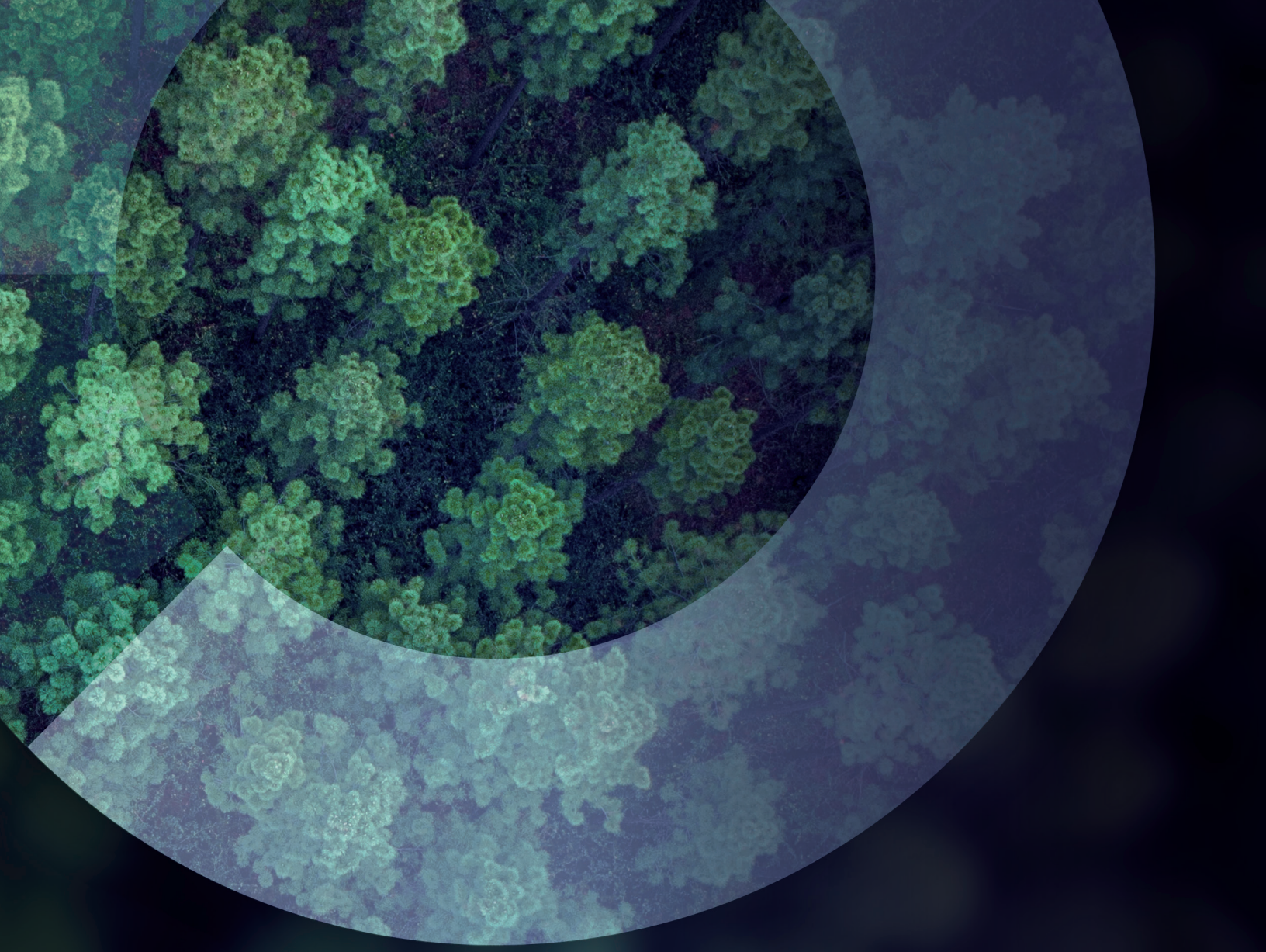


ESG360° | Kapnick on Climate

The global carbon market: How offsets, regulations and new standards may catalyze lower emissions and create opportunities

October 2021

J.P.Morgan
Asset Management

DR. SARAH KAPNICK, Managing Director, is Senior Climate Scientist and Sustainability Strategist for the Asset and Wealth Management (AWM) Strategy & Business Development organization. Dr. Kapnick supports AWM's sustainability and climate action efforts and serves as an advisor on new business and investment opportunities and risks.

Dr. Kapnick joins J.P. Morgan from the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL), where she was a climate scientist and Deputy Division Leader on Seasonal to Decadal Variability and Predictability and Group Lead on Climate Risk. Dr. Kapnick led development of NOAA GFDL's seasonal prediction products, climate risk quantification efforts, and worked with national and international partners to plan for extreme events and climate change. Her research included seasonal climate prediction, mountain snowpack, extreme storms, water security and climate impacts. Dr. Kapnick served as an expert and reviewer for NOAA's Small Business Innovation Research Program, was a member of its Eastern Region Climate Team, sat on the science panel for Climate.gov, and was the NOAA team lead for the National Aeronautics and Space Administration High Mountain Asia Team.

Dr. Kapnick is a member of the American Geophysical Union, American Meteorological Society and the American Association for the Advancement of Science. Prior to her graduate studies when she became an expert in the hydroclimate—water in the climate system including snow, precipitation extremes, mountain hydroclimate and water resources—she spent two years as an investment banking analyst with Goldman Sachs covering financial institutions. She received a Ph.D. in Atmospheric and Oceanic Sciences with a Certificate in Sustainability from UCLA, and an A.B in Mathematics with a Certificate in Finance from Princeton University.

