off-grid energy supply chains.



key component of its greener future. The country has seen the single largest jump in the 2022 Green Future Index rankings (from 60th place to 19th), in large part because of steps taken in 2021 to increase decarbonization efforts and aspirations. Japan's updated 2030 NDC target moved up its emission reduction targets from 26% to 46%, with a stretch goal of 50%.[41] Japan's Ministry of Economy, Trade, and Industry (METI) also released its sixth Strategic Energy Plan in October 2021 and has made substantial progress in energy investment transition.

Hydrogen projects feature prominently in Japan's efforts. "Hydrogen is key technology for a carbon-neutral Japan. It has the potential to develop a low-carbon energy system by integrating it into our existing energy vectors," observes Eiji Ohira, the director of the Fuel Cell and Hydrogen Technology office of Japan's New Energy and Industrial Technology Development Organization (NEDO). He points out that while hydrogen energy itself "will not be a substantial part of Japan's energy mix for the next decade"—METI's sixth energy plan estimates that hydrogen will generate at most 1% of Japan's energy by 2030[42]—"it will serve as an important part of our long-term energy innovation capabilities. A hydrogen supply chain can exploit synergies in our technology, transportation, and heavy industry sectors." In 2021, NEDO allocated $210 million to research and development in fuel cells, hydrogen refueling stations (of which it expects Japan to have 900 nationwide by 2023), and energy system projects. These latter projects include the development of hydrogen transportation using liquefied hydrogen and organic chemical hydrides, and creating hydrogen gas turbines and hydrogen engine boilers. Ohira expects these technologies will contribute to achieve Japan's hydrogen cost target of $2 per kilogram by 2050.[43]

Although decarbonization and energy transition progress is often slow, it will be substantial and transformative. Much of the world will have the majority of its electricity sourced from clean power sources in the next quarter century. The International Energy Agency's pathway to net zero assumes that by 2050, 90% of world electricity generation will be renewable—a stretch, but not unobtainable at our current rates of energy transition.[44] In a world where most of the industrial output is powered by clean sources, and the possibility of developing green hydrogen and other next-generation clean fuels at scale becomes more feasible, a "tipping point" could emerge in our quest to attain, and sustain, a carbon-neutral economy. This would create immense green future opportunities, says Bill Hare of Climate Analytics—but it will also signal the beginning of another immense transformation undertaking: "From a systems point of view, decarbonizing our power system will in turn decarbonize our manufactured output. This will lead to a big transformation in the material flows and our supply chains. But when we get to this carbon tipping point, we will need to critically examine the energy needs of technological applications like green hydrogen. We imagine the renewables-based energy will be free once we figure it out, but there will still be environmental space limitations and a lot of political economy issues to accommodate as we totally reinvent our public and industrial infrastructure platforms to prepare for this massive rollout of variable renewable energy systems," says Hare.

Partner perspective

Citrix

As a pioneer of secure hybrid work, sustainability isn't just a priority – it's in our nature. We believe technology should make our world a better place to work and live. This is why we create solutions that empower people to do their best work from anywhere and get the most out of their resources.

Empowerment starts with helping our customers embrace hybrid work by transitioning to long-term flexible work models that not only reduce their carbon footprint, but also make work more accessible for every employee.

Citrix solutions enable people to securely access their apps, desktops, and data from wherever they are, which facilitates more people working remotely and fewer people commuting to the office. Transportation emissions alone account for 10 percent of greenhouse gas emissions globally and 28 percent in the United States[1]. But people who work remotely in the U.S. avoid emitting 3.6 tons of transportation-related emissions – that's equal to planting 91 million trees[2].

Because our solutions eliminate the need to store apps and data on people's individual devices, organizations can shift to more energy-efficient data storage solutions. These are some of the reasons why the University of Cambridge chose to partner with Citrix.

Steve Hoensch, the university's head of frontline services, needed a solution to reduce power consumption for the university's 15,000 desktops. After deploying Citrix Virtual Apps and Desktops, he told us, "Moving people from a 450W desktop PC that's powered 24/7 to a Raspberry Pi that's running between 5W and 15W brings a substantial savings."

Additionally, Hoensch added, "We were looking at the environmental cost of people needing to drive here just to access their files, do their work, then drive home again, getting stuck in the regular rush-hour traffic. Enabling people to work securely and easily from home is another big factor in reducing our carbon footprint."

Our solutions also help organizations extend the lifespan of devices by three to seven years just by moving computer workloads off individual devices and into the cloud. This is critically important because of the 50 million tons of electronic waste produced each year, only 20 percent is recycled[3]. The more life we can get out of our devices, the more we can reduce this massive waste.

Another way we help organizations reduce their carbon footprint – and costs – is by helping them shift from less efficient on-premises data centers to highly efficient public clouds. Neste, the world's leading producer of renewable diesel and sustainable aviation fuel, is one step closer to its goal of becoming carbon neutral by 2035 by reducing the number of on-premises servers using Citrix cloud services on Google Cloud Platform.

These are just a few examples. We believe being ethical and transparent is the only way today's organizations can effect change. Prioritizing environmental sustainability isn't just good citizenship – it's good business. Together with our partners and customers, we're committed to making work more equitable and sustainable for all.

Tim Minahan
EVP, Business Strategy and Chief Marketing Officer,
Citrix

Sources
1. United States Environmental Protection Agency's "Carbon Pollution from Transportation"

2. Adie Tomer, "America's commuting choices: 5 major takeaways from 2016 census data," The Brookings Institution (blog), Oct. 3, 2017

3. "A New Circular Vision for Electronics Time for a Global Reboot," The Platform for Accelerating the Circular Economy (PACE), January 2019

05 (Still) not easy: Green society and clean innovation

Scores in the next two Green Future Index pillars – green society and clean innovation – measure progress toward somewhat higher-order sustainability objectives, such as efforts to transition nations into sustainable economies through low-impact modes of living, and the development of scientific and technological innovations that can ensure these climate-friendly habits last.

Leaders in the green society pillar are overrepresented by nations, many in Asia, that have managed to incorporate strong civil planning and societal development goals into policy, regulation, and public infrastructure spending (see Figure 10). The top two in the pillar include the world's best-ranked recycling economies, Singapore and South Korea, both of which routinely expand policy programs to encourage better waste management. In June 2022, South Korea, working to mitigate the waste impact from Asia's largest café economy and the rise in takeaway and delivered food brought on by the pandemic, plans to introduce a deposit return scheme for all disposable coffee cups and other single-use beverage containers.[45] Singapore is contemplating similar legislation as part of its growing efforts to enact "extended producer responsibility" schemes to enforce recycling. Yet, these efforts are hard, even for Green Leaders. Ireland, which ranks third in the green society pillar, is facing an "extremely challenging" battle to expand its recycling rate from 22.5% in 2019 to 55% by 2030, according to a recent report from the country's Environmental Protection Agency.[46]

Reforestation efforts and attempts to expand the protection of primary growth woodlands, marine areas, and other biodiverse resources are also proving tricky – although there are some glimmers of hope. In its 2020 report on forest loss, the UN Food and Agriculture Organization estimates that the world has lost forest land equivalent to the size of Libya since 1990, although the rate of decline has significantly slowed, from 7.8 million hectares per year in the 1990s to 4.7 million hectares annually from 2010 to 2020.[47] Unfortunately, most of that loss continues to come from climate-vulnerable economies in South America or Africa (see Figure 11), the two regions from which the majority of our lowest-ranked green society countries come.

Leaders in the green society pillar are overrepresented by nations, many in Asia, that have managed to incorporate strong civil planning and societal development goals into policy, regulation, and public infrastructure spending.

