2023 ASPEN INSTITUTE WINTER ENERGY FORUM

ACCELERATING DECARBONIZATION & A CLEAN ENERGY TRANSITION

A Report from
2023 Aspen Institute Winter Energy Forum

Roger Ballentine & Jim Connaughton, Co-Chairs
Dave Grossman, Rapporteur

Energy & Environment
aspen institute

The Aspen Institute is an educational and policy studies organization based in Washington, D.C. Its mission is to foster leadership based on enduring values and to provide a nonpartisan venue for dealing with critical issues. The Institute has campuses in Aspen, Colorado, and Washington, D.C. It also maintains offices in New York City and has an international network of partners. www.aspeninstitute.org

Aspen Institute Energy and Environment Program (EEP) explores significant challenges with diverse thinkers and doers to make a more prosperous, equitable, and sustainable society for all. We address critical energy, environmental, and climate change issues through non-partisan, non-ideological convening, with the specific intent of bringing together diverse stakeholders to improve the process and progress of policy-level dialogue. This enables EEP to sit at a critical intersection in the conversation and bring together diverse groups of expert stakeholders. In addition to energy and environmental policy, which the program has been addressing for several decades, EEP is now actively and purposefully engaging in climate change policy – mitigating the effects of climate change, adapting to the inevitable impacts of climate change, and the international cooperation needed to achieve these goals.

This report from the **Aspen Winter Energy Forum** is issued under the auspices of the **Aspen Institute Energy & Environment Program**, and attempts to capture key themes, ideas, and perspectives raised during the Forum. This convening, like most hosted by the Energy & Environment Program, was held under a not-for-attribution rule, with the exception of the publication of the names and affiliations of participants in the appendix of this report.

Participants were not asked to agree to the wording of this report and, therefore, neither participants, sponsors, discussants, nor their organizations, are responsible for the report contents. Not all views captured in this report were unanimous and the contents of the report cannot be attributed to any one individual or group of individuals in attendance. The report does not necessarily represent the views of the Aspen Institute nor the Energy and Environment Program, nor any of their respective staff or scholars.

For all inquiries, please contact:

Energy & Environment Program
The Aspen Institute
2300 N Street, NW | Suite 700
Washington, DC 20037
Phone: 202.736.2933

The Aspen Institute
2300 N Street, NW | Suite 700
Washington, DC 20037

Published in the United States of America in 2023 by The Aspen Institute

TABLE OF CONTENTS

EXECUTIVE SUMMARY 2

FEDERAL POLICY GAINS 5

ROLE OF CAPITAL MARKETS 10

ELECTRICITY SECTOR 12

OIL & GAS 17

DECARBONIZING CEMENT 20

A GLOBAL CHALLENGE 25

CARBON REMOVAL 29

APPENDICES

- PARTICIPANTS 33
- AGENDA 35

EXECUTIVE SUMMARY

Over the past couple of years, the U.S. Congress has enacted a suite of federal laws that aim to deploy infrastructure, enhance energy security, and accelerate a clean energy transition. These laws, for the most part, consist entirely of carrots and no sticks; they provide a truly massive amount of funding. While the laws are already impacting companies' decisions and creating a giant pull of capital to the United States, guidance from the Treasury Department on a range of provisions is essential to spur projects and investments. There are also other potential obstacles that could slow deployment, including requirements in the laws (e.g., related to domestic content and environmental justice), supply chain constraints, and siting and permitting challenges. The delivery of most of the federal funding occurs in and through the states. Each state has its own unique priorities, attributes, and challenges, though many challenges are similar, including a significant lack of capacity and bandwidth. In addition, the laws provide the Department of Energy with billions of dollars for advanced clean energy demonstrations, but picking the right projects is a challenge; there will be a tsunami of applications in the coming months, and independent experts are needed to evaluate and score the proposals.

While the recent federal laws will deliver billions of dollars in funding per year, trillions need to be deployed globally each year to achieve climate goals. Public money must mobilize private investment. The recent laws provide large subsidies that could accelerate investments in climate-friendly technologies but could also cause viable projects to wait to deploy until they can get federal money. Policy can create additional risks for investors and financial institutions as well, such as the current political tensions over environmental, social, and governance (ESG) investing; the reality is that low-carbon projects are still getting significantly less financing than fossil projects. To achieve long-term goals, the blending and balance between the E and S of ESG will be critically important, both in areas where those are in tension (e.g., new mining) and in areas where those are mutually reinforcing (e.g., environmental justice). Beyond banks and investors, there are customers and companies with money to spend and sustainability commitments to meet. Since the large quasi-regulatory ecosystem of greenhouse gas accounting rules and protocols around carbon credits and offsets has a huge influence on flows of private capital to address climate, developing the appropriate incentive structures in the voluntary carbon market is vital.

Of the big sectoral sources of greenhouse gas emissions, the easiest one to decarbonize is electricity — but it is still incredibly hard. To get to net-zero, the power sector will need to grow a lot, but transmission access, siting, and permitting remain fundamental challenges. The growth needed in the grid also means many terawatts of carbon-free generation need to be built. The recent federal laws have started spurring utilities to increase planned deployments of carbon-free resources and battery storage, early retirements of coal plants, and retention of existing nuclear. Utilities can get much, but not all, of the way to 100% clean with current technologies, but they will need some form of new clean dispatchable generation. Community opposition could present potential roadblocks to deployment of some technological options, particularly at scale. Affirmative, proactive, honest community engagement must be pursued in a way it has not been in the past. Consultative processes matter, as do job creation, health benefits, and opportunities for wealth creation. Utilities and regulators are in a tough spot, trying to achieve decarbonization in a cost-effective way while the costs of reliability and the burdens of energy costs on communities are both mounting. At the same time, some big energy buyers have deployed a ton of energy efficiency and renewable energy measures, but each big customer pursuing its own aims will not result in the systemic changes necessary; large buyers should be figuring out how they can contribute to plans for decarbonizing their regional grids.

As for the oil and gas sector, most big companies are having active internal conversations about their decarbonization and transition strategies. Given the global turmoil in energy markets and the sanctions against Russia, large oil and gas producers simultaneously feel an obligation to supply energy to ally countries. Some oil and gas companies have revisited their climate targets, including making decisions to slow the divestment of mature assets from company portfolios (though divestment of an asset does not actually further decarbonization if someone else buys and operates it). While it is necessary to backfill lost supply to meet current hydrocarbon demand, care must be taken to move in the direction of fundamentally reducing demand and to avoid making near-term decisions that lock in emitting infrastructure for decades. Meeting climate goals, however, does not necessarily mean a world with no fossil fuels, and who produces those fuels matters a great deal in terms of international cooperation and security. Markets are not currently set up to differentiate lower-carbon supplies of oil and gas. In terms of options besides oil and gas, electrification can replace oil and gas demand in some cases, but there will also be a need for zero-carbon molecules. Some companies are using capital generated from oil and gas to invest in biofuels, hydrogen, and carbon capture, which all have promise and challenges.

With respect to industrial production, cement and concrete represent a small but significant percentage of annual global greenhouse gas emissions, with substantial growth expected in developing countries. Decarbonization of current cement production involves addressing either the heat used in making cement or the carbon dioxide released from the chemical breakdown of limestone during the cement-making process itself. Energy costs for cement kilns are very low, so economic decarbonization options for heat must be developed. To address the emissions from the chemical breakdown of limestone, carbon capture is one option, and there are also companies developing new chemical processes on new rock to make ordinary cement. Another approach to reducing emissions from the sector is to simply use less cement, which could involve efforts on both the demand side (e.g., changing designs, utilizing new building methods) and the supply side (e.g., novel cements, replacement materials). New materials, however, face challenges in terms of permitting, regulations, insurance, and convincing engineers that they can be used safely. There is a need for policy to enable wide market adoption of fully commercialized incremental improvements and interventions, as well as to de-risk new and emerging technologies. Emissions targets, procurement commitments (from both the public and private sectors), and significant funding for research and demonstrations could make a real difference in bringing new low-carbon cement approaches to market.