AUTHOR

Dr. Sarah Kapnick
Managing Director
Senior Climate Scientist
and Sustainability Strategist

THE GLOBAL CARBON MARKET:

HOW OFFSETS, REGULATIONS AND NEW STANDARDS MAY CATALYZE LOWER EMISSIONS AND CREATE NEW OPPORTUNITIES

THE SCIENCE IS CLEAR: Climate change is predominantly caused by the emission of greenhouse gases into the atmosphere.[1] The atmosphere is composed of many gases, but one, carbon dioxide (CO_2)—at a 0.042% concentration today, up from only 0.031% 50 years ago[2]—is the main driver of climate change.[3] It may seem counterintuitive that such a small amount of CO_2 can warm an entire planet, but it is the most abundant "greenhouse," or heat-absorbing, gas. While 99% of the atmosphere is nitrogen and oxygen, they do not absorb the Earth's heat. Much like a tiny virus that can make you sick, CO_2 in the atmosphere is minuscule but mighty.

Zeroing out most emissions—by replacing fossil fuels with clean energy technology, improving energy efficiency and reducing other sources of emissions—will not be enough to halt and reverse climate change.[4] To keep global warming trends below 2º Celsius (C), the threshold outlined by the 2015 Paris Agreement[5] and recommended by scientists to avoid major future climatic damages, CO_2 removal technologies, potentially both nature-based and mechanical, will be needed. To reach negative net emissions by 2050, carbon removal (along with other strategies) will be necessary.

DESIRE FOR A NET-ZERO WORLD HAS LED TO THE EXPANSION OF THE GLOBAL CARBON MARKET—AN IMPORTANT INVESTMENT AREA

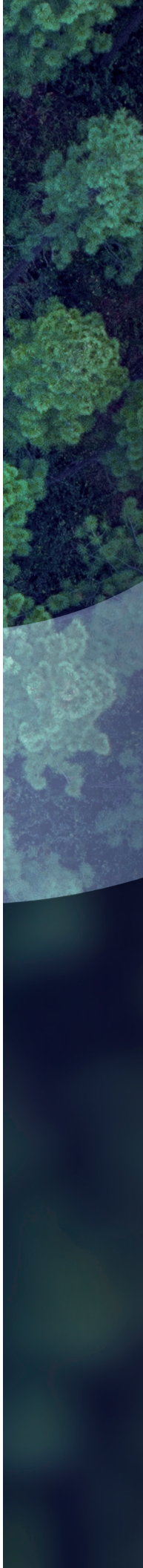
This desire for a net-zero world, in which greenhouse gases emitted are canceled out by those removed from the atmosphere, has led to a significant expansion of the global carbon (shorthand for carbon dioxide, CO_2) market. In a carbon market, technologies that reduce the amount of carbon a company (or an individual) produces—their "footprint"—create units of value called carbon offset credits, along with systems for certifying, registering and trading them.

Furthered by regulation and societal pressure, verified carbon credits have become an emerging investment area for companies and individuals as well as investors who may wish to help solve climate change and also achieve long-term returns. However, the carbon market's growth has been uneven, with notable national variances. The U.S., for example, has no current federal carbon regulation but does have two regional compliance markets.

Carbon removal technologies include nature-based and mechanical solutions. Both approaches can create carbon offsets that can be held, sold and traded on exchanges by those who want help compensating for carbon emissions occurring elsewhere. Many companies, governments and individuals are more than willing to purchase carbon offsets.

Forestry is the current dominant carbon offset solution. Forests sequester carbon through the growth of trees, which pull CO_2 out of the atmosphere and combine it with soil nutrients and water to grow. The segment remains a particularly appealing removal offset, especially as mounting scrutiny is given to some avoidance offsets (being paid to avoid a CO_2-emitting activity). Forestry also offers the potential for even greater stewardship opportunities.

Carbon market standards are still new and evolving. What exists today may not be right for the future. Here's some background on the carbon market opportunity, including forestry offsets, as well as some of the standards and limits to consider.



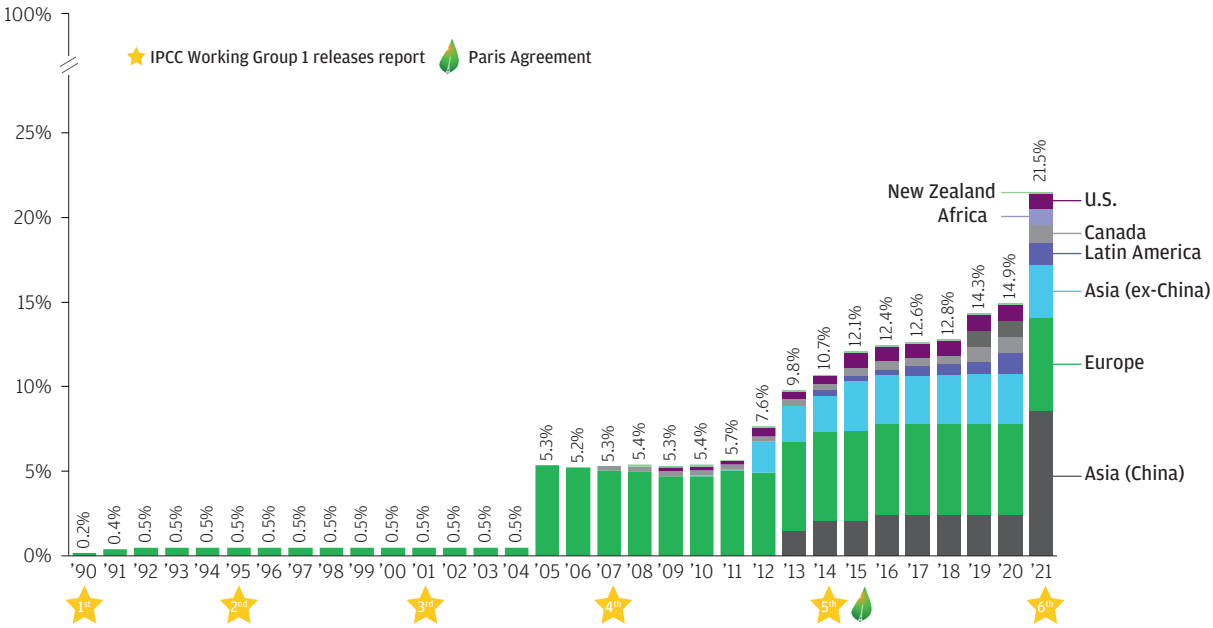
Carbon regulation and market development

Carbon regulation to reach a net-zero emissions world has been in development since 1990, when the first of a series of international reports began showing the growing urgency of action to reverse climate change (**EXHIBIT 1**). Regulation, by creating a pricing mechanism, incentivizes emissions reductions, carbon offsets and investment in technologies to reduce emissions.