The fostering of green innovations – Pillar 4 in the index – also proved tricky for many economies, including countries that take both innovation and decarbonization seriously. A combination of factors in this pillar rank countries not only on their ability to cultivate scientific discovery around environmentally conscious technologies and solutions, but also their willingness to invest in green energy and infrastructure efforts across their own

borders (or play host to those efforts). Perhaps unsurprisingly, therefore, geopolitically isolated Iran ranks lowest in the clean innovation pillar, as do many economies that are either unable to develop or attract green technologists (Peru and the Philippines, for example) or are overly focused on domestic economic agendas. This last category of countries includes resource-rich places like Saudi Arabia and Australia. The latter's climate change isolationism – it failed to sign the coal pledge at COP26 – is in large part rooted in the country's economic dependency on carbon-intensive exports (mineral fuels were more than a quarter of

Figure 10: Highest and lowest performers in the green society and clean innovation pillars: The Green Future Index 2021 and 2022

PILLAR 3: Green society

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

RANK 2022		2021	COUNTRY	SCORE
1	↑	3	South Korea	7.04
2	↓	1	Singapore	6.84
3	↓	2	Ireland	6.79
4	↑	8	Germany	6.54
5	↑	7	United States	6.51
6	↑	17	Iceland	6.44
7	↓	4	Taiwan	6.43
8	↓	5	Philippines	6.29
9	↓	6	Czech Republic	6.26
10	↑	13	Canada	6.22

RANK 2022		2021	COUNTRY	SCORE
67	↓	65	Romania	3.91
68	↑	71	Brazil	3.83
69	↓	61	Angola	3.81
70	↑	72	Ukraine	3.79
71	↓	67	Algeria	3.78
72	↓	55	Zambia	3.73
73	↓	68	Nigeria	3.71
74	↓	73	Pakistan	3.60
75	↓	70	Kazakhstan	3.57
76	↓	74	Argentina	3.17

PILLAR 4: Clean innovation

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

RANK 2022		2021	COUNTRY	SCORE
1	↑	2	Finland	7.67
2	↑	16	Iceland	7.29
3	↑	37	Sweden	7.23
4	↓	1	Singapore	7.18
5	↑	24	Netherlands	7.06
6	↑	27	Norway	6.87
7	↑	9	France	6.8
8	↑	64	South Korea	6.73
9	↑	28	Belgium	6.66
10	↑	63	Japan	6.53

RANK 2022		2021	COUNTRY	SCORE
67	↑	69	Romania	4.09
68	↓	55	Australia	4.06
69	↓	42	Saudi Arabia	3.91
70	↓	10	Uruguay	3.87
71	↓	59	Guatemala	3.34
72	—	72	Iran	2.89
73	↓	66	Slovakia	2.62
74	↓	53	Taiwan	2.56
75	↓	52	Malaysia	2.50
76	↓	75	Algeria	1.00

Source: MIT Technology Review Insights, 2022

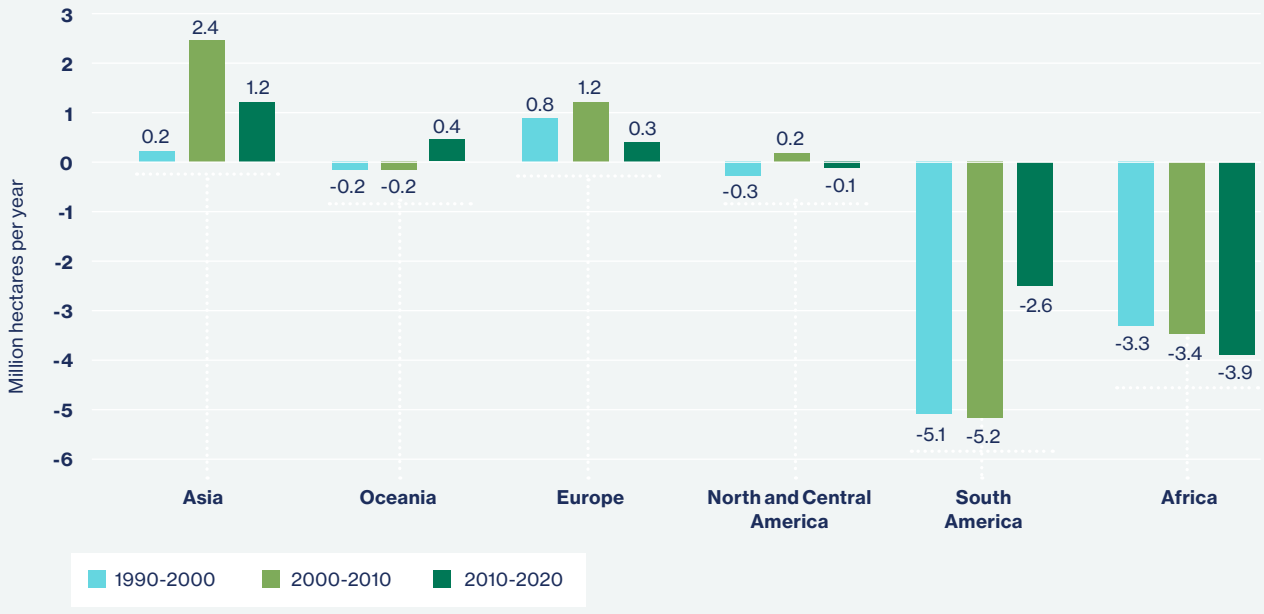
The UN Food and Agriculture Organization estimates that the world has lost forest land equivalent to the size of Libya since 1990, although the rate of decline has significantly slowed, from 7.8 million hectares per year in the 1990s to 4.7 million hectares annually from 2010 to 2020.

exports, and agricultural products over 10%). But also scoring low on this measure is Israel, which is a clear global leader in foodtech innovation but has not devoted a significant amount of its climate change development efforts to either growing its overall stock of climate innovation IP or investing in overseas initiatives.

Feed the world

Climate challenges have also placed urgency on the need to develop more efficient means of agricultural production and distribution by leveraging fast-advancing digital, industrial, and biological technologies. This is for an ironically (and tragically) interdependent pair of factors: our growing global production capacity continues to place pressure on natural resources and climate (the agriculture industry collectively contributes to between a fifth and a quarter of global GHG emissions), yet the bounty this creates still does not adequately feed us all. The World Health Organization (WHO) estimated in July 2021 that 9.9% of the world's population – 811 million people – were undernourished in 2020, a sharp rise from 2019's 8.4% level.[49] WHO estimates that nearly one-in-five people are hungry in Africa, one of the world's fastest-growing agricultural production centers, and a region particularly susceptible to climate change-induced extreme weather events.

Figure 11: Annual forest area net change, by decade and region, 1990-2020



Source: Food and Agriculture Organization of the United Nations, 2020[48]

As reported in the 2021 Green Future Index, transitioning the world's food economy toward more sustainable modes of production, distribution, and consumption is proving difficult. Reducing appetites for carbon-intensive meat and dairy is incredibly hard, particularly in countries with high-income economies. Of the 20 worst-scoring countries in this category, all but two are high-income economies (and most are in the overall Green Leaders cohort) where average protein consumption per capita exceeds 100% of daily nutritional requirements (see Figure 12). This is why much attention in "foodtech" circles has been focused on efforts to produce sustainable, affordable, and scalable meat substitutes. Plant-based meat companies such as Beyond and Impossible have been investor darlings as they attract burger-loving converts, largely in high-income countries. Another avenue for protein transitioning is ramping up production and consumption of marine protein, as it is eight-to-10 times less carbon-intensive than beef. Investment in marine environments, such as seaweed beds or mangrove forests, produces a decarbonization multiplier effect of sorts: scaling up natural environments acting as "carbon sinks" as well as new sources for low-carbon nutrition.

Figure 12: Highest and lowest performers in the meat and dairy consumption indicator: The Green Future Index 2022

INDICATOR 3.4: **Meat and dairy consumption**

A higher score in this indicator means lower meat and dairy consumption.