If emissions cannot be reduced and removed at a sufficient rate, humanity may be driven to more drastic interventions (e.g., solar radiation management) to stop planetary systems from irreversibly declining.

Climate change and the energy transition are global challenges, and decisions made now could have long-lasting effects that lock in emissions. A global energy transition is necessary, but historically, new energy has been added on top of — not displaced — old energy. The United States needs to help drive the cost of clean alternatives down to close to or less than high-emission options to spur rapid and widespread adoption in developing countries. Since countries will be at different places in their transitions for decades, it is imperative to address the trade-climate nexus. There is some political interest in the United States in pursuing a carbon border adjustment mechanism to take advantage of the U.S. emissions advantage over Chinese industrial production. Since the United States (unlike the European Union) has no domestic carbon pricing system, a carbon border adjustment could look to carbon performance per unit of output as a metric of comparison. More thinking is needed, however, on how to incentivize, encourage, and facilitate more climate solutions in quickly growing developing economies, including by opening (not narrowing) trade avenues. Getting production-related emissions data from emerging economies is an additional challenge, but averaged data can get the process started for trade regimes and can create incentives to get product- and facility-level data voluntarily disclosed.

While reducing greenhouse gas emissions is paramount, the science has been clear for a long time about the need to also remove carbon dioxide from the atmosphere — to clean up the mess humanity already made (and perhaps to offset emissions from sectors where the cost of abatement may stay too high). There are engineered removal approaches utilizing various chemical pathways to take carbon dioxide directly out of the air or the ocean, as well as engineered biological pathways that involve capturing carbon dioxide through biomass growth, producing power from that biomass, and adding carbon capture to the system. In terms of natural removal approaches, trees, plants, and soils are key carbon sinks that can remove carbon more cheaply, but generally less permanently, than engineered approaches. Policy and government involvement are essential for scaling carbon removal, including funding for innovation, financing support, and public procurement. Until carbon removal gets to the point of being widely procured as a public good, support could also come from both compliance and voluntary markets, as well as from co-generation of valuable products (including the captured carbon dioxide, which can be utilized for a range of commercial purposes). If emissions cannot be reduced and removed at a sufficient rate, humanity may be driven to more drastic interventions (e.g., solar radiation management) to stop planetary systems from irreversibly declining.

FEDERAL POLICY GAINS

There have been several times in the recent past that the United States has made big changes within 20-30-year time horizons. Reductions of air pollution under the Clean Air Act, rural electrification, the interstate highway system, and other examples all made huge amounts of progress within that time horizon. With the recent enactment of federal laws that aim to deploy infrastructure, enhance energy security, and accelerate decarbonization and a clean energy transition, the United States may be poised for another big change.

RECENT FEDERAL LAWS

The United States is in a moment of enormous opportunity in terms of energy, climate, and geopolitics. A lot of that is due to two pieces of bipartisan legislation — the Infrastructure Investment and Jobs Act (IIJA or the "bipartisan infrastructure law") and the CHIPS and Science Act — and one partisan piece, the Inflation Reduction Act (IRA). These laws provide an unprecedented amount of funding to advance clean energy (although the CHIPS and Science Act only authorizes that funding, which still must be appropriated).

The funding available across all three laws is truly massive, roughly equivalent to the annual budget of the Department of Defense (depending which programs one counts). The laws utilize a range of tools (e.g., tax credits, loans, rebates), focus on numerous sectors and priorities (e.g., power, buildings, agriculture, manufacturing, community investment), and involve many different lead agencies (e.g., Department of the Treasury, Department of Energy (DOE), Environmental Protection Agency (EPA)).

The IRA alone is a behemoth in terms of spending and sectors. In the power sector, among many other things, the IRA extends the investment tax credit and the production tax credit for wind and solar to 2024, establishes a new tech-neutral tax credit (45Y) starting in 2025, and provides new tax credits for storage, hydrogen, and more. Some of the credits include important provisions for direct pay and for transferability to third parties, as well as bonus provisions for activity in traditional energy communities and low-income or tribal communities. The IRA also includes new programs and grants for transmission, a new program (including credit subsidies) to support reinvestment in and repurposing of old energy infrastructure, and grants for rural electrification and offshore wind. In addition, the IRA creates a massive multi-billion-dollar grant program at the EPA for non-profits, green banks, community development finance institutions, and others, as well as separate grants for tribes.

The IRA goes well beyond just the power sector. In the transportation sector, for example, it creates a new tax credit for used clean vehicles, grants billions to the U.S. Postal Service to move to electric delivery trucks, provides funding to reduce air pollution at airports, and increases support for loans at DOE's Advanced Technology Vehicle program. For buildings, the IRA extends the residential energy efficiency tax credit, funds a clean energy credit for solar at homes and buildings, adds an energy efficient home tax credit, and provides billions in new grant funding for high-efficiency homes, whole house retrofits, improvements in affordable housing, and upgrades of federal buildings to high-performance buildings. For industry, the IRA reauthorizes the manufacturing tax credit (with 40% of funds going to legacy coal communities), establishes a new production tax credit to accelerate the manufacturing of solar, wind turbines, batteries, and critical materials, and provides billions in grants for manufacturers to support low-carbon materials, cuts in emissions from energy-intensive industries, and reductions in methane emissions from the oil and gas sector. In terms of agriculture and forestry, the IRA provides billions for a broad array of activities, including soil carbon storage in natural systems, protection of marine habitats, hazardous fuel reduction in forests, and use of conservation easements. With respect to community investment and environmental justice, in addition to the billions in grants at the EPA, there are additional billions for states, municipalities, and tribes to cut greenhouse gas emissions, a new program to improve indoor air quality and energy efficiency, and efforts to improve transportation access and water access in disadvantaged communities.

All of that is just in the IRA (and is by no means everything relevant to clean energy and climate change in the IRA). IIJA and CHIPS have many important provisions as well. The bipartisan infrastructure law, for example, includes billions for clean energy demonstrations and research hubs, including on carbon capture and storage (CCS), hydrogen, advanced nuclear, and more. IIJA also includes billions for grid resilience, a range of support for the battery supply chain, and billions to fix or tear down dams in the United States. The CHIPS and Science Act, meanwhile, also includes serious money for clean energy research, development, and demonstration (RD&D), though again, that funding has only been authorized and not yet appropriated.

A common theme across these laws is that they are, for the most part, all carrots and no sticks. The carrot-only approach means there will be some very large subsidies utilized to achieve really expensive emission reductions, whereas if there were a simple federal mandate and/or carbon price, it could focus investment on getting the cheapest tons of reductions available. By their nature, tax credits help make uneconomic things viable, and cheaper ways to achieve or produce things may end up getting crowded out of the market due to subsidies. There is concern that building lots of technologies under heavy subsidies will result in technologies that are not lowest-cost and so will not scale globally. Mandates will also have to be utilized (judiciously) in addition to carrots.

IMPLEMENTATION

All the money appropriated through the recent federal laws is only as good as the implementation. In the 2009 stimulus, collective bureaucracy (at the federal, state, and local levels) and the lack of shovel-ready (i.e., permitted and insured) projects meant that much of the funding never got deployed. A little more than a third of the billions earmarked for infrastructure actually made it out the door; Congress reclaimed the rest a few years later and put it to other uses. That example should be a cautionary tale for the present opportunity, where the volume of funding available is many times greater.

There may come a moment within the next few years when there will be political questions asked about where the projects are that the money was meant to spur. Already, for instance, there are concerns about the fact that DOE's Loan Programs Office (LPO) has only gotten a small amount of the billions it got under the laws out the door. (Some are optimistic, though, that LPO will accelerate its loan issuance, as well as its loan subsidy money, as it works to put systems back in place that got shut down under the previous administration.) Likewise, there is a sense that EPA must accelerate implementation of the green bank funding it received. Recognizing that no Republicans voted for the IRA and that elections could bring changes in party control of the White House and Congress, it will be imperative to lay a strong foundation over the next couple of years for the survival of the funding, including by deploying the funds effectively and efficiently and by integrating them with private sector action.