But while the scientific evidence of climate change has strengthened, carbon regulation has not kept pace, developing only slowly. The share of global emissions subject to regulation was roughly stagnant from 2005–11. Recently, however, the share of global emissions covered by regulation has grown sharply, to 22% globally in 2021 from 5% in 2010. Regulatory coverage has risen steadily every year since the 2015 Paris Agreement. New carbon regulations (implemented and scheduled) jumped in 2021 as countries sought to show leadership in advance of November's U.N. Climate Change Conference 26 (COP26) in Glasgow, where countries will negotiate measures for addressing climate change. Carbon emissions are now subject to regulation worldwide.

Carbon regulation has grown steadily, albeit slowly, over time

EXHIBIT 1: GLOBAL EMISSIONS COVERED BY A CARBON TAX OR EMISSIONS TRADING SYSTEM (%)



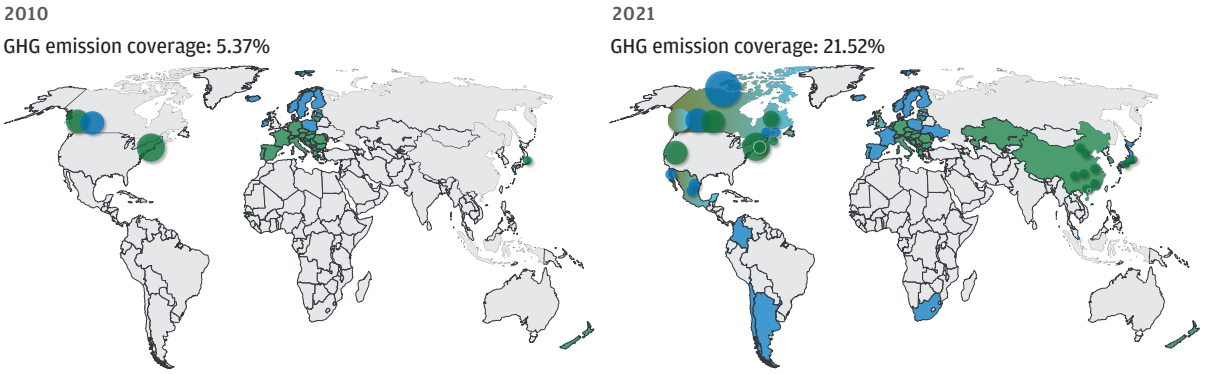
Source: World Bank Carbon Tracker, U.N. Intergovernmental Panel on Climate Change; data as of April 1, 2021, and August 9, 2021, respectively.

Global participation in carbon regulation: Growing but uneven adoption

The number of countries participating in carbon market regulation has been growing (**EXHIBIT 2**). As of 2021, China's national emissions trading scheme (ETS) covers the largest share of global greenhouse gas (GHG) emissions (7%),[6] followed by the European Union's (EU's) ETS (3%) and Japan's carbon tax (2%). Regulations, including these, don't necessarily cover all carbon emitters; they may only cover specific sectors and thus have the potential to grow within each jurisdiction. For example, the Chinese regulation market presently covers the power sector, representing 40% of national emissions. But the government has indicated its intention to expand to other sectors in the future.

Global carbon regulation has expanded notably

EXHIBIT 2: COUNTRIES OR REGIONS COVERED BY CARBON REGULATION (TAX OR ETS), 2010 VS. 2021

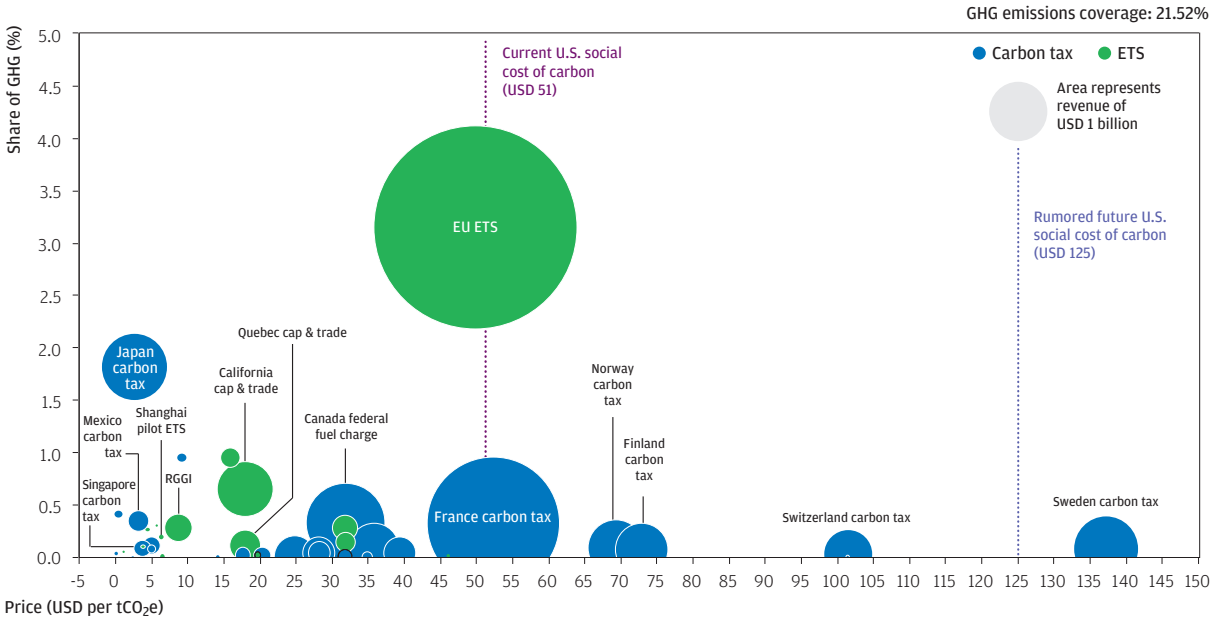


Source: World Bank Carbon Tracker; data as of April, 1, 2021. Includes initiatives scheduled for implementation (formally adopted through legislation with an official start date) and "under consideration" (the government's intention to work toward implementation announced and formally confirmed by official sources). GHG: greenhouse gases; ETS: emissions trading system.