RANK	COUNTRY	SCORE	RANK	COUNTRY	SCORE
1	Nigeria	10.0	57	Belgium	3.4
2	Ghana	9.9	58	Poland	3.2
3	Bangladesh	9.9	59	Austria	3.0
4	Cameroon	9.7	60	Kazakhstan	2.9
5	Indonesia	9.7	61	United Kingdom	2.7
6	Ethiopia	9.6	62	Germany	2.7
7	Zambia	9.4	63	Norway	2.6
8	Uganda	9.0	64	Sweden	2.5
9	Angola	9.0	65	Denmark	2.4
10	Guatemala	8.6	66	United States	2.2
=11	Egypt	8.3	67	France	2.1
=11	Kenya	8.3	68	Argentina	2.0
13	Peru	8.2	69	Australia	1.9
14	Thailand	8.2	70	Hong Kong, China	1.8
15	Paraguay	8.2	71	Netherlands	1.8
16	Morocco	8.2	72	Luxembourg	1.5
17	India	8	73	Switzerland	1.3
18	Philippines	7.9	=74	Finland	1.0
19	Iran	7.9	=74	Iceland	1.0
20	Malaysia	74	=74	Ireland	1.0

Source: MIT Technology Review Insights, 2022

"Transportation is the largest single driver of fossil fuel energy consumption outside the manufacturing sector. The push for electrification of transportation is motivated, first and foremost, by energy security."

Bill Russo
Founder and CEO, Automobility Ltd

Transitioning food industries to alternative forms of protein is further complicated by long-simmering tensions between proponents of small-scale organic growing methods and industrial-scale agriculture. Organic beef production is kinder to livestock, but free-range cows produce much more methane than those raised in more industrial conditions. This conundrum is particularly felt in New Zealand, a country that is taking many conscientious steps toward a green future but is nevertheless challenged by its economic dependence on beef production. Kevin Trenberth, a climate scientist with the University of Auckland and Distinguished Scholar with the US National Centre of Atmospheric Research, notes: "There's been quite a lot of focus on methane in New Zealand and good research about how to reduce methane emissions from cattle. But this works a lot better in more industrialized markets like the US, where there are feed lots and cattle are housed in barns in winter. All of New Zealand's cattle is free-range, so it's hard to control diet and feces deposits, which means that, inevitably, the main means of reducing methane is to reduce overall numbers of livestock." This is a difficult proposition for New Zealand when its competitors, such as Australia and South America, have much more scale and are often less committed to climate objectives.

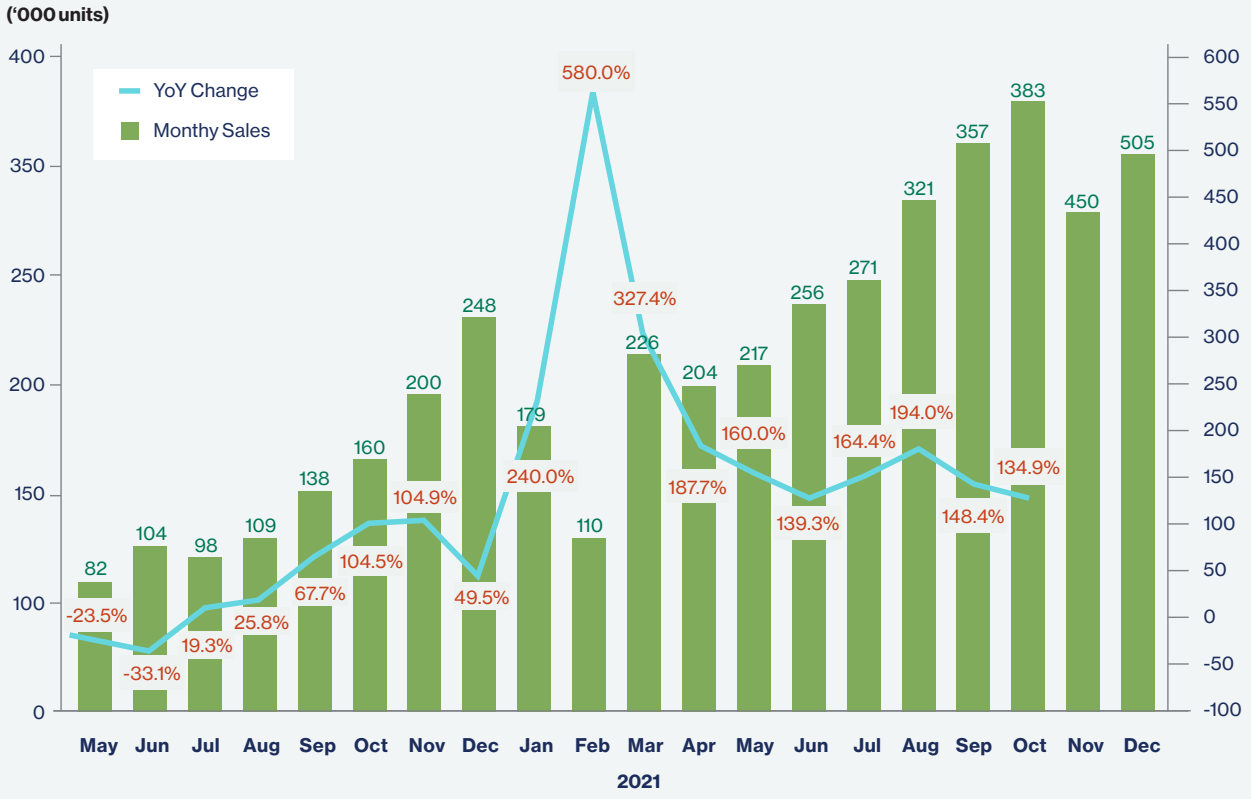
Electric avenues: EVs and the future of mobility

The 2022 green society pillar was enhanced with a new indicator, which measured each economy's efforts to incorporate electric vehicles into its respective transportation grid. Electrifying mobility is as essential to encoding sustainability into our societal structures and behaviors as ramped-up reforestation efforts, recycling, or more energy-efficient buildings.

China's recent adoption of EVs is not only a significant and growing part of the country's decarbonization strategy, but one with potentially important lessons for the rest of the world. The take-up rate of EVs in China was prodigious in 2021. Average monthly sales now make up 12% of total passenger vehicles sold, and the 3.3 million EVs bought in China in 2021 (over three-quarters of which were produced by domestic automakers) represent just over half of all new electric cars sold worldwide that year[50] (see Figure 13). However, the real transformative power of China's new mobility space is going to come in the form of a complete and systemic reimagining of the country's mobility sector, according to Bill Russo, CEO of Automobility Ltd, a Shanghai-based new mobility strategy and investment advisory firm. He believes China's policymakers are driven to electrify mobility by the knowledge that "transportation is the largest single driver of fossil fuel energy consumption outside the manufacturing sector, and the push for electrification of transportation is motivated, first and foremost, by energy security." This, Russo notes, has also informed broader systemic efforts to develop longer-term solutions, "particularly hydrogen energy and fuel cell electric vehicle technologies." While many potential hydrogen applications are not relevant for personal and public mobility, he believes that centralized planning objectives have linked the two to provide much-needed scale to China's overall "new energy" scientific and industrial development efforts.

However, it is in the secondary objective of China's transport electrification project that its real transformative power lies. While China leads the world in EV ownership, Russo points out that overall personal vehicle ownership per capita is very low when compared to other high- and middle-income countries, and he believes this will continue to be the case. Indeed, overall automobile sales have been steadily declining in China since 2017. This transition is useful for China on two fronts. First, it gives China an opportunity to wean itself off foreign technology, and the focus on EVs allows China to reset the race for new