Because the public sector has enabled, the private sector will lead.

The laws are already impacting companies' decisions and creating a giant pull of capital to the United States. Because the public sector has enabled, the private sector will lead. Manufacturers are deciding to build factories and hire people this year because of the IRA. Projects that have been sitting are moving now because of the tax incentives and direct pay optionality.

Treasury guidance is essential, however, to get money invested quickly. Treasury guidance is needed, for instance, on direct pay, transferability of tax credits, and a glide path for requirements related to domestic content and U.S. manufacturing. (U.S. manufacturing requirements are important for security and supply chain reasons, but the desire for more U.S. products tomorrow should not slow deployment of currently available technologies today.) Until the detailed rules are written and clear, investors will not know how to factor the credits into their plans and capital stacks.

Treasury guidance is also needed on the 45Y tech-neutral tax credit. The credit, which starts in 2025, goes until the later of either 2032 or when the United States has reduced power sector emissions by 75% from 2022 levels. (That is in some ways a national clean energy standard enacted through the tax code, though unlike an actual clean energy standard, a carrot-only approach for new clean energy does not mean existing high-emitting sources will be retired.) Typically, there is no investment in projects dependent on tax credits until Treasury guidance is issued. Final investment decisions are typically made about two years ahead of time, so for a tax credit that starts in 2025, guidance would ideally be issued immediately. The Treasury Department, however, has delayed issuing 45Y guidance because of the later start date. That not only delays final investment decisions, but also creates political vulnerability for the 45Y credit should control of government change in 2024.

The IRA places significant focus on low-income communities, including tax credit adders for projects benefitting low-income communities. There is debate about how to qualify low-income customers. Typically, this is done by income, and low-income programs have many rules about making poor people prove they are poor — the result of which has been fewer low-income people participating in those programs. The policy solution may be self-attestation — i.e., believing people when they say they are poor. There is precedent for this, but there is opposition from those who believe, despite studies to the contrary, that welfare fraud is rampant.

Even with the guidance and rules from Treasury, there are fundamental obstacles that could slow implementation. There are concerns, for instance, about whether the domestic content, environmental justice, and other requirements in the laws will significantly hinder near-term deployment by limiting the eligible options available. The many agencies involved in disbursing funds also have different rules and interpretations, and the more requirements increase in volume and complexity, the slower the process goes and the fewer projects get completed in a timely way. Similarly, projects are competing for limited resources and materials, and engineering, procurement, and construction (EPC) firms are overwhelmed with work; the results are cost increases for materials and projects, which mean the federal dollars may not go as far as originally hoped.

For many of the funds directed at buildings (including for installation of heat pumps, water heaters, induction stoves, and the like), contractors often end up making the decision (or at least determining the options) for homeowners, and most contractors are not very aware of the range of opportunities in the IRA for customers. In communities where budgets tend not to support going through contractors, most folks either have relatives help update their homes or do it themselves, which presents a very different educational challenge. Getting technological solutions adopted requires socializing them, which in turn requires understanding the different values and dynamics among the various fragmented members of society.

In addition, it is virtually impossible to build stuff in the United States to address climate change unless siting and permitting challenges are addressed. There is a wide spectrum of public opinion on siting decisions and energy infrastructure projects of all kinds, and some clean energy projects can be stymied by local opposition, wildlife protection considerations, and lengthy National Environmental Policy Act (NEPA) processes. Renewable energy development is increasingly becoming part of political tensions — an ideological challenge in local communities. There are anti-wind moratoria and setback requirements in formerly friendly places such as Iowa, and local opposition has become a huge problem across the entire country. Massive increases in renewables deployment may be impossible unless something changes in the relationship between counties and states with respect to siting and permitting. To accelerate permitting, there have been some calls for immediate approvals for decarbonization projects with well-understood impacts, but it is not clear how to achieve that. Another possibility is automatic denials for projects that are not compatible with the climate future, but that is also challenging.

STATES

The delivery of most of the federal funding from the recent laws occurs in and through the states. It is truly a deployment centered in cooperative federalism, and there will be a huge need for intergovernmental cooperation, both across and within levels of government.

The federal funding, while not enough to build every single project needed for decarbonization, has been sufficient to motivate state politicians (of both parties) and industries to take projects off the sidelines and push them forward collectively. Some states are working hard to find matching funds, pursue labor commitments, engage environmental justice communities, and line up other elements needed to compete for federal funds. The efforts are extending environmental and energy agencies' work into new areas.

Each state has its own unique priorities, attributes, and challenges, though many challenges are similar. For example, the capacity challenges at the state and local (and federal) levels to implement the IRA and the IIJA are immense. States and localities do not want to miss out on federal funding opportunities, but there is a significant lack of capacity and bandwidth to track the many existing and new funding opportunities, understand the various agencies' different requirements and interpretations, and respond within the short turn-around times. Many states have had trouble recruiting and retaining skilled agency staff. The IRA includes millions in funding for additional human resources for federal and state permitting, but when split up among 50 states, the funding will not be sufficient to make a meaningful dent in states' human capacity challenges.

Implementation of the federal laws creates other challenges for states as well. For instance, there is a need for technical support to help state engineers understand and gain confidence in new technologies. Federal funding can also help states do spatial planning in pre-permitting to assess in-state locations that may be appropriate (or least bad) for siting certain technologies; particularly in densely populated states, it is important to try to minimize the amount of land-intensive energy generation needed, such as via more energy efficiency and more transmission. There are also additional burdens on state agency staff from other elements of the clean energy transition that have not received as much attention or funding, such as how to address disposal of clean energy equipment (e.g., wind turbine blades) at the end of their lives.

CLEAN ENERGY DEMONSTRATIONS

The recent suite of federal legislation provided DOE's new Office of Clean Energy Demonstrations (OCED) with significant funding, including billions for demonstrations related to carbon management (e.g., CCS, direct air capture (DAC)), clean hydrogen, advanced nuclear, long-duration energy storage, and industrial decarbonization, as well as for energy improvements in mine lands and in rural remote communities. OCED has issued most of the funding opportunity announcements (FOAs) for the demonstrations, and the last ones should be released soon.

These clean energy demonstrations are not meant to be prototypes. They are first-of-a-kind commercial-scale facilities that are meant to be going concerns (without government involvement) after they get operating. Cost-share minimums for the demonstrations make sure the private sector has skin in the game. Cost shares can be very challenging for applicants, however, particularly for billion-dollar investments and given some of the decision timetables laid out in OCED FOAs.

OCED has been preparing reports exploring the pathways to commercial lift-off for each of the various key technologies. These are not policy documents. The reports are meant to be easily digestible roadmaps capturing the perspective of the private sector with respect to the current state of play and what it will take to achieve market lift-off. The aim is to get to a common fact base, build confidence that these are investible, bankable solutions, and ensure that DOE investments are de-risking the challenges identified in the reports. The reports also provide context for the FOAs and will be used to facilitate more informed conversations with the top teams applying for some FOAs, to learn about their approach and risk management plans.

Picking the right projects is a central challenge for OCED. The Office has to evaluate applications on costs, technological readiness, lifecycle benefits, impacts, replicability, community acceptance, environmental justice benefits, how quickly they can get done, and more. OCED needs independent experts who understand the challenges around project finance and commercial-scale projects to read the proposals, evaluate and score them, and help make decisions about which ones receive investment. There will be a tsunami of merit reviews needed in the coming months, which means OCED needs hundreds of people to help evaluate proposals. It is hard, however, for DOE to find the right experts to do rigorous merit reviews of the applications. The private sector is scooping up much of the available human capacity to work on projects, which is great, but it means lots of experts are conflicted out of helping DOE. There could be a role for philanthropy in creating an army of seasoned, retired professionals to do reviews.