This global patchwork of regulations has led to a wide range in price per metric ton of CO_2 and equivalents—tCO_2e—around the world (tCO_2e allows all regulated gases to be converted to the same unit for common pricing) (**EXHIBIT 3**). The tCO_2e price is either set by a carbon tax or varies in response to a market. In some markets, prices vary by individual greenhouse gas, reflecting different costs for their reduction or differences in the desired phase-out date. The primary price for fossil fuel-based CO_2e is called the "tier 1" carbon price. For perspective, an average American emits more than 15 tCO_2e a year; globally, the average is around 4.5 tCO_2e per person.[7]

A global patchwork of regulation created a wide range in price for a ton of carbon or its equivalents (tCO_2e)

EXHIBIT 3: SHARE OF GLOBAL EMISSIONS, CARBON PRICING AND REVENUES



Source: World Bank Carbon Tracker; data as of April 1, 2021 (carbon share and pricing), and December 31, 2020 (carbon tax, ETS revenues). All prices use tier 1 pricing. Chart excludes China because with very recent ETS implementation, data is not currently available.

THE LATEST ON CARBON PRICING: GOVERNMENTS AND MARKETS, EU AND U.S.

Historically, carbon pricing has been higher when calculated by governments for the purposes of a carbon tax than when priced by markets in emissions trading systems. If, in the future, markets were constrained by lower allowable emissions allotments (by governments acting more aggressively to reach net-zero goals), ETS prices would increase. Differences in regional carbon prices, often the outgrowth of more lax emissions standards in some locations, have led the European Commission's Fit for 55 plan[8] to include a proposed "carbon border adjustment mechanism," much like a tax, to prevent carbon leakage: the transfer of carbon-intensive activities to jurisdictions with laxer emissions rules. These constraints are policy decisions, either through the levying of taxes, typically based on a set carbon price, or through emissions caps that set maximum emissions, with carbon prices moving in a trading system.

Of note, there is no current U.S. federal carbon regulation. Despite signing the Paris Agreement in 2015, the U.S. began withdrawal in 2017 and formally dropped out on November 4, 2020. During this time, carbon regulation was stagnant. The U.S. formally rejoined on February 19, 2021, after President Joe Biden signed an executive order.

While there is not a carbon price in the U.S. on which to base regulation, there is a pricing framework to aid policy decisions. In early 2021, the Biden administration revised the federal social cost of carbon, a value per tCO_2e to guide federal cost-benefit analyses of greenhouse gas emissions, to inform planning for setting a carbon tax or an ETS carbon emissions cap.[9] The estimate was temporarily set to USD 51 per tCO_2e—the prevailing price during the Obama administration.[10] During the Trump administration, carbon was priced as low as USD 1 per tCO_2e. An interagency working group is presently reviewing the latest science and economics to develop a new estimate, due January 2022.[11] There is speculation a price could be set above USD 125 per tCO_2e.[12] The UK updated its regulatory pricing guidelines in September 2021, with this year's ranges between GBP 122 and GBP 367 per tCO_2e.[13] Debate is growing over the use of social cost of carbon to inform policy,[14] yet the conversation itself highlights the surging interest and focus on the developing carbon market.

TWO TYPES OF CO_2 REMOVAL TECHNOLOGIES

In order for carbon, and carbon offsets, to trade on exchanges that carbon pricing has and will continue to foster, carbon removal technologies are a linchpin. Such technologies include:

- **Nature-based solutions** that manage ecosystems like forests, mangroves, kelp beds and soils that naturally sequester CO_2.
- **Mechanical removal of CO_2 from air or the ocean with direct capture technologies that use machines to extract CO_2** to create other carbon-based materials, including plastics, carbon-embedded cements and rocks buried deep underground.

Projects using these technologies to remove or reduce a carbon footprint can be verified for carbon offset credits. Companies and individuals can purchase verified carbon credits to reduce their overall emission counts. Investors can invest in these types of environmental projects or technologies to help provide climate change solutions and for their long-term return potential.

CARBON REGISTRIES: KEY FOR OFFSET VERIFICATION AND CERTIFICATION

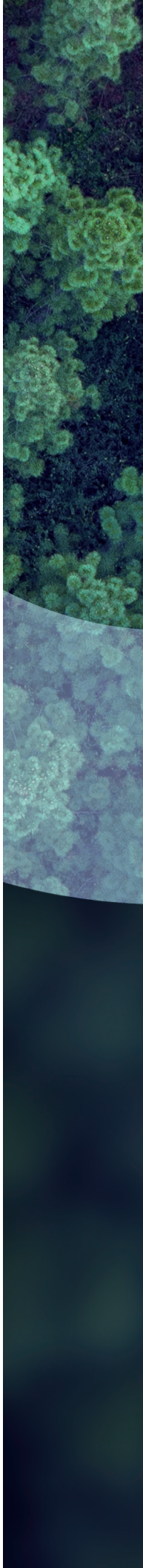
Carbon registries help verify, certify and track carbon offset projects to avoid double counting. There are two types of registries: compliance and voluntary. Compliance registries are a market used by entities that are required by law to account for their carbon emissions. Voluntary carbon registries have formed in the last 20 years to meet emerging demand for both carbon offsets and overall carbon management where interest has grown faster than regulation.[15] **EXHIBIT 4** describes a number of registries.