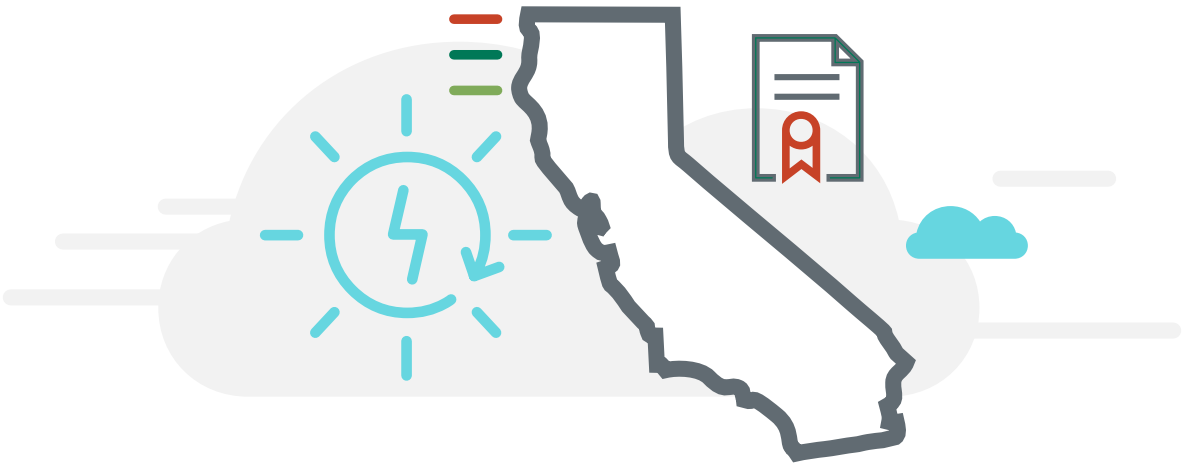
Figure 13: New electric vehicle sales in China, May 2020-December 2021



Sources: Compiled by MIT Technology Review Insights based on data from the China Association of Automobile Manufacturers, China Passenger Car Association, Automobility, and MIT Technology Review Insights estimates, 2022

mobility intellectual property. "China's traditional internal combustion engine auto industry doesn't have the same legacy [as in the West], so its firms are not intellectual property leaders," says Russo. Second, the fact that individual vehicle use is slowing supports sustainability objectives, and as EV growth rises, it allows China to fundamentally rethink mobility. "EVs are not just creating a secular shift, but a generational shift as to what 'owning' mobility means," says Russo. Younger consumers in China, unlike their counterparts in many other markets, are not buying the priciest, highest-performance models. Russo notes the biggest EV in China is the modest Wuling Hongguang mini EV, which is priced at around $5,000. "I think we are going to see the demographics of EV shifting to a younger, more environmentally conscious demographic," Russo adds.

EV consumption habits, therefore, will start to further disrupt mobility, Russo explains. "More alternatives to the consumption of personally owned vehicles will emerge, and the aspiration to own a vehicle will go away, increasing the notion of mobility as a service. This makes EVs more productive, and when you increase the productive utility of the vehicle from 5% to 40%, it significantly reduces the number of vehicles you need to serve that mobility." This, he believes will usher in China's "Mobility 2.0" era: "smart EVs with autonomous or early-stage drive-assistance technology, which will be developed in parallel with the electrification of transportation." The result, Russo believes, will be nothing short of a radical scaling up of sustainable transportation in China. Given the country's prodigious efforts to build up export manufacturing competency in other climate-friendly technologies such as wind and solar, China's EVs will likely soon start having similar impacts on many other countries' green futures as well.



Even though California is a large contributor to the climate crisis—generating around 1% of global emissions—it also has a uniquely powerful green innovation cluster with policy direction, regulation, and scientific resources.

California's green innovation

Broad-based and multifaceted innovation efforts to solve the complex challenge of lowering carbon emissions often gain traction when they are "clustered" in an economy. And with proper regulatory oversight and coordination, they can be impactful. This can be seen in many of the world's prodigious foodtech clusters, particularly in Israel which, despite its population of less than 10 million, has the world's third-highest number of foodtech-related startups. These startups draw on decades of agricultural science innovation invested in the country's early quest for food security, and the industry now has dozens of leading firms developing sustainable solutions in alternative proteins, carbon-efficient food distribution, and technologies that reduce the use of pesticides and fertilizer. An example of the latter includes Save Foods, which uses biochemical carbon-neutral processes to reduce fungus and the need for fungicides, notably in Israel's citrus sector.[51]

William Collins, director of the climate and ecosystem sciences division for the Earth and environmental sciences area at the Lawrence Berkeley National Laboratory in California, believes that, while his state is a large contributor to the climate crisis – he estimates California generates 1% of the world's emissions – it also has a uniquely powerful green innovation cluster, a confluence of policy direction, regulation, and dense academic and scientific resources that is "making our economy as green as humanly possible." His own laboratory has a portfolio of carbon capture and sequestration experiments, which include weathering, crushing, and burying rock, "which will not only increase soil health, but it will, if it gets stashed down to a meter below the surface, store the carbon for 1,000 years." Other projects include efforts to develop remote carbon sensing of soil and extracting carbon dioxide from sea water.

More broadly, California's forestry and agricultural sectors, in response to both the state's decarbonization goals and its pernicious wildfires, are continuously searching for the best mitigation strategies. These are to make "carbon-neutral technologies cost efficient and harmonious with other existing technologies, like producing biofuels from field gleanings, or taking trees that we are cutting down to reduce fire risk and turning them into bio parks and biofuels," says Collins. Taken together, he says, "this will give California, and the United States, a basket of solutions that are cost equivalent to each other, and this is the first major step" toward a broad-based sustainable economy.

Partner perspective

Iris Ceramica Group

Since we began producing high-end ceramic surfaces over 60 years ago, environmental sustainability has been one of our main priorities. We believe that ethics, technology and aesthetics must share the same path, strengthening each other along the way.

With production sites in Italy, Germany and the United States, we are investing in research, innovation and sustainable development, not just to support our manufacturing activities and the creation of pioneering ceramic surfaces, but also to promote and safeguard the unique relationship binding humans and nature throughout the world.

This principle has been part of our DNA since the 1960s, when my far-sighted father, Romano Minozzi, chairman and founder of Iris Ceramica Group, coined the equation economy=ecology, indicating that the way to move forward is an economy collectively serving humans and the environment.

Ceramics are one of the noblest materials found in nature and include some of the world's most high-performing technical and mechanical properties. But they require energy-intensive production processes.

Our commitment to environmental sustainability is also demonstrated by our investments in industrial plants equipped with regenerative thermal oxidizers, which reduce the emission of volatile organic compounds (VOCs) and odorous particles to almost zero. Moreover, in the plant in Vetschau, Germany, a 2.4-megawatt peak (MWp) photovoltaic system covers a surface of 50,000 square meters on the roof, reducing more than 2,000 tons per year of CO2 emissions.

1,052 tons per year

The planned reduction of CO2 emissions in absolute terms, with the approach of blending 50 percent hydrogen and 50 percent natural gas.

Our ceramic materials are also eco-compatible, made from superior raw materials and colored with natural agents, and we recycle and reuse the scrap. Our eco-active ceramics take just two years to offset the nitrogen oxide (NOx) emissions required to produce them.

Energy transition is another crucial frontier for the company. Building a sustainable world is an ambitious challenge, which is epitomized by our construction of the world's first green hydrogen-powered ceramics production plant, launching a new chapter in the history of the ceramics industry.

The new facility, which will be opened by the end of 2022, represents extraordinary eco-innovation. It will include a photovoltaic plant, with 2.5 MW power output, installed on the roof of the facility; it will be combined with an electrolyzer and a storage system for the renewable hydrogen produced on-site. Initially, we will use a blend of green hydrogen and natural gas, immediately reducing CO2 emissions.

Ultimately, the plant is designed to run on 100 percent green hydrogen, a renewable energy that will pave the way to produce zero carbon emissions ceramics. This will be a key factor in achieving our carbon neutral goal by 2050.

As we continue to tackle challenges and embrace opportunities with the same determination we have always shown, we will also continue to promote that extraordinary sustainable beauty that ceramics can offer the world.

Federica Minozzi
Chief Executive Officer,
Iris Ceramica Group

06 Green policy in practice: climate policy

The climate policy pillar is the Green Future Index's most heavily weighted, at 40% of the overall rankings. This reflects our view that the indicators that measure and rank aspects of a country's climate regulation "toolkit" reveal the most important elements of not only what is guiding a country's decarbonization today, but what policy frameworks will ensure that its economic and societal development will continue steadily toward a carbon-neutral future in the decades to come. The climate policy pillar contains several indicators: how well-aligned a country's climate-related policies are with its Paris Agreement commitments, what steps it has taken to foster carbon management practices within its industrial economy and financial sector, and what percentage of a country's total investment in energy and other public infrastructure is directed at green projects.