It is vital to design and deploy a portfolio of successful demonstration projects quickly, to withstand the naysayers that are inevitable in DC and to influence everything else coming down the pike. However, managing major capital expenditures and major capital projects principally for speed may involve tradeoffs with respect to quality and cost, which could affect the success of the transition. If speed is to be a driving force, it should perhaps be so only for the early stage-gates, not for the full spend. DOE can de-obligate and reallocate funds as needed if projects are not coming to fruition, to ensure federal money is put to productive use.

While the OCED demonstrations are focused on big, multi-million-dollar projects driven by companies that are scaling today, there are huge numbers of startups that are looking for much smaller opportunities to do pilots or demonstrations. Innovators — particularly in states that do not have rigorous programs for incubators and startups — need help at a much smaller scale than what is available in the federal funding opportunities. The CHIPS and Science Act created a national incubator program, but it still has to be funded. To build the pipeline of innovation, more support for little projects is needed, whether from the private sector or DOE.

ROLE OF CAPITAL MARKETS

While the recent federal laws will deliver billions of dollars in funding per year, trillions need to be deployed globally each year (and billions every day) to achieve climate goals. There are three general categories of capital relevant to the transition: taxpayer capital, ratepayer capital, and private capital. Since taxpayer and ratepayer dollars are limited, private investment is vital.

INTERSECTION OF POLICY & MARKETS

Markets are often talked of as a climate solution, but they are also a big reason the problem exists in the first place. Markets are set up to privatize gains and socialize costs, to the detriment of the atmosphere, communities, and more. If done right, policy and proxies for policy — such as environmental, social, and governance (ESG) investing, voluntary carbon markets, and greenhouse gas accounting rules — could start to tether private gain to social and climate benefit. Policymakers know that public money must mobilize private investment and that policies must be designed to intersect with capital markets. That is how the trillions of dollars ultimately needed will be unleashed.

There is, however, competition for capital. If dirty has a higher rate of return than clean, that is where the capital will go. The problem at its root is the lack of a price on carbon. Policy has consisted of contorted efforts to get around that, such as by giving things with more climate value large subsidies. Large subsidies and financing programs such as those in the IRA, however, raise concerns about moral hazard and may in some cases risk slowing, not accelerating, progress. Based on the long history of federal incentives (e.g., solar and wind tax credits), developers will be told to wait on projects until they can get the federal money, even when they could have profitably deployed private capital anyway. At the same time, it is not good for the market to believe that the tax credits could disappear or that provisions and funding could get rolled back, making it essential for Treasury to issue guidance as soon as possible in order to get money and projects moving.

If the goal is to get new technologies into the market faster, there may have to be greater willingness to use blunter and faster instruments, such as procurement orders and advance market commitments. These instruments can lead to faster capital formation, bring technologies down the learning curve, and help them build a profile more attractive to more traditional investors.

ESG

While policy can de-risk projects and investments, policy can also create additional risks. A clear example of that is the current political tension over ESG investing. ESG is under heavy fire from the political right (though it is also somewhat under fire from the left). The anti-ESG legislation being passed or pushed in some states could present an existential threat to the clean energy industry and challenges for clean energy investors. The industry must get smarter about how it reacts. Financial companies are making clean energy investment commitments because that is where the market is going (and they are the right thing to do), but it can be very hard for financial corporations with a global portfolio to manage the political realities in the United States compared to those in the rest of the world.

The political tensions about ESG are also a distraction from actual financial reality. Analyses of bank financing have found that low-carbon projects are still getting significantly less financing than fossil projects, but achieving climate targets will require low-carbon projects to be receiving several times the financing for fossil by 2030. More pressure, including via shareholder resolutions, is needed on banks to shift financing to low-carbon projects. The problem, again, is that the returns tend to be better on one side than the other, due to the lack of a carbon price, and the energy system is run by profit-seeking companies selling products and services to utility-seeking customers.

To achieve long-term goals, the blending and balance between the E and S of ESG will be critically important, as the issue of mining makes clear. The energy transition will require a massive increase in the number of mines producing many critical mineral commodities. It takes many years to get a mine going, compared to only a couple of years to get a gigafactory up and running — which suggests those factories will be facing material shortages. Prices are reacting to shortages, which is incentivizing new supply and spurring investment of equity capital into mining assets. Although building more mines is essential to producing more critical minerals for clean energy technologies, it is hard to see how that will be accomplished in a way that does not significantly impact underserved communities and lead to widescale environmental (and other) issues.

There are opportunities, though, to achieve both E and S objectives. For instance, the financial community has one arm working on Opportunity Zones and another arm working on implementation of the federal incentives, but those have not yet been linked. Opportunity Zones will direct trillions of dollars of investment into disadvantaged communities. If that opportunity was expanded to include energy communities and other IRA designations, there would be a ready-made multi-trillion dollar receiving environment that also meets environmental justice goals.

VOLUNTARY CARBON MARKET

Capital flow is not just about banks and investors; it is also about customers and companies with money to spend and sustainability commitments to meet. The private sector is at the end of the beginning of big net-zero announcements, as companies are pressured to show how they will make investments over the rest of this decade. Having a robust voluntary market in carbon credits would bring in more capital and liquidity. If the markets can go beyond short-term trading to create long-term pricing signals for carbon, such long-term instruments (which are in place in other markets) could unlock even more money and underpin financing of companies. Although voluntary carbon markets can scale, they still have a long way to go, many issues to work through, and not much time to do it.

There is a large quasi-regulatory ecosystem, involving greenhouse gas accounting rules and protocols around carbon credits and offsets, that has a huge influence on flows of private capital to address climate. Companies will direct capital towards things they get credit for under systems such as the Greenhouse Gas (GHG) Protocol and the Science Based Targets initiative (SBTi). The rules are not directing capital in the most carbon-effective fashion. Without the right incentives, companies will spend capital on things with no climate value but get credit for doing them. The carbon accounting rules are hugely important.

Although voluntary carbon markets can scale, they still have a long way to go, many issues to work through, and not much time to do it.

Developing the appropriate incentive structures is vital. For example, it would be beneficial to center the concept of present value in the financial discussion, creating a time-weighted system that recognizes the cumulative nature of the greenhouse gas problem. Retiring a credit today should be worth more than waiting 10 years; earlier emission reductions are more important than delayed ones. If that was present in the incentives, capital could be deployed faster.

The GHG Protocol is launching an update process, the outcome of which is not yet clear. Since it provides the basis for how companies and the private financial sector set goals and deploy climate-related capital, the updates could have significant impact in increasing demand in the voluntary carbon market. Engagement in the GHG Protocol and SBTi processes to get the rules right must be a priority.

ELECTRICITY SECTOR

Of the big sectoral sources of greenhouse gas emissions, the easiest one to decarbonize is electricity — but it is still incredibly hard. It is also a sector that most people agree will need to get bigger to solve the climate problem. It is both part of the problem and part of the solution.

A BIGGER, DECARBONIZED SYSTEM

To get to net-zero, the power sector has to decarbonize on an earlier timeframe than other sectors. The electricity system will also need to grow a lot, though not much more than it has grown historically. Getting to a much bigger grid will be challenging, however, given how hard it is to build any infrastructure in the United States right now.

In particular, transmission access, siting, and permitting remain fundamental challenges. The interconnection queue process is broken, and solutions must be found to cut timelines for getting clean energy on the grid. A large portion of the potential emission reductions from the IRA could be lost if the rate of transmission buildout does not increase dramatically. There has been significant opposition from industrial customers to big transmission expansions, out of concern about costs going up. Landowners, too, have been strong opponents, sometimes going as far as harassing employees of companies that are large energy buyers and that have advocated for transmission projects. The voice of skeptics is rising in public narratives, raising doubts about the ability of the broader transmission ecosystem to be ready to connect clean energy resources; there is a need to more clearly and publicly articulate that these ecosystem challenges are being worked on. In addition, when transmission is built, it is vitally important to build with the expectation of growth, so the infrastructure can endure without significant retrofit. Transmission to maximize offshore wind, for example, may want to install DC lines first, rather than starting with AC lines.

Beyond siting and permitting, transmission planning will be key, and more states should voluntarily plan together.