Carbon registries can vary in specialization and regional footprint

EXHIBIT 4: CHARACTERISTICS OF COMPLIANCE AND VOLUNTARY REGISTRIES WORLDWIDE

Source	Location	Started	First issued	Type	Total Credits Registered ($MtCO_2e$)	Offsets (%)	Countries
Verra	Washington, DC	2007	N/A	Voluntary	291 (annual)	• Energy (58%) • Agriculture, forestry & other (31%) • Fugitive emissions (5%)	• India (25.3%) • China (23.6%) • Indonesia (5.4%)
ARB Offset Credit Issuance	Sacramento, CA	2018	2013 (earliest vintage 2004)	Compliance	224 (lifetime)	• Forest (82%) • Ozone depleting substances (11%) • Mine methane capture (4%)	All U.S.: • AK (18.7%) • CA (14.4%) • WV (10.8%)
American Carbon Registry (ACR)	Arlington, VA	1996 (the first econ-wide cap-and-trade prog. in the U.S., since Dec '12)	2002 (earliest vintage 1998)	Voluntary	194 (lifetime)	• Forestcarbon (64%) • Carbon capture & storage (13%) • Ozone depleting substances (6%)	• U.S. (97.4%) • Brazil (2.5%)
Gold Standard	Geneva, Switzerland	2003	2008 (earliest vintage 1996)	Voluntary	182 (lifetime)	• Wind (32%) • Energy efficiency (29%) • Other (15%) – includes forestry	• Turkey (25.5%) • India (14.0%) • China (13.6%)
Carbon Plan (CDR)	CA	2020	2020	Voluntary	171 (lifetime)	• Forests (62%) • Biomass (17%) • Soil (9%)	• U.S. & North America (48.0%) • Australia (6.4%) • Philippines (5.9%)
Climate Action Reserve (CAR)	Los Angeles, CA	2001	2005	Voluntary	166 (lifetime)	• Forestry (50%) • Landfill (21%) • Ozone depleting substances (11%)	• U.S. (99.8%)
Clean Development Mechanism (CDM)	Bonn, Germany (current); Geneva, Switzerland (previously)	Secretariat was established in 1992 when countries adopted the UNFCCC	2012	Compliance	75 (lifetime)	• Energy industries & demand (51%) • Chemical industries (25%) • Waste handling & disposal (10%) • Afforestation & reforestation (8%)	• Korea (33.5%) • India (17.6%) • Brazil (8.8%)

Source: Individual registries; data as of August 11, 2021 (Clean Development Mechanism as of July 2, 2021). Total credits registered are the annual estimated credits (Verra), total lifetime credits issued (ARB, American Carbon Registry, Gold Standard, Climate Action Reserve) and total lifetime credits retired for carbon(plan) and Clean Development Mechanism. ARB credits are also registered in American Carbon Registry, Climate Action Reserve and Verra. UNFCCC: UN Framework Convention on Climate Change.



TYPES OF CARBON EMISSION OFFSETS

Offsets can take two main forms:

- **Avoidance offsets** are generated by activities that reduce future emissions through prevention—for example, by building a wind farm instead of a new natural gas energy plant.
- **Removal offsets** extract carbon from the atmosphere or ocean by nature—such as forestry—or by mechanical removal.

Of late, avoidance offsets have come under scrutiny, especially as energy from renewables becomes more cost-competitive with fossil fuels. Evolving carbon regulations and verification standards may prompt stricter requirements for offsets, particularly around verification of carbon offset delivery and proof that projects do not result in leakage. Ultimately, carbon markets develop to provide financial incentives to reduce emissions.

Forestry represents the majority of both removal offsets and total offsets, by tCO_2e, across all registries. In 2021, forestry represented 40% of all offsets registered—both those available on the market (called "issued" projects) and those already purchased (called "retired" projects). U.S. registries have significant forestry holdings. For example, at Climate Action Reserve, a major U.S. registry, forests accounted for over 80% of offsets in 2019. Standards and projects are also evolving for other nature-based removal offsets, including mangroves, kelp beds and soils, as early standards did not consistently deliver carbon removal.[16]

Technologies to directly capture carbon from the air or oceans are still in early development. Major barriers to adoption relate to their materials and energy requirements,[17] as well as costs (estimated low ranges are from USD 250–USD 600 per tCO_2e) that far exceed the current price of carbon in the compliance or voluntary markets (EXHIBIT 3).[18] The largest facility, recently opened under ideal conditions in Iceland, took 18 months to build and will annually remove the equivalent of only 860 U.S. gasoline-powered cars.[19, 20]

A FORESTRY CASE STUDY: TREES' EFFICIENCY IN CAPTURING CARBON

Forests remove carbon from the atmosphere because trees grow by taking in CO_2 and combining it with soil nutrients and water. Forestry carbon offsets are generated by the growth of forests as trees mature and sequester carbon in their wood. It takes roughly 40 years for a hardwood tree to sequester 1 tCO_2e.

Most offset projects relate to reforestation, where trees are replanted or grown where a forest once stood, or afforestation, where trees are planted where they have not previously stood. These projects are designed to maximize carbon removal, a different approach from that taken with mature forests, which have less sequestration potential. In mature old-growth forests, avoided deforestation offsets have been used to incentivize leaving trees standing, but they have come under scrutiny for fear of leakage.

Varied standards have developed for forestry offset certification to ensure common practices and measure whether they deliver their stated carbon removal targets. However, there is room for improvement (**EXHIBIT 5**). A review of offsets from available registries has shown that some forestry projects have been overcredited; for these projects, carbon removal assumptions were systematically low because they reflected carbon removal for the wrong tree species.[21] This highlights the need for making the definitions and methods to calculate carbon removal more robust, to ensure accurate delivery.