Most of the leaders in the climate policy pillar are European nations, a testament to the "Green New Deal" framework the EU is putting in place to become the world's first decarbonized economy by 2050.

As with the 2021 Green Future Index, most of the leaders in this pillar are European nations (see Figure 14), a testament to the "Green New Deal" framework the EU is putting in place to become the world's first decarbonized economy by 2050. Leading this pack is Denmark, which in December 2021 saw the successful sale of $762 million in green bonds raised to fund the country's ambitious energy transition programs. Denmark expects that roughly a quarter of its sovereign debt issued in 2022 will be in the form of green bonds.[52] Europe's efforts to fund its decarbonization involve a world-leading set of environmental taxes and carbon trading programs, although efforts to create a globally impactful taxation regime through its Carbon Border Adjustment Mechanism have yet to be finalized. Moreover, there are some concerning indications that Europe's environmental tax base is slipping. A recent European Environmental Agency report found that while the EU generated €330 billion in such taxes in 2019, the share of environmental taxes as a proportion of its total tax revenues has slipped slightly over the last two decades, from 6.6% in 2002 to 5.9% in 2019.[53]

At the bottom of the climate policy pillar's ranks are a number of emerging economies that, for the most part, remain dependent on hydrocarbon or other resource extraction industries that largely have not been able to muster either the political will or the financing to pivot their recovery efforts toward more sustainable activities. These include Argentina, which – while having enacted a Climate Change Law in 2019 (the same year it declared a climate emergency, the implications of which are still threatening

Figure 14: Highest and lowest performers in the climate policy pillar: The Green Future Index 2021 and 2022

PILLAR 5: Climate policy

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

RANK 2022		2021	COUNTRY	SCORE
1	↑	2	Denmark	8.12
2	↑	4	Netherlands	7.85
3	↑	22	United Kingdom	7.64
4	↓	2	France	7.36
5	—	5	Iceland	7.23
6	↑	9	Spain	7.22
7	↑	11	Poland	7.11
8	↑	14	Germany	6.99
9	↑	11	Canada	6.74
10	↓	7	Norway	6.65

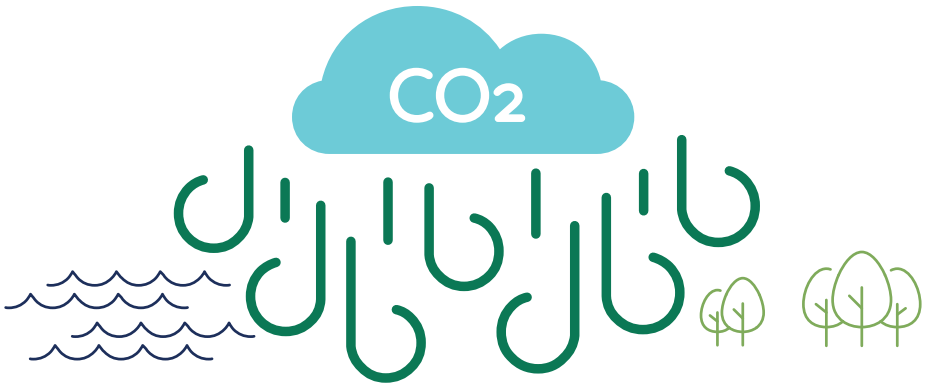
RANK 2022		2021	COUNTRY	SCORE
67	↓	59	Kuwait	2.59
68	↓	53	Argentina	2.53
69	↓	62	Ecuador	2.40
70	↑	72	Uganda	2.16
71	—	71	Qatar	2.09
72	↓	69	Ghana	1.95
73	↓	65	Turkey	1.69
74	↑	75	Paraguay	1.63
75	↓	74	Guatemala	1.51
76	↓	73	Iran	1.30

Source: MIT Technology Review Insights, 2022

the country with droughts and wildfires today) – continues to use subsidies and other policy tools to support its fossil fuel sector. Such subsidies, however, could be phased out as a condition of a recent $45 billion International Monetary Fund loan negotiated in January 2022.[54]

Building deeply impactful long-term climate resilience through policy action is difficult. Challenges in Hong Kong, for example, serve to illustrate these difficulties. The Hong Kong government's Environmental Protection Department noted to MIT Technology Review Insights that at 64th place in the 2021 Green Future Index, Hong Kong's rank "may not truly reflect its actual green performance and commitment." Indeed, between 2015 and 2020, the percentage of coal in the fuel mix was reduced from half to less than a quarter of the total, reducing its carbon emissions by 7.3 million tons over those five years (or 18% of its total) and lowering per capita carbon emissions from 6.2 tons to 4.5 tons. Hong Kong's greatly improved decarbonization progress was a primary reason why the territory jumped to 45th place in its overall Green Future Index ranking this year. In October 2021, Hong Kong published its Climate Action Plan 2050,[55] which sets an agenda to reduce the territory's carbon emissions by 50% before 2035 and to achieve carbon neutrality before 2050. Strategies to achieve these goals include "net-zero electricity generation," where the government intends that zero-carbon energy for electricity generation will be between 60% and 70% by 2035. Hong Kong's pragmatic and fast policy work is yielding short-term results, but its long-range policy commitment to sustainability is still lacking.

Out of thin air: Carbon capture and sequestration



Michael Manion is CEO of Seattle-based innovation consultancy Keon Research, which works with a number of firms to develop carbon capture solutions. Manion believes that a shift away from offsets and toward the use of carbon capture and sequestration (CCS) will increase over the next decade, not so much because of technology innovation (he points out that many CCS technologies are now more than two decades old), but due to innovations in business models. His team is working on using electrochemistry processes to convert carbon dioxide into raw materials that can be used to store hydrogen or other forms of energy, such as "buckyballs" or carbon onions, all with "interesting materials properties for use into other materials to strengthen them or to provide electrical conductivity," Manion explains. By building out portfolios of various carbon materials, he believes a marketplace can be developed around them, rather than finding a core application. "Our thinking is, instead of us trying to think of the best use for these, it's to put out a massive catalog of materials into the world and let the market come up with applications," he says.

As the economics of more industrial CCS efforts still present adoption challenges, many in the climate community are looking to nature-based solutions to play a larger role. And indeed, efforts to preserve or enhance primary growth forest, peat bogs, mangroves, and seaweed beds in order to increase their carbon absorption potential are gaining traction. "Blue" carbon reduction efforts, focused on natural maritime ecosystems, are seen as a way to capitalize on the world's oceans' already central role as our largest carbon sink (oceans absorb at least a quarter of the world's GHG produced annually, and as reported in MIT Technology Review Insight's 2021 Blue Technology Barometer, recent scientific research suggests it could be as high as one-third).[58]

"I'm always a fan of letting nature do its job," says Manion. "Self-assembling biology is much more scalable than anything we can build, and algae, for example, is a great way to pull carbon out of water." But there, again, the challenge of extracting carbon completely and efficiently into a permanent stored state persists: "We still need to expend energy to remove the water from the algae and then extract the carbon, ideally using nature and photosynthesis to do the job so that we're not having to burn more coal to pull the carbon out. There are pretty good solvent technologies coming through, and metal organic framework technologies with good kinetics, but they're still not economic at scale."

Many CCS technology projects seek to address the scale issue by looking to applications that can replace carbon-intensive production processes for high-volume materials, such as steel or, as in the case of US CCS startup CarbonBuilt, concrete. The company retrofits existing concrete production infrastructure with direct air capture capabilities to reduce emissions, and then "cures" concrete blocks with

steam and carbon dioxide to store the carbon permanently. Rahul Shendure, CarbonBuilt's CEO, explains, "the concrete industry has the right balance of being big enough, permanent enough, and economically important enough to be a sector where CCS efforts will have significant impact, sooner rather than later. It's not that getting CO2 into concrete is easy, but it's a lot easier than many other applications."