Beyond siting and permitting, transmission planning will be key, and more states should voluntarily plan together. The Federal Energy Regulatory Commission (FERC) also needs to determine some standard way to evaluate and assign benefits and costs, especially for interregional projects. Indeed, better planning is needed across all the inter-related systems, including generation, transmission, distribution, and natural gas. The whole interconnected network has to decarbonize. Distribution may be one of the hardest to solve for, as it is most closely tied to customers' desires and experiences. There is no software or model available off the shelf to plan for all these systems; there is a huge need to develop a piece of software to do it.

The growth needed in the grid means many terawatts of carbon-free generation need to be built, but utilities' integrated resource plans (IRPs) are falling short in trending toward a clean electricity system. The stated targets in these plans, much less what the plans actually intend to build, do not get the sector to where it needs to be in 2035. Most utilities are not even coming close. Aggressive implementation of the IRA's tools is needed to bridge the gap. The IRA has started spurring some utilities to shift their IRPs dramatically, including massive increases in deployment of carbon-free resources and battery storage (tied to the IRA's tax credits) and early retirement of coal plants (tied to the IRA's loan facility, put into LPO, to support transition and early retirement of energy infrastructure). The IRA's tax credit for retaining existing nuclear will also be very consequential. If the IRA is used well, it enhances the ability of utilities to move faster, shift assets, benefit consumers, and reduce emissions.

Although many utilities have put forth net-zero commitments, others have not (even if they aspire to net-zero), given a lack of clarity around the technologies and options to actually get to 100% clean. They can get much, but not all, of the way there with current technologies, including significantly increasing renewables, closing coal, and extending the operating lives of existing nuclear. Utilities know, however, they will need some form of new 24/7 dispatchable generation. There need to be solutions that can cover new surges in daily or seasonal usage, whether EVs charging at night or buildings' heating demand in winter. Any new options have to be ready and available by the late 2020s and early 2030s at the latest, so it is imperative to think, plan, and act now about technologies — centralized and distributed — that will be needed. State legislatures and utility commissions, however, are still debating which technologies utilities should be allowed to use; there is a need for education of officials about the importance of firm, clean resources. In the absence of something new that is carbon-free and dispatchable, ensuring reliability and sufficient capacity may require natural gas combustion turbines that run very rarely.

All clean technologies will be needed, as there will be starkly different uptake of different technologies in different parts of the country (and the world). Delivering reliable decarbonization of the electricity sector also requires differentiation of the various solutions and the attributes they bring beyond just zero-carbon. Capacity markets are not designed to do this. Grid operators have to provide top-down clarity of what is needed to decarbonize the grid reliably, which will provide the signal private capital needs to invest. In addition, there are national-level decisions that will affect buildout and technological availability, including decisions about tariffs on imported solar components and development of high-assay low-enriched uranium (HALEU) production for advanced nuclear reactor fuel. These technological unknowns are another wrinkle in the challenge of transition planning.

COMMUNITY ENGAGEMENT & OWNERSHIP

Community desires and opposition could present potential roadblocks to deployment of some technological options, particularly at scale. Communities sometimes have strong views on what they want and do not want. In some communities, there is deep, intergenerational resentment of energy companies, chemical companies, and others. Community resistance also builds up due to past overpromising about the number and quality of jobs that would be created from renewable energy development; many clean energy projects do not create a lot of sustained jobs. There are different sets of people with different reasons for being skeptical about projects and for fearing a transition that is unfamiliar to them. When it comes to siting energy infrastructure, NIMBYism (not-in-my-backyard) is not political. People sometimes do not want energy infrastructure, of any sort, going through their yards or in their communities.

Community desires and opposition could present potential roadblocks to deployment of some technological options, particularly at scale.

Paying insufficient attention to human and community elements is built into current systems. Engineering students, for instance, may only ever talk about humans in one class about ethics. It is vital to understand what is happening on the ground with people and align that reality with the objective of addressing climate change.

Community engagement is essential. People protest projects when they feel like they have not been consulted. Developers often do not talk to communities until they already have permits, and then they encounter opposition. Such roadblocks are very avoidable. Talking to communities earlier can make it much easier to earn trust. Some states' community solar programs give points to developers that have already talked to communities (though too small a percentage of the community solar built so far has been for low- and moderate-income customers). Similarly, in California, efforts to engage communities and environmental justice groups early, in good faith, and with nuance opened up avenues for progress on a bill establishing a framework for deploying CCS in the state. Affirmative, proactive, honest community engagement has to be part of the checklist in a way it has not been in the past, and regulators should demand that investors and developers talk to communities before applying.

Community engagement is in the clean energy community's self-interest in other ways too. For example, there is genius-level talent and energy in communities that will not stop working to fix and develop those communities; that talent and energy must be leveraged.

Consultative processes matter, but so do job creation and other local benefits. Not enough people currently benefit from clean energy to constitute an active constituency that will advocate for it in the public sphere. The way some people are talking about community benefits now is very focused on jobs and employment. There are lots of ways that the clean energy transition can help communities, including health benefits and wealth creation. Expanding the conversation could bring more people along.

If communities have the opportunity for wealth creation, they are more likely to want things built in their communities. Community ownership promotes multiple definitions of equity, including both social justice and stock ownership.

The health benefits of clean energy and other decarbonization solutions are substantial. In fact, in certain localities, the health burdens caused by pollution have become so expensive that the local healthcare system, in its own economic interest, has decided to pay for residential building electrification efforts. The preventative health care benefits that clean energy and electrification provide should be an important element not only in policy and financing discussions, but also in community engagements.

Likewise, community ownership can be a key part of a bargain with low-income communities with respect to siting and permitting of infrastructure. A small stream of revenues from clean energy projects can make a big difference in reducing communities' opposition. Startups that cannot offer communities a share of revenues (as that represents lost company value) can offer a share of equity in the project, which means the community is investing in the success of the project, taking a risk with the developers, and getting a multiplier of dollars if the project is successful. Similarly, offering people the opportunity to be co-owners of shares in a local clean energy microgrid could change what is possible from a regulatory and permitting perspective. If communities have the opportunity for wealth creation, they are more likely to want things built in their communities. Community ownership promotes multiple definitions of equity, including both social justice and stock ownership. Clean energy developers need to add community ownership to their toolboxes.

Not all developers are willing to reach out and provide benefits to communities, and they make everyone else's job harder. On the other hand, it can be hard for project developers to identify "the community" they should be reaching out to.

There should also be incentives for YIMBY communities. There is no need to persuade every community in the country. Instead, developers should find communities and people who have enthusiasm and will compete to host their projects. Finding the communities that are ready to go can catalyze the communities that are not quite sure.

CHALLENGES IN PROVIDING A RELIABLE, SAFE, & AFFORDABLE SYSTEM

As people are relying on electricity more than ever, utilities and regulators are looking at how to provide reliable, resilient, accessible, affordable, and clean energy. Some consumers care where their electrons come from, but affordability and reliability, which are what most customers focus on, are immovable guardrails. High cost will slow the transition; lack of reliability will stop it.

States are failing citizens repeatedly when it comes to reliability and safety. Storms regularly knock out power for hundreds of thousands of people, both in summer and winter. Reliability challenges will only grow as states experience more impacts from climate change. Reliability is generally more about the state of the distribution (and, somewhat, transmission) system than about power generation. The distribution system must be made more reliable. People, including children, are being killed due to contacts with downed wires. Solutions such as advanced nuclear and CCS do not necessarily bring customers greater reliability and safety in communities. More decentralized solutions may be better in that regard, such as microgrids, community solar, and solar with storage. Virtual power plants, energy efficiency, and demand response should also be accelerated. In addition, unlike a decade ago, software, computing ability, sensors, and physical data center and fiber infrastructure are readily available to every utility, operator, and planner; these digital tools are wildly underused, and state utility regulators are not aware of their capabilities.