How forestry projects are credited could be improved

EXHIBIT 5: STANDARDS FOR FORESTRY CARBON OFFSET CERTIFICATION

Forest inventory is monitored, with specified forest measurement intervals and sub-regions, and in-person, on-the -ground verification. Newer registries are also including satellite monitoring guidelines.	**Use of an estimation methodology, including modeling uncertainty,** to extrapolate carbon sequestration from a few monitoring sites across a broader region held for offsets (instead of measuring every tree, a subset of trees are monitored). Some stipulate measurement and modeling error thresholds, demanding an estimate of error and specific precision.	**Risk management** is included. Guidelines stipulate that a percentage of forests be held as a "buffer pool" to ensure carbon offsets are delivered. If losses of trees due to extreme weather, wildfire, disease or pests exceed those of the buffer pool, there may be penalties.	**Permanence guidelines** vary among registry providers. Since the goal of forestry offsets is to remove carbon from the atmosphere to provide a climate solution, end users burning wood for energy, or deforestation releasing carbon, would undermine the offsets. Permanence guidelines can require holding timber for between 10 and 100 years. Newer, satellite-based verification services do allow for cash flows from forestry assets, but if trees are later removed, offsets could later be reversed.	**Species-specific guidelines** may also cover certain tree types, since carbon sequestration can differ by tree species and climate (humid and warm vs. cooler and drier). These are less common than other guidelines.

Source: J.P. Morgan Asset Management.

A criticism of forest offsets has emerged: that primarily single-species tree farms are being grown rather than developing healthy ecosystems. By contrast, the highest quality forestry carbon offsets could provide forestry stewardship, protecting and expanding forests critical for carbon removal and global forestry health,[22] with pricing reflecting the costs to deliver sustainability goals.

This would allow for the bundling of positive outcomes from forestry offsets, including:

- **Carbon removal** by capturing CO_2 from the atmosphere and transforming it into biomass (i.e., trees, kelp, mangroves). This requires planting, watering and potentially fertilizing to "farm" carbon removal.
- **Meeting the conservation goal** of protecting natural land; this may be of special interest to countries making "30 x 30" pledges in advance of COP26 (protecting 30% of land and ocean for conservation by 2030).
- **Meeting the biodiversity goals** of planting trees and monitoring wildlife to develop healthy ecosystems and support biodiversity.
- **Supporting rural economies** by creating jobs and access to forests for tourism and recreation.
- **Supporting indigenous populations** in maintaining cultural traditions through access to forests and creating an income source in managing land (our analysis to create EXHIBIT 4 found that several U.S. projects are managed by indigenous people).
- **Lowering wildfire risk** by removing debris and other active fire reduction management strategies. The history of fire suppression activities in certain dry forests (e.g., the western U.S.) with natural wildfire cycles have left excess fuel for fires to burn more intensely once ignited. With increased wildfire risks due to climate change, intentional management may lower the risks of catastrophic, large-scale fires,[23] but this requires careful management, clear standards and scientific research to guide activities.
- **Climate adaptation** by planting tree species for projected regional climate change conditions to improve long-term forest resilience.

OFFSETS' CURRENT PHYSICAL LIMITS, WITH A LIKELY RISE IN DEMAND AHEAD

There is the potential for an offset supply issue, given the likelihood of increased demand as corporations strive to meet their net-zero commitments. This could put substantial pressure on carbon prices.

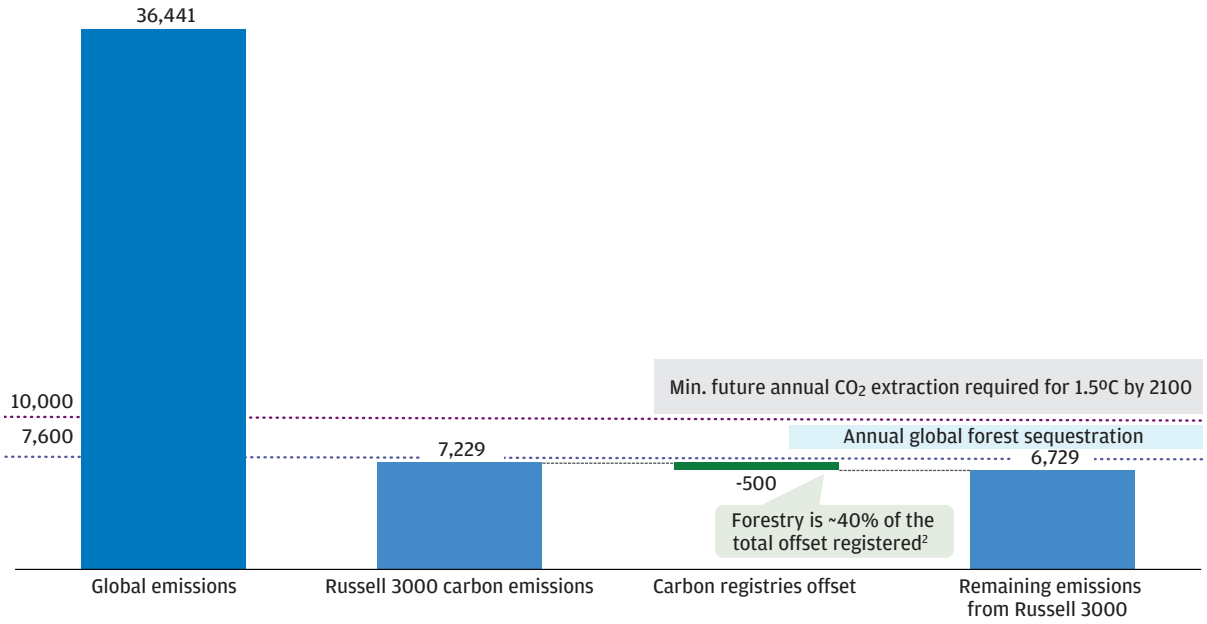
Consider **EXHIBIT 6**: In 2019, global emissions from all sources reached 36 billion tCO_2e. The Russell 3000 Index, benchmarking the entire U.S. stock market, emitted 7 billion tCO_2e.