Taken as a whole, therefore, the current state of play in CCS technology is casting doubts on the ultimate impact it will have on our green future. "I don't believe that CCS has a significant role to play in the fossil fuel space," says Bill Hare, CEO of Climate Analytics, positing that developments elsewhere in the clean energy space may have passed by CCS. "The economics [of CCS] are not at all good, particularly given the cost reductions in renewables storage and other technologies that would replace carbon-intensive feedstocks. Very little has developed in the CCS space over the last 15 years, while the real cost of renewable energy technologies has dropped dramatically and keeps dropping." Hale sees continued divergence of these two technology development trajectories making it difficult for CCS to be cost-effectively deployed, even in carbon-intensive production processes like steel. "Five years ago, if you'd asked me, I would have said, 'yeah, steel's a scenario where you might need CCS.' Now, green hydrogen looks like it's going to be cost competitive with metallurgical coal for steel making within the decade, so that space has narrowed."

Yet, while fostering CCS capabilities is widely recognized as an important policy component, the constant introduction of new and maturing technologies and practices into policy frameworks opens these policies up to the risk of "greenwashing." As regulators and policymakers attempt to codify these evolving concepts into classification systems that allow financiers and developers to access funds marked for green projects or tax breaks, definitions can get stretched and argued over. Resulting disputes can potentially delay progress on climate change initiatives, as is happening with the current European debate over whether nuclear and natural gas investments qualify for green financing.

Companies can also hide carbon-intensive projects behind ill-defined or overly broad categories, explains Dongjae Oh, a climate finance researcher with Solutions for our Climate, a Seoul-based nongovernmental organization that works to reduce Korea's economic exposure to carbon-intensive industries. "While Korea has made significant investments in renewable energy, our collective investment in the oil and gas industry over the last decade has been $127 billion, dozens of times greater than our spending on renewables." Oh attributes this to two factors: "The productivity of Korean renewables companies is low, and many of our most important industrial sectors, such as shipping and shipbuilding, have high reliance on the oil and gas value chain." As a result, he says, Korean hydrocarbon firms are often given a lot of "green" leeway. Oh gives the example of South Korean energy firm SK E&S, which tried to secure export credit financing earmarked for green projects in a $3.6 billion offshore gas field project in northern Australia, "as the project uses CCS technology to reportedly reduce gas emissions by about 16%" despite its overall extreme carbon intensity.

One of the ways policy regimes could fairly and accurately account for each product or service's carbon footprint could be through democratizing information. In theory, this could be done using the internet of things (IoT), where IoT-enabled data transmits the carbon footprint of a container of shoes or powdered milk along every link along the supply chain. Bill Hare reckons this "would provide a good market signal, and I think it's a great business opportunity if you can get it right. But there will likely be a number of different competing platforms to do this using very different numbers. You already see this in the offset space, in the climate benchmark space, in the supply chain reporting base. You could be forgiven for believing that there are parallel universes out there where mathematical rules are different." Added to this complexity is the fact that there are 190 different signatory countries "with many different things going on," he says "It's not going to be easy, but it would be very important, and an interesting thing for the scientific community to buy into and bring some firepower to bear on it."

One of the clearest messages that have come out of the "post"-pandemic reevaluation of global climate action is that nations also need to ramp up efforts to remove carbon and other greenhouse gases from the atmosphere, largely through carbon capture and sequestration.

By 2035, only 10% of Hong Kong's electricity will come from renewable sources, only rising to 15% beyond that.[56]

While its energy transition policy is not sufficiently farsighted, Hong Kong's Climate Plan 2050 does show some vision in placing significant attention on climate adaptation – that is, putting in place infrastructure and processes to mitigate the impact of climate change-related weather events and natural disasters, such as building sea walls to combat the effects of tropical storms and rising sea levels. National adaptation plan frameworks were first introduced in COP proceedings at the 2010 Cancun summit, although many advanced economies, beginning with Finland in 2005, had already put them in place, according to Johanna Nalau, a climate adaptation scientist at Australia's Griffith University. While vulnerable emerging economies have largely struggled to put adaptation frameworks in place (the UNFCC reports that as of the 2021 Glasgow summit, COP 26, fewer than 30 developing countries and territories had submitted plans[57]), Nalau notes that the 2021 COP proceedings created a global goal development program that should begin to create standards and best practices, such as adopting a risk-management approach to climate resilience.

"Adaptation is inevitable, and countries need to get foundational assumptions in place to make effective decisions and provide effective policy guidance. Much like a 12-step program, policymakers must first accept that this is happening – that climate change has to be taken seriously as a national policy issue – and then determine what can be done about it." In the most progressive instances, this involves incorporating risk management practices, such as in New Zealand, where recent legislation required climate risk to be incorporated into corporate governance. "There's a lot of movement on climate risk in the private sector," Nalau says, which is a benefit for governments, as private sector risk practices help manage complexity. "Climate mitigation is, in a sense, pretty straightforward," she says, as well-established metrics and processes exist to measure emissions reductions. "With adaptation, it's a completely different ballgame: there are all kinds of intertwined factors that contribute to adaptation. How do heat waves impact our health system? How can we start preparing communities to build capacity in hospitals? When sea levels start rising dramatically and you have more intense hurricanes, how do you make sure that homeowners in vulnerable communities can still have insurance?"

One of the clearest messages that have come out of the "post"-pandemic reevaluation of global climate action is that, despite gradually rising nationally determined contribution commitments on reducing carbon dioxide emissions (or rather, because they are only gradually rising), nations also need to ramp up efforts to remove carbon and other GHG from the atmosphere, largely through carbon capture and sequestration. The 2022 Green Future Index was modified to reflect this by adding to the climate policy pillar an indicator that assessed each country's "CCS readiness" on a policy, technology, and infrastructure level. This assessment rewards economies that have a robust collection of needed assets – that is, mature manufacturing and agricultural industries that, while carbon-intensive, also serve as useful platforms to test and scale capture and sequestration methods, as well as a regulatory framework and innovation ecosystems that promote their use. The United States is this indicator's top scorer, as befits the country that arguably serves as the grandfather of CCS (thanks to 1963's landmark Clean Air Act) and still is host to many of the world's most compelling CCS innovators (see section "Out of thin air: Carbon capture and sequestration"). All the other top 10 scorers – largely European countries, along with China and Japan – share the traits of having large, developed multi-faceted carbon-intensive industries together with policy regimes geared toward getting producers to invest in carbon scrubbers for their smokestacks or lessen the release of GHG in the fertilization and planting of crops.

Yet, while fostering CCS capabilities is widely recognized as an important policy component, the constant introduction of new and maturing technologies and practices into policy frameworks opens these policies up to the risk of "greenwashing." As regulators and policymakers attempt to codify these evolving concepts into classification systems that allow financiers and developers to access funds marked for green projects or tax breaks, definitions can get stretched and argued over. Resulting disputes can potentially delay progress on climate change initiatives, as is happening with the current European debate over whether nuclear and natural gas investments qualify for green financing.

Companies can also hide carbon-intensive projects behind ill-defined or overly broad categories, explains Dongjae Oh, a climate finance researcher with Solutions for our Climate, a Seoul-based nongovernmental organization that works to reduce South Korea's economic exposure to carbon-intensive industries.

"While Korea has made significant investments in renewable energy, our collective investment in the oil and gas industry over the last decade has been $127 billion, dozens of times greater than our spending on renewables." Oh attributes this to two factors: "The productivity of Korean renewables companies is low, and many of our most important industrial sectors, such as shipping and shipbuilding, have high reliance on the oil and gas value chain." As a result, he says, Korean hydrocarbon firms are often given a lot of "green" leeway. Oh gives the example of South Korean energy firm SK E&S, which tried to secure export credit financing earmarked for green projects in a $3.6 billion offshore gas field project in northern Australia, "as the project uses CCS technology to reportedly reduce gas emissions by about 16%" despite its overall extreme carbon intensity.