The costs of maintaining reliability are mounting precipitously, and those costs are going into rates. Energy costs are rising. Arrearages are piling up. Regulators are in a tough spot, trying to achieve decarbonization in a cost-effective way while the costs of reliability and the burdens of energy costs on communities are both mounting. Constraints related to what can be rate-based and concerns about customer bill impacts have stalled projects that would otherwise be economical, but education of regulators and stakeholders can sometimes carve out a path for clean, affordable, reliable technological solutions or green tariff options.

Federal funding in the IRA will lower costs for customers, and regulators are asking utilities to include federal incentives for consumers in utility plans, but utilities do not administer those programs and do not know who participates. There is a need for a workable evaluation, measurement, and verification (EM&V) model that utilities can bring to their states to account for the federal incentives.

A change in ratemaking could spur better results on reliability, safety, cost, and other areas. Performance-based ratemaking, instead of just giving utilities an allowed rate of return, could score elements such as emissions, cost, reliability, and safety and set up an incentive system to align returns with achievement of those objectives. The idea has been talked about for decades.

ROLE OF LARGE ENERGY BUYERS

Some big energy buyers have deployed a ton of energy efficiency and renewable energy measures, but they are running into the same problems that many others are: costs are up, supplies are down, solar panel sourcing is complicated, and regulatory approval processes are cumbersome. For companies that are large energy buyers, state tariff structures are what determine the power they use, but tariff structures under which people and companies sign up for clean energy have not really changed in how they are designed and regulated for decades. More people and entities need to be educating regulators, intervening and offering comments in proceedings, and focusing on changing the products offered to consumers. In the meantime, leading energy consumers are working with the many utilities they take service from to create programs that give customers (themselves and others) greater access to clean energy.

Energy buyer capital has been deployed in renewable energy primarily through power purchase agreements (PPAs) because there were not really other mechanisms to invest in the marketplace. The investments started as a willingness to spend to meet sustainability goals, but they became a hedge against the volatility of natural gas prices. If fossil fuels are eventually phased out of the grid, however, there will be no marginal signal to hedge around. There is a big industry built around a product signal that may at some point be driven out of business. This represents a serious threat to private capital deployment from companies with significant load — load that will only increase as transportation and other end-uses electrify. For buyers to deploy capital, they need a mechanism that is not based on the differential between renewable PPA cost and natural gas cost.

Buyers' focus on PPAs has also been driven by the way customer goals and carbon accounting are set up — incentivizing buyers to pursue actions that deliver renewable energy credits (RECs), such as via PPAs, and disincentivizing support for utility innovation to decarbonize the grid mix. Utilities and customers may both want more clean energy, but because of the fight over RECs, they cannot really work together. Grids, however, are more than the sum of their parts. Each big customer pursuing its own aims feels like the right approach from an enterprise standpoint, but it will not result in the systemic changes necessary. The best-case result is an inefficient system, and the worst case is an unreliable one. For example, some utilities are finding that large energy buyers procuring huge amounts of renewable energy are putting utilities in a place where they feel the need to have emitting resources on the grid to ensure reliability. Public and private customers' policies focused on procuring certain percentages of renewable electricity could end up having no impact on reducing greenhouse gases in some grids. Decarbonization is a systems issue, and the current arrangement is not optimized for decarbonization. While operation and investment occur at enterprise scale, planning must occur at grid scale. Instead of looking at the carbon accounting within a company, large buyers should be looking at the plans for decarbonizing their regional grids and figuring out how they can contribute to the aggregate outcome, whether that involves storage, transmission, or other efforts. Ways must be found to reward customer actions that support grid decarbonization, and utilities and buyers need to push for plans to get to decarbonized grids faster.

OIL & GAS

Most big oil and gas companies are having active internal conversations about their decarbonization and transition ambitions and strategies. At the same time, given the global turmoil in energy markets and the sanctions against Russia, large oil and gas producers feel an obligation to supply energy to ally countries to help them with energy reliability and security challenges. There are some clear tensions and conflicting imperatives in the sector.

GEOPOLITICS, CLIMATE, & LOCK-IN RISK

The oil and gas industry is not monolithic, but rather features a range of actors and owners. The household names of the publicly owned integrated oil and gas companies, sometimes called supermajors, represent a relatively small percentage of global oil and gas production. A roughly equivalent amount of oil and gas production is owned by private equity. A much larger amount of production comes from national oil companies (NOCs), which are owned by countries. These three types of entities have different incentives, intentions, and priorities as the world goes through geopolitical upheavals and contemplates a global energy transition.

Solutions such as wind and solar are already the lowest-cost form of new energy for almost the entire world.

The planet's fossil consumption has either already peaked or will by the end of the decade, according to analyses. Coal has already peaked, oil is peaking, and gas's peak has been pulled forward by Russia's invasion of Ukraine. Although there can be false peaks, solutions such as wind and solar are already the lowest-cost form of new energy for almost the entire world. No one wants to be the investor that invested at the peak. As markets recognize this, the first actors to bear the brunt will be the publicly owned integrated companies, which tend to be the best actors in terms of overall performance. Such a market reaction is not yet evident in those companies' stock prices, but if it happens, that will put more of the decarbonization challenge on the NOCs, which have some perverse incentives and are likely to make less economically rational decisions.

In light of the need to increase production in response to near-term geopolitical realities, some oil and gas companies have revisited their climate targets, including making decisions to slow the divestment of mature assets from company portfolios. Companies are getting criticized by some for increasing production, but they have yet to be taken to task for how their climate commitments were structured in the first place to allow asset divestment to count. Companies that have divested mature emitting assets have been rewarded by investors and can focus more attention on low-carbon solutions, but while divestment of an asset will affect a company's carbon accounting, it does not actually further decarbonization if someone else buys and operates that asset. Divestment just changes the name on the deed. If assets are sold to entities that are not as good stewards of them, divestment could actually lead to emissions being worse. Companies need to determine if there is a class of companies they will not sell assets to and if there are liabilities they will retain (across pollution issues, not just climate).

While it is necessary to backfill lost supply to meet current hydrocarbon demand, it is not possible to meet the Paris climate goals while using oil, gas, and coal at anything like current levels. It is imperative to move in the direction of fundamentally reducing demand. Filling the energy gap caused by geopolitical disruptions, for instance, has occurred both by finding more molecules and by reducing demand (e.g., by exponentially increasing heat pump installations in

Europe).

When immediate energy supply becomes insecure, people can respond by making decisions that have long-term implications. There is a question, for instance, of whether oil and gas companies investing in new infrastructure are willing to retire it early after the near-term backfilling need has passed. The new infrastructure has a lifespan of many decades, past the point at which much of it must be retired, repurposed, or replaced if climate targets are to be met. When capital is deployed for emitting infrastructure that requires 20-30 year paybacks, there is concern about locking in emissions for decades. In contrast, of less concern are investments that have very short payback periods, such as investments in incremental production and improved gathering infrastructure.

The tensions between transitioning and meeting current hydrocarbon demand will be present for decades. There is a huge divide between the path the world is currently on and the path and speed the science says are needed to reduce emissions to limit warming to even 2°C or 2.5°C. Some maintain the oil and gas sector can contribute to near-term emission reductions, such as by replacing coal around the world with liquefied natural gas (LNG). Since carbon dioxide (CO2) emissions persist in the atmosphere, emissions reduced today are worth more than emissions reduced in a few years, and approaches that emit less than current options should be pursued. Lock-in challenges, however, apply to such efforts too; near-term reductions that result in locking in long-lived emitting infrastructure for decades could lead to emission reduction pathways that dead-end well short of climate targets. In addition, methane has such a powerful short-term warming impact — with a global warming potential (GWP) many times greater than CO2 — that if even relatively small percentages of gas leak, the short-term climate impact may not make the longer-term carbon benefit worth it. The details matter a lot. (The sense of risk and urgency around methane should be further heightened by the fact that, as the planet warms, the expectation is for huge amounts of methane to be released from permafrost in the Arctic.)