Global forests sequester significant CO_2 from the atmosphere annually. Measuring this removal over the last decades using satellites, scientists estimate that 7.6 gigatons (Gt) of CO_2 e are absorbed by forests annually, as represented by the dotted purple line in the chart.[24] But this uptake of carbon is not a global offset to be monetized, as it does not create additional removal to reduce emissions and slow or reverse climate change. For corporations to achieve net-zero emissions by offsetting their total global emissions by forestry alone, the world would have to more than double this natural process. Meeting the annual carbon removal required by the Paris Agreement to reverse climate change and stop further warming (if 2ºC or 1.5ºC targets are the goal) by 2100 would demand a sizable scaling up, as shown by the dotted purple line in Exhibit 6.

Yet we estimate a global offset supply of only 0.5 Gt CO_2e, highlighting the need for significant expansion to reduce emissions and meet net-zero goals in the coming decades. Of course, forestry will not be the only solution, but it is the dominant (40% of offsets in 2019) and only scalable removal method today.

The supply of carbon offsets currently listed on registries is small compared with U.S. corporate emissions

EXHIBIT 6: EMISSIONS DWARF THE SUPPLY OF CARBON OFFSETS



Source: Global Carbon Atlas, Russell 3000, MSCI, carbon registries; data as of December 31, 2019. Offsets are those registered on Climate Action Reserve, American Carbon Registry, Carbon Plan, Gold Standard, Verra and Clean Development Mechanism.

Globally, however, as human activities emit CO_2 beyond what the Earth system can naturally absorb in forests and oceans, ecosystems are likely to become more stressed and oceans warmer, potentially reducing these natural sinks and leaving even more carbon emissions in the atmosphere each year, accelerating climate change. As long as global emissions exceed removal, climate change will follow.

Ultimately, the global climate warms in proportion to the amount of CO_2e left in the atmosphere. Every ton of carbon emissions matters. Solutions need to scale to reduce global emissions; offsets play a part, but they are not the sole solution.

WHAT DOES THIS ALL MEAN?

To reach a net-zero world, emissions need to decline. To keep global temperature rises below 2ºC, both nature-based and mechanical offsets will need to scale. High quality, nature-based offsets such as forests may provide additional positive economic, natural, cultural and other outcomes. Global coordination, such as the COP26 meeting in Glasgow and private sector efforts led by the Taskforce on Scaling Voluntary Carbon Markets, will bring carbon markets and offset development further into focus.

Investing during a time of climate change

Mitigating and reversing climate change will take significant investment. Up to USD 4 trillion per year will be needed globally through 2050 to achieve a 1.5ºC target across various sectors, such as power, iron and steel, cement, chemicals, transport, aviation, shipping, agriculture and buildings.[25]

This requires:

- **Replacing high emission activities**, such as fossil fuel energy generation, with clean energy.
- **Reducing emissions in all sectors** as close to zero as feasible, given technological availability. This means improving energy efficiency where there are no zero-carbon alternatives.
- N**ew technologies, materials and recycling** to decarbonize sectors beyond energy production. This includes hard-to-decarbonize sectors without clear technological solutions, such as aviation and cement.
- **Waste and agriculture management** for the reduction of methane, a short-lived greenhouse gas whose main impact lasts a decade.

For processes that cannot be replaced with zero-carbon alternatives now and/or in the future, carbon removal through nature-based or mechanical means will be necessary. Investment today is critical—to deploy existing solutions and develop the technologies of tomorrow needed to combat climate change.

TAKING PERSONAL ACTION

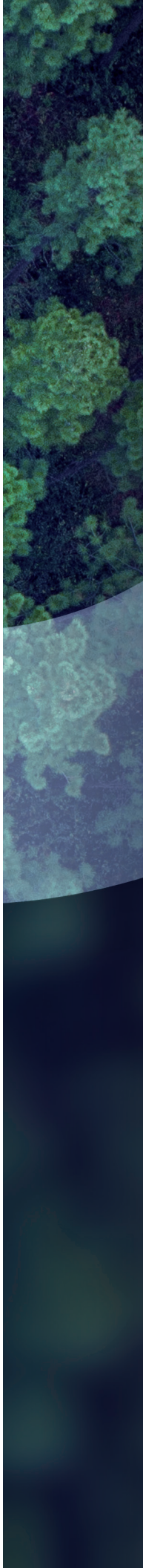
If you are curious about your own carbon footprint, there are calculators to identify your carbon emission total and its sources. In the U.S., the EPA offers a calculator that can help quantify your household carbon footprint.[26] The World Wildlife Fund has developed country-specific calculators.[27]

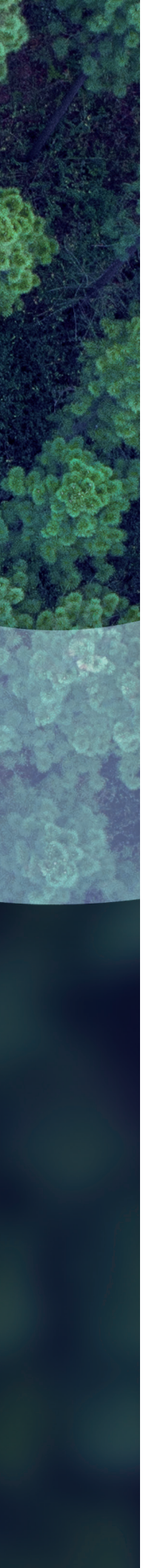
Given the likelihood of growing carbon regulation worldwide and cross-border carbon taxes, business managers would be prudent to begin monitoring CO_2e emissions and budgeting for potential future costs.

To date, several nongovernmental organizations have been involved in forest conservation and carbon offset projects, and they have provided the research, monitoring and local engagement to make many nature-based solutions possible. For further information, see the Trust for Public Land, National Forest Foundation and Conservation International.

Compliance and voluntary carbon registries developed in response to past regulation and social pressures. In the near future, new U.S. regulations may catalyze carbon reductions. The infrastructure package before the U.S. Congress could reduce annual emissions by 1 billion tCO_2e by 2030 if implemented.[28] The EU's Fit for 55 package outlines measures to reduce emissions by at least 55% by 2030. For more information on environmental voting issues, review the Environmental Voter Project and Citizens' Climate Lobby.

To discuss this paper or learn more about our climate change work please speak to your J.P. Morgan representative, or visit the Sustainable Investing section of our website.