One of the ways policy regimes could fairly and accurately account for each product or service's carbon footprint could be through democratizing information. In theory, this could be done using the internet of things (IoT), where IoT-enabled data transmits the carbon footprint of a container of shoes or powdered milk along every link along the supply chain. Bill Hare reckons this "would provide a good market signal, and I think it's a great business opportunity if you can get it right. But there will likely be a number of different competing platforms to do this using very different numbers. You already see this in the offset space, in the climate benchmark space, in the supply chain reporting base. You could be forgiven for believing that there are parallel universes out there where mathematical rules are different." Added to this complexity is the fact that there are 190 different signatory countries "with many different things going on," he says. "It's not going to be easy, but it would be very important, and an interesting thing for the scientific community to buy into and bring some firepower to bear on it."

07 Conclusion

Despite seemingly promising emission-reduction changes in 2020, the world's progress toward our collective green future slowed in 2021 as countries attempted to return to "normal" modes of economic activity. Moreover, many of the changes to which countries have agreed over the last two years are still not considered substantial enough in relation to the Paris Agreement. As such, most countries are still scrambling to increase carbon reduction commitments and are highly unlikely to meet their current self-imposed targets.

But this does not at all imply we should consider the battle against climate change lost. Rather, we should recover a glimmer of optimism from the incredible amount of climate-friendly activity taking place globally, from the incorporation of sustainability agendas into economic development policy and regulations to the development of scalable and impactful technologies and processes to reduce (and increasingly, extract) carbon dioxide and other greenhouse gases, and the commitment to financing for climate-friendly outcomes.

Promising advances in new energy generation (particularly the long-anticipated progress in nuclear fusion) and CCS technologies, together with rapid growth in alternative protein food production and the takeup of EVs, will create opportunities for future escalation of green practices, and virtuous development cycles will emerge once these technologies and solutions come to maturity. We see examples of these shifts occurring as Europe deploys Green New Deal policy levers and transnational collaboration to effect a permanent shift to sustainable economic development, or as China's growing use of electric vehicles signals more of a transition to entirely new modes of low-carbon mobility than a replacement of its internal combustion engine passenger car fleet. So, too, will multifaceted green development ecosystems, such as in California, the UK, or in Japan's emerging hydrogen cluster, bolster our collective efforts to create a global clean-energy economy.

As we've seen in 2021, it is extremely difficult for nations and societies to commit to greener ways of life. This is true even when every climate-related disaster serves as a stark reminder of the ramifications of fossil-fueled progress, and the global pandemic showed us that we can quickly and efficiently transition to new ways of living and working. High-income areas of the world (and, increasingly, the emerging world as well) will still consume far too much meat and dairy for decades to come, compounding our methane gas problems and contributing to the destruction of our most important sources of biodiversity and carbon sinks. Even with the COP26 coal pledge, much of the world will still be burning coal to supply power to its increasingly urban populations for a quarter-century or more. These challenges will serve to complicate efforts to shape societal and economic behavior toward climate-friendly outcomes and, as the 2022 Green Future Index shows, countries that struggle to implement any of these dimensions can quickly slip in their progress. Yet, as many countries – both Green Leaders and emerging Greening Middle countries – have shown, those countries that can maintain a solid commitment to change across all the pillars of their Green Future will achieve substantial, and hopefully indelible, progress.

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GFI 2022 Footnotes

1. UNEP Copenhagen Climate Centre, "Emissions Gap Report 2021," United Nations Environment Programme (UNEP), Oct. 26, 2021, https://www.unep.org/resources/emissions-gap-report-2021, page 17.
2. "The Green Future Index 2021," MIT Technology Review Insights, https://mittrinsights.s3.amazonaws.com/GFI/Report2021.pdf, page 5.
3. UNEP Copenhagen Climate Centre, "Emissions Gap Report 2021," United Nations Environment Programme (UNEP), Oct. 26, 2021, https://www.unep.org/resources/emissions-gap-report-2021, page 17.
4. "World Energy Investment 2021," IEA, June 2021, https://www.iea.org/reports/world-energy-investment-2021, page 7
5. "World Energy Investment 2021," IEA, June 2021, https://www.iea.org/reports/world-energy-investment-2021, page 7
6. Sarah Brown, "Cattle boom in Brazil's Acre spells doom for Amazon rainforest, activists warn," Mongabay, Jan. 7, 2022, https://news.mongabay.com/2022/01/cattle-boom-in-brazils-acre-spells-doom-for-amazon-rainforest-activists-warn/.
7. "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," The Intergovernmental Panel on Climate Change (IPCC), Aug. 9, 2021, https://www.ipcc.ch/report/ar6/wg1/.
8. "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," The Intergovernmental Panel on Climate Change (IPCC), Aug. 9, 2021, https://www.ipcc.ch/report/ar6/wg1/.
9. Arabinda K Padhee , Anthony Whitbread, "Indian agriculture: The route post-CoP 26," DownToEarth (blog), Jan. 18, 2022, https://www.downtoearth.org.in/blog/climate-change/indian-agriculture-the-route-post-cop-26-81154.
10. UNEP Copenhagen Climate Centre, "Emissions Gap Report 2021," United Nations Environment Programme (UNEP), Oct.r 26, 2021, https://www.unep.org/resources/emissions-gap-report-2021, page 16.
11. Matt McGrath, "Climate change: 'Fragile win' at COP26 summit under threat," BBC News, Jan. 24, 2022, https://www.bbc.com/news/science-environment-60115969
12. Sara Velezmoro, "Global sustainable bond issuance hits record $1 trillion in 2021," FinanceAsia, Jan. 25, 2022, https://www.financeasia.com/article/global-sustainable-bond-issuance-hits-record-1-trillion-in-2021/475382.
13. "ESG-labelled bond issuance poised to explode in coming decade – Pictet/IIF study," (press release) Institute of International Finance (IIF), Jan. 20, 2022, https://www.iif.com/Press/View/ID/4746/ESG-labelled-bond-issuance-poised-to-explode-in-coming-decade-PictetIIF-study.
14. "The Green Future Index," MIT Technology Review, 2021, https://mittrinsights.s3.amazonaws.com/GFI/Report2021.pdf.
15. Leonardo Paoli, Timur Gül, "Electric cars fend off supply challenges to more than double global sales," International Energy Agency (IEA), Jan. 30, 2022, https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales.
16. "Global sales and sales market share of electric cars, 2010-2021," IEA, Feb. 1, 2022, https://www.iea.org/data-and-statistics/charts/global-sales-and-sales-market-share-of-electric-cars-2010-2021.
17. "Energy Trends December 2021," Department for Business, Energy & Industrial Strategy, Dec. 23, 2021, page 1, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043311/Energy_Trends_December_2021.pdf.
18. Roger Harrabin, "All UK's electricity will come from clean sources by 2035, says PM," BBC News, Oct. 4, 2021, https://www.bbc.com/news/uk-politics-58792261.
19. "NextGenerationEU: European Commission disburses €271 million in pre-financing to Finland," European Commission (press release), Jan. 21, 2022, https://ec.europa.eu/commission/presscorner/detail/en/IP_22_430.
20. Paul Tugwell, "Greece Eyes Green Energy Shift With $21 Billion in Projects," Bloomberg Green, May 27, 2021, https://www.bloomberg.com/news/articles/2021-05-27/greece-eyes-green-energy-shift-with-projects-worth-21-billion.
21. Climate Action Tracker's (CAT's) "Costa Rica Country Summary," CAT, https://climateactiontracker.org/countries/costa-rica/.
22. Ruchira Singh, "India's state coal companies target installing 5.56 GW renewable power by 2030," S&P Global Commodity Insights, Nov. 19, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/energy-transition/111921-indias-state-coal-companies-target-installing-556-gw-renewable-power-by-2030.
23. Tanvi Deshpande, "Budget 2022: India's new climate pledges await funding push," Business Standard, Jan. 30, 2022, https://www.business-standard.com/budget/article/budget-2022-india-s-new-climate-pledges-await-funding-push-122013000073_1.html.
24. UN Environment Programme, "The Heat is On: a world of climate promises not yet delivered," UNEP, 2021, page 36, https://www.unep.org/resources/emissions-gap-report-2021.
25. UN Environment Programme, "The Heat is On: a world of climate promises not yet delivered," UNEP, 2021, page 36, https://www.unep.org/resources/emissions-gap-report-2021.
26. Plamena Tisheva, "UK's renewables share drops to 35.9% in Q3 2021 on slow winds," Renewables Now, Jan. 5, 2022, https://renewablesnow.com/news/uks-renewables-share-drops-to-359-in-q3-2021-on-slow-winds-768155/.
27. Nathaniel Bullard, "Technology Drives a Power Transition," Bloomberg Green, Dec. 2, 2021, https://www.bloomberg.com/news/articles/2021-12-02/technology-drives-a-power-transition?sref=E9Urfma4
28. Samuel Petrequin, "EU wants to allow natural gas, nuclear in green investment," Associated Press, Feb. 2, 2022, https://apnews.com/article/climate-business-france-environment-and-nature-europe-0e67a855946d49631560d11ba493e749.
29. "Nuclear Power in Belgium," World Nuclear Association, January 2021, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/belgium.aspx
30. European Commission, "Fossil fuels in gross available energy: 70% in 2020," Eurostat, Feb. 16, 2022, https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220216-1.