Oil and gas companies need to figure out how much carbon and methane they will be selling in a few years, and the market may need to drive that answer. Companies need a driving force to get there collectively, and if the market is demanding it, companies will respond. For companies that are at least partially owned by countries, pressure from the government and the public can complement the market as a driving force. In addition, it is worth thinking about which parts and attributes of the oil and gas industry will be needed or useful for a much longer period of time. For example, aspects of the industry are very skilled at managing big energy systems and building large projects offshore, both of which are skills that will continue to be valuable in a decarbonized future.

DIFFERENTIATION

A Paris-compliant world is not necessarily a world with no fossil fuels, and energy access in lower-income countries still depends on fossil fuels. The environmental community makes a tactical error in equating climate security with zero fossil fuels. If there will still be fossil fuels used going forward, a key question is who will be producing them. If a lot of leading countries and companies exit oil and gas production in an effort to transition, but demand is not reduced, the vacuum of energy supply will be filled by someone. Who fills the vacuum matters a great deal in terms of international cooperation and security.

There are national oil companies in the Middle East that can credibly claim that they have the lowest-carbon barrels of oil and should be the ones producing the last barrels. Crude oil market trading is not currently set up to recognize such differentiation, though it could be, and there are some conversations occurring. Although most of oil's climate impact comes from its consumption, the upstream can make a significant difference in the overall emissions associated with any given barrel. There are challenges with the notion, however. For instance, independent third parties will not be going into every company, and certainly not into every country with a national oil company, to verify claims, so questions of carbon accounting and transparency would loom large. In addition, one barrel of oil could be molecularly different from another.

The differentiation question arises for natural gas, too, but conversations there may be less advanced. State public utilities commissions (PUCs) review gas supply plans from utilities, but apart from inquiring about reliability, they tend not to inquire about the upstream (e.g., minimum production standards, flaring protocols) — though they could. Accounting, tracking, targets, and attributes are associated with the supply of electrons on the electricity side, but the same has not been done for methane molecules. The consumer muscle of states with carbon targets has not yet been leveraged.

OTHER OPTIONS FOR MOLECULES

Electrification can replace oil and gas demand in some cases. For instance, for light-duty vehicles, electricity is the cleanest and most efficient answer. For building energy needs, electrification may be the best approach in warm climates, whereas in colder climates, a hybrid, dual-fuel approach may be more viable, with the gas system as a backup for peak heating days. In the United States, most gas utilities are part of a combined gas-electricity utility system, which can provide a transition pathway for those utilities and their investors.

Even if huge amounts of renewables are deployed and sectors are electrified, there are some things electricity cannot do (at least with current technologies). In sectors such as aviation, shipping, and industrial production, there will be a need for zero-carbon molecules to go along with the zero-carbon electrons. A key conversation that needs to be had with oil and gas companies is what those molecules should be and where to get them. (There is also a question about whether remaining solely in the molecules business is enough of a strategy on which to base the future of the business.) The integrated oil and gas companies are choosing different pathways, and it is good that many approaches are being developed, as it is unclear what the answer (or answers) will be. If these companies lead the way, NOCs will have to follow.

In sectors such as aviation, shipping, and industrial production, there will be a need for zero-carbon molecules to go along with the zero-carbon electrons.

Some companies are using capital generated from oil and gas to invest in new technologies for the transition. Some in the sector, for example, are directing funding into biofuels, hydrogen, and CCS, which all have promise and challenges. For biomass, there is not nearly enough sustainable biomass supply. Still, the biodiesel industry is only 20 years old and is already producing a decent percentage of on-road diesel in the United States. There have been periods during that 20 years when biodiesel did not seem promising, but the technology, product quality, and breadth of feedstock are better today, as are the carbon intensity reductions. Biodiesel today is not biodiesel a decade ago, and the innovations will keep coming to address remaining challenges.

Hydrogen, depending on how it is produced, could play a big role in industry and in providing heavy transport fuels, but probably not as a retail fuel. Several gas utilities have put forward the idea that gas assets will not be stranded because they will be repurposed to deliver hydrogen to homes, but that may not be a viable option; the reality will just be locking in gas infrastructure. Because of the IRA, more opportunities are opening in hydrogen (and ammonia), but although federal investments can help make clean hydrogen cheap, they cannot make people buy it. Hydrogen demand is a big issue. How hydrogen is produced also strongly affects its climate impact. In addition, hydrogen has its own indirect climate impacts when it leaks into the atmosphere. The GWP of hydrogen is several times that of carbon dioxide, and the leakiness of hydrogen for different applications must be considered.

DECARBONIZING CEMENT

Cement and concrete, which are foundational to societies, represent a small but significant percentage of global greenhouse gas emissions each year. Cement is the binder ingredient in concrete and is what pretty much all of concrete's carbon emissions are attributable to. Most of those emissions are in the developing world, and an even greater percentage will be in the coming decades. The United States can pioneer things, but systems must be built for emerging markets and developing economies.

ADDRESSING THE CURRENT CEMENT PRODUCTION PROCESS

Decarbonization of current cement production involves addressing either the heat used in making cement or the carbon dioxide released from the chemical breakdown of limestone during the cement-making process itself. With respect to the former, most cement kilns burn coal and petcoke. One of the main decarbonization levers the industry is pursuing in the near term is to replace some coal or petcoke with waste-derived fuel that can be diverted from landfills; this is low-cost but controversial, as it does not produce significant emission reductions and is a debatable waste management strategy. Cement kilns burn things at really high temperatures, with long residence times in kilns, so most things will burn completely; they just cannot burn things that will exceed air pollution permits. It is worth exploring what role there is for traditional environmental regulation (e.g., air pollution, water pollution, solid waste management) in decarbonizing cement.

Decarbonization of current cement production involves addressing either the heat used in making cement or the carbon dioxide released from the chemical breakdown of limestone during the cement-making process itself.

Since pretty much anything can be thrown into a cement kiln, energy costs for kilns are very, very low. Electrification of industrial processes is physically possible, such as through electric arc furnaces, but for high-temperature exothermic industrial processes (such as making cement), electricity is very unlikely to be cheaper than a disordered form of energy such as heat. Electrification of high temperatures involves much higher costs than current processes. Clean hydrogen is also more expensive. There are explorations underway of alternative heating approaches, including next-generation concentrated solar power that could provide high temperatures cleanly, but these are not yet commercialized. To address cement emissions (and industrial emissions more broadly) globally and at scale, economic decarbonization options for heat must be developed.

Even if a decarbonized fuel source is found, the existing way cement is produced — the chemical breakdown of limestone — leads to substantial process emissions. CCS could be very helpful, there are several technologies already deployed or under development that can do it, and there is sufficient potential carbon storage space available. There are also a lot of potential synergies, such as closing the loop by using the captured CO_2 for curing. However, economic drivers to install CCS technologies are limited, and the technologies' costs are fairly high (though the costs may be better than existing estimates suggest, and the 45Q tax credit could make a difference in the economics). Adding CCS into the cement-making process does not add value, and voluntary markets are not big enough to make it economical. The technology therefore is not yet widely deployed in the industrial sector. There is not even a pilot, although a couple of U.S. plants are currently doing front-end engineering design studies to investigate CCS with

DOE, and there may be pilot projects that include CCS within a couple of years. CCS costs about the same as electrification, but potentially with greater emission reductions. As an alternative way to address cement's process emissions, there are also companies that are developing new chemical processes on new rock (i.e., not involving the chemical breakdown of limestone) to make ordinary Portland cement in ways that are low-cost and potentially carbon-negative.

There are incremental measures to reduce emissions from cement and concrete that should not be overlooked in favor of shiny new technologies, particularly since there are lots of federal dollars flowing now into infrastructure and buildings that will require a lot of cement. Some companies are pursuing process solutions with conventional cement that could achieve some measure of emission reductions, including blended cements that replace some of the traditional clinker (one of the key raw materials) with lower-carbon supplementary cementitious materials (SCMs) such as clays and ground glass.

The average life of a cement plant is 40-50 years. U.S. plants are very old, with an average age of 34 years. The impending fleet turnover is an opportunity to come in with investments to retrofit facilities, but that ready opportunity is not the case outside the United States.

Retrofitting cement plants to improve energy efficiency or otherwise change systems could be part of decarbonizing the sector, but retrofitting plants in developing countries would be necessary. The average life of a cement plant is 40-50 years. U.S. plants are very old, with an average age of 34 years. The impending fleet turnover is an opportunity to come in with investments to retrofit facilities, but that ready opportunity is not the case outside the United States. Chinese plants, for instance, are very young, and it is unlikely the Chinese cement industry (which is by far the largest) will be pursuing retrofits anytime soon.

The different approaches have different potentials for achieving emission reductions, with electrification falling pretty low on the scale. Resources should be allocated to accelerating the opportunities with greater potential, including novel processes for making the same cement, CCS, and SCM alternatives.

REDUCING & REPLACING CONVENTIONAL CEMENT

Another approach to reducing emissions from the sector is to simply use less cement. That could involve efforts on both the demand side and the supply side. With respect to demand, promoting more efficient deployment and use of cement could be part of a durable solution. Significant emission savings globally could come from changing designs up front and by utilizing new building methods that reduce waste. For example, one way to radically reduce the cost of new nuclear power is to rethink the use of concrete to use lower volumes and do more prefab.

Recycling could theoretically reduce some of the need for new supply, but it faces numerous challenges. For example, recycling concrete to incorporate demolished structures into new concrete would be a new composition, so it would have to be evaluated for cost and for strength over time, and building codes would need to be changed. Recycling concrete as aggregate (which is basically gravel) also has rather minimal emission reduction potential, since the emissions associated with aggregate are mostly from transporting it. There is an opportunity to grind up demolition waste concrete, spread it out, let it absorb CO2 from the atmosphere, and then use it as an aggregate, but the economics do not really work, and space is needed to do it. In addition, there is more novel technology that can take old concrete, mill or grind it, separate out the rocks from the cement powder, and put the cement powder back into a kiln to reduce some of the original feedstock. Cement absorbs carbon dioxide over its lifetime, though, so when it is put back into a kiln, that CO2 gets re-emitted; depending on the cement involved, the level of emission reductions is probably small, but not insignificant.

There are people working on a range of novel cements, but these could be very slow to adopt, and regulations do not allow their use in structures. Deployment would require convincing structural engineers the new material is acceptable to use and educating the world workforce on the installation of the new material. A related area of research is on carbon curing. Making a concrete block usually involves lots of steam and high amounts of energy. If curing occurs in a CO2 environment, it happens much faster with much lower energy input, and the CO2 gets fixed into the concrete blocks. This could be one of the few uses for captured CO2 that has some permanence; if structures are not demolished for decades, the CO2 should stay fixed for a long time. If those structures are made via 3-D printing and so have no steel, even more carbon can be put into the concrete. Again, though, there are challenges about regulations, materials testing, and establishing and convincing people that it can be used safely for structural purposes. There are, however, uses of concrete (e.g., paving) that are not structural.

There are also efforts to develop and deploy materials to replace concrete. People rarely realize how ubiquitous concrete is; it is among the most used materials on earth. Especially for structural, load-bearing needs, there are not many alternatives that are as available and as cheap. There could be opportunities for substitution, however, on the margins of the product. For example, mass timber could replace concrete in some construction uses, but it depends somewhat on the regional availability of timber. There are also structural limits on how much can be used and for what. Wood is a good alternative in some regions for low-rise buildings, but not for many other concrete uses (e.g., big bridges). Likewise, there are companies working to create pure graphene, which can replace some cement uses and provide greater strength. Novel replacement materials, however, will face challenges similar to those facing novel cements, including permitting, regulations, and convincing engineers that it is safe to use a never-before-used material to make a building, dam, or some other infrastructure. Even if engineers are convinced and building codes updated, there are several layers of insurance that could present problems. Concrete companies will insure their products; insurance on new products is much more difficult.

POLICY NEEDS

Policy support and market development are needed along the entire chain, including applied R&D, demonstration, early deployment, and mass diffusion. There is a need for policy to enable wide market adoption of fully commercialized incremental improvements and interventions (e.g., alternative SCMs), as well as to de-risk new and emerging technologies that will be needed. The politics of this, however, could be interesting and complex, since alternative SCMs, new aggregate technologies, and other approaches could all affect particular constituencies (e.g., industries that mine aggregates).

Policy support and market development are needed along the entire chain, including applied R&D, demonstration, early deployment, and mass diffusion.

In the developed world, the cement industry will not be rebuilt from scratch; policy is needed to help decarbonize the existing fleet. On the production side, California is the only state with a legally binding emissions target for the cement industry (net-zero by 2045). That policy could serve as a model for other states. State policies can make a difference, since concrete is a regional material. Because of its weight and low cost, it is not worth trucking long distances. On average, it moves within a 250-mile radius, so neighboring states can produce it, but for states that do not have access to ports (to bring cement in via barge or ship), cement imports are unlikely.

California does not, however, have a procurement directive commensurate with its emissions target; its Buy Clean law does not include cement or concrete. (New Jersey has a new law to incentivize low-carbon concrete procurement.) Government procurement commitments could make a real difference in bringing new low-carbon cement approaches to market. Incentives and public subsidies can help reduce the costs of technologies, but government procurement can complement direct incentives and emissions targets by providing a steady market and a buyer willing to absorb an initial green premium. Procurement also provides data and transparency about which materials are cleanest and should be rewarded in the market.

Procurement policies can be designed in many ways. Environmental product declarations (EPDs), which document the environmental attributes of a product, are a tool that policies are starting to require from the industry to enable measurement and transparency. EPDs and lifecycle analyses, however, can be obstacles for startups. EPDs are for full-scale plants that have been operating for at least a year. If EPDs are required for procurement, that means startups would have to build and operate a plant in order to secure procurement, but many require procurement first in order to secure the funding they would need to support a plant. Such a procurement system would benefit giant companies, not startups.

Advance market commitments can be a powerful procurement policy tool. Policies can be designed to support existing technologies while also committing to products that can achieve greater reductions but are not yet ready or available at scale. The advance commitment does not have to be at a premium, but rather could be at market rate; just the existence of advance commitments would have an impact. There is also a need to think about things like performance standards down the road, as well as other regulatory mechanisms to support uptake.

There could be a private sector role in driving demand as well, but it will depend on greenhouse gas accounting rules. People are also considering whether lower-carbon cement could lend itself to an instrument market, similar to RECs, though the challenges may be greater for novel materials than for new ways of producing the same material. There are efforts underway to develop a framework analogous to unbundled RECs in the industry space, to credit value chain investments in emission reductions.

Since many technologies for cement decarbonization are at very low levels of technological readiness, however, the greater need currently may be for support, policies, and funding targeting the earlier stages of development. The suite of policy support needs to include significant R&D funding and support for demonstrations. Big leaps forward will have to be directly funded. With funding for the first time becoming available for industrial decarbonization, it is a good time to talk about increasing ambition.

The recent pieces of federal legislation have provided lots of investment and incentives for low-carbon materials and industrial decarbonization. The first meaningful dollars are going into the sector now from the recent bills, and a huge increase in resources is needed in the years ahead. Innovation on industrial decarbonization is far, far behind at DOE, which has historically been very focused on the power sector, but the energy-intensive, big-emitting industrial sectors are the next horizon for DOE innovation policy. It is important that the money going into industrial decarbonization not get diverted from heavy industry to light manufacturing. Heavy industry is not "hard to abate" anymore, and federal funding will catalyze the deployment of technological tools in the market.

The funding that OCED already has for cement is substantial, but the quality of the applications that industry will submit is key. High-quality, high-impact applications must be encouraged. Over the next few years, the industry and government have a chance to determine what the trajectory of the industry will look like. Aiming big could unlock new technologies, shift markets to low-carbon materials, and provide substantial emission reductions. Tinkering on the edges or thinking small could mean missing the opportunity to turn a massive global industry.

Over the