ENDNOTES

1 Gases that trap heat in the atmosphere include carbon dioxide (CO_2), methane, nitrous oxide and fluorinated gases. In the U.S., these gases represent 80%, 10%, 7% and 3%, respectively, of 2019 greenhouse gas emissions by tons of CO_2 equivalents. "Overview of Greenhouse Gases," U.S. Environmental Protection Agency.

2 "The Keeling Curve," Scripps Institution of Oceanography, UC San Diego.

3 There have been six reports by the United Nation's Intergovernmental Panel on Climate Change (IPCC) (in 1990, 1995, 2001, 2007, 2014 and 2021), which changed in tone from providing a theoretical basis for climate change with some observed changes to later making unequivocal statements on the human influence on the climate and the potential for major changes and extreme events if emissions continue.

4 Climate simulations in the sixth IPCC report used models with five main methods to reduce global emissions to net zero/negative: 1) reduce fossil fuel use, 2) reduce energy demand, 3) use nature-based solutions, 4) reduce greenhouse gas emissions besides CO_2, and 5) mechanical removal from the air. Jordan Wilkerson, "Half of the IPCC Scenarios to Limit Warming Don't Work," Eos 102, July 7, 2021.

5 The Paris Agreement is a legally binding international climate change treaty adopted by 196 countries at U.N. Climate Change Conference 21 (COP21), held in Paris in 2015, with the goal of keeping global warming below 2ºC and preferably below 1.5ºC, compared with preindustrial temperatures (before 1860).

6 Developed first for provinces and cities, over the last decade the Chinese ETS was recently implemented nationally.

7 "CO_2 emissions (metric tons per capita)," World Bank.

8 See note 7.

9 This value quantifies the cost of additional damages caused by CO_2e emissions, including but not limited to: health effects, loss of life, damage to properties, reductions in agricultural productivity and damage to ecosystems.

10 "A Return to Science: Evidence-Based Estimates of the Benefits of Reducing Climate Pollution," the White House (blog), February 26, 2021.

11 "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide: Interim Estimates under Executive Order 13990," Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, February 2021.

12 Paul Voosen, "Trump downplayed the costs of carbon pollution. That's about to change," Science 371, no. 6528, January 29, 2021.

13 "Valuation of greenhouse gas emissions: for policy appraisal and evaluation," UK Department for Business, Energy & Industrial Strategy, September 2, 2021.

14 Joseph E. Aldy, Matthew J. Kotchen, Robert N. Stavins, et al., "Keep climate policy focused on the social cost of carbon," Science 373, no. 6557, August 20, 2021.

15 A legally binding voluntary greenhouse gas trading system, the Chicago Climate Exchange, operated from 2003-10, covering six greenhouse gas emission sources and offset projects but closing due to inactivity and lack of regulatory development.

16 Jane Zelikova, Freya Chay, Jeremy Freeman et al., "A buyer's guide to soil carbon offsets," (carbon) plan, July 15, 2021.

17 Sudipta Chatterjee and Huang Kuo-Wei, "Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways," Nature Communications 11, no. 1, July 3, 2020.

18 Katie Lebling, Noah McQueen, Max Pisciotta et al., "Direct Air Capture: Resource Considerations and Costs for Carbon Removal," World Resources Institute, January 6, 2021.

19 On September 8, 2021, Climeworks announced it had broken ground for its first major direct air carbon capture facility in Iceland. The location was chosen for the site's abundance of cheap, renewable geothermal power to run the plant and the location's ideal geology deep underground to convert and store CO_2 as rock.

20 Using 2020 estimates from the U.S. Environmental Protection Agency and the Federal Highway Administration. See "Greenhouse Gases Equivalencies Calculator—Calculations and References," EPA.

21 Grayson Badgley, Jeremy Freeman, Joseph Hamman et al., "Systematic over-crediting of forest offsets," carbon(plan), April 29, 2021.

22 Johan Rockström, Tim Beringer, David Hole et al., "We need biosphere stewardship that protects carbon sinks and builds resilience," Proceedings of the National Academy of Sciences of the United States of America 118, no. 38, September 21, 2021.

23 Paul F. Hessburg, Susan J. Prichard, R. Keala Hagmann et al., "Wildfire and climate change adaptation of western North American forests: a case for intentional management," Ecological Applications, 2021.

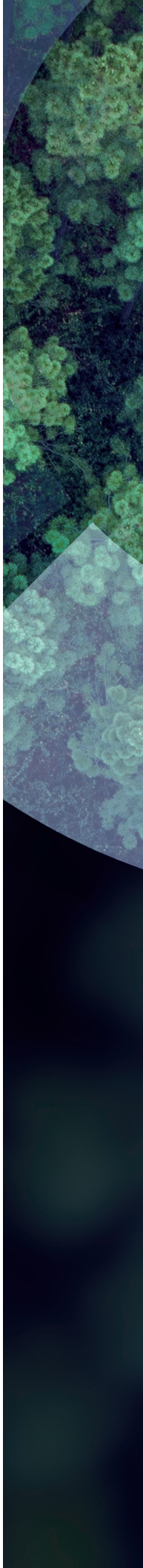
24 Nancy L. Harris, David A. Gibbs, Alessandro Baccini et al., "Global maps of twenty-first century forest carbon fluxes," Nature Climate Change 11, no. 3, 2021.

25 "Climate Finance Markets and the Real Economy," Boston Consulting Group and Global Financial Markets Association, December 3, 2020.

26 "Carbon Footprint Calculator," U.S. Environmental Protection Agency.

27 "Local footprint calculators," World Wildlife Fund.

28 Net U.S. emissions were 5.8 Gt CO_2e in 2019, according to the EPA. For an estimate of infrastructure package reduction, see John Larsen, Ben King, Hannah Kolus et al., "Pathways to Build Back Better: Nearly a Gigaton on the Table in Congress," Rhodium Group, September 15, 2021.



LET'S SOLVE IT®

LV–JPM53391 | 10/21 | 09dl211310114223