31. "Media office: Dubai aims to cut carbon emissions 30% by 2030," i24News, Feb. 6, 2022, https://www.i24news.tv/en/news/middle-east/environment/1644135011-media-office-dubai-aims-to-cut-carbon-emissions-30-by-2030.
32. "Environment Minister Explains How Nigeria Will Achieve Net Zero," Nigerian Tribune, Feb. 3, 2022, https://tribuneonlineng.com/environment-minister-explains-how-nigeria-will-achieve-net-zero/.
33. "Morocco targets 80% renewable energy by 2050 with technological evolution in energy storage, green hydrogen, and decreasing energy costs, says GlobalData," GlobalData, Feb. 7, 2022, https://www.globaldata.com/morocco-targets-80-renewable-energy-2050-technological-evolution-energy-storage-green-hydrogen-decreasing-energy-costs-says-globaldata/.
34. Benoit-Ivan Wansi, "MOROCCO: EU to invest €1.6bn in energy transition by 2027," Afrik 21, Feb. 11, 2022, https://www.afrik21.africa/en/morocco-eu-to-invest-e1-6bn-in-energy-transition-by-2027/.
35. "The Indonesian SDG Bond: A Leap Towards Financing the SDGs," UNDP, Oct. 6, 2021, https://www.id.undp.org/content/indonesia/en/home/presscenter/articles/2021/20211007.html.
36. "$150mn ADB Loan to Support Green Recovery in Indonesia," Tempo.co, Feb. 16, 2022, https://en.tempo.co/read/1561496/150mn-adb-loan-to-support-green-recovery-in-indonesia.
37. International Energy Agency, "World Energy Investment 2021," IEA, June 2021, page 15, https://www.iea.org/reports/world-energy-investment-2021.
38. David Vetter, "China Built More Offshore Wind In 2021 Than Every Other Country Built In 5 Years," Forbes, Jan. 26, 2022, https://www.forbes.com/sites/davidrvetter/2022/01/26/china-built-more-offshore-wind-in-2021-than-every-other-country-built-in-5-years/?sh=e5bacf646347.
39. Abhinav Chugh, Emanuele Taibi, "What is green hydrogen and why do we need it? An expert explains," World Economic Forum, Dec. 21, 2021, https://www.weforum.org/agenda/2021/12/what-is-green-hydrogen-expert-explains-benefits/#:~:text=Today%20the%20pipeline%20for%20green,the%20next%205%2D10%20years.
40. James P. O'Brien, Stanislav Sirot, Matthew I. Martin, and Rebecca Matey, "United States: Hydrogen technology receives substantial support and funding under the Infrastructure Investment and Jobs Act," Lexology, Feb. 11, 2022, https://www.lexology.com/library/detail.aspx?g=a9a9ef5f-d8b9-4d49-8364-5d9253895848.
41. Climate Action Tracker, "Japan," Climate Action Tracker, Feb. 10, 2022, https://climateactiontracker.org/countries/japan/.
42. Ministry of Economy, Trade, and Industry, "Outline of Strategic Energy Plan," METI, October 2021, https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf, page 12.
43. Reginald Davey, "Japanese Hydrogen Production: Electrolysis Fueled by Power from Chinese Offshore Wind," AZO Materials, Dec. 13, 2021, https://www.azom.com/news.aspx?newsID=57667#:~:text=To%20facilitate%20the%20economic%20viability,cost%2Dcompetitive%20with%20natural%20gas.
44. "Net Zero by 2050: A Roadmap for the Global Energy Sector," International Energy Agency (IEA), October 2021, https://www.iea.org/reports/net-zero-by-2050.
45. Ng Wai Mun, "Plastic to go? All eyes on world's first compulsory deposit return scheme for takeaway cups in South Korea," Eco-Business, Jan. 11, 2022, https://www.eco-business.com/news/plastic-to-go-all-eyes-on-worlds-first-compulsory-deposit-return-scheme-for-takeaway-cups-in-south-korea/.
46. Lauren Boland, "Targets for recycling plastic packaging will be 'extremely challenging' - so how do we do it?," TheJournal.ie, Jan. 22, 2022, https://www.thejournal.ie/plastic-packaging-waste-recycling-5654841-Jan2022/.
47. "Global Forest Resources Assessment 2020," Food and Agriculture Organization (FAO) of the United Nations, May 2020, https://www.fao.org/3/CA8753EN/CA8753EN.pdf#page=6, page 6.
48. "Global Forest Resources Assessment 2020," Food and Agriculture Organization (FAO) of the United Nations, May 2020, https://www.fao.org/3/CA8753EN/CA8753EN.pdf#page=6, page 7.
49. Joint News Release, "UN Report: Pandemic year marked by spike in world hunger," World Health Organization, July 12, 2021, https://www.who.int/news/item/12-07-2021-un-report-pandemic-year-marked-by-spike-in-world-hunger.
50. Chris Randall, "China counts more than 3 million NEV sales in 2021," Electrive.com, Jan. 11, 2022, https://www.electrive.com/2022/01/11/china-counts-more-than-3-million-nev-sales-in-2021/.
51. "Israel's Largest Fresh Produce Exporter, Mehadrin, to Use Save Foods' Treatments," Save Foods, Inc., (press release), Feb. 7, 2022, https://www.globenewswire.com/news-release/2022/02/07/2380066/0/en/Israel-s-Largest-Fresh-Produce-Exporter-Mehadrin-to-Use-Save-Foods-Treatments.html.
52. Nikolaj Skydsgaard, "Denmark's first green bond sees strong demand," The Jakarta Post, Jan. 20, 2022, https://www.thejakartapost.com/business/2022/01/20/demand-fordenmarks-first-green-bond-strong-as-it-raises-762-million.html.
53. "Europe's environmental taxes in decline, despite potentially crucial role," European Environment Agency (EEA), Feb. 7, 2022, https://www.eea.europa.eu/highlights/europes-environmental-taxes-in-decline.
54. Agustin Geist, Nicolas Misculin, and Adam Jourdan, "Argentina strikes breakthrough deal with IMF in $45 bln debt talks," Reuters, Jan. 28, 2022, https://www.reuters.com/world/americas/argentina-strikes-breakthrough-deal-with-imf-40-bln-debt-talks-2022-01-28/
55. "Hong Kong's Climate Action Plan 2050," Hong Kong government agencies (published policy plan), October 2021, https://www.climateready.gov.hk/files/pdf/CAP2050_booklet_en.pdf.
56. Zoe Low, "Hong Kong to phase out coal as a power generation source by 2035, Carrie Lam pledges in policy address," South China Morning Post, Oct. 7, 2021, https://www.scmp.com/news/hong-kong/health-environment/article/3151409/hong-kong-phase-out-coal-power-generation-source
57. United Nations Framework Convention on Climate Change, "NAPS from developing countries," UNFCCC, https://www4.unfccc.int/sites/NAPC/Pages/national-adaptation-plans.aspx
58. MIT Technology Review Insights, "The Blue Technology Barometer," MIT Technology Review, https://www.technologyreview.com/2022/01/05/1040367/the-blue-technology-barometer/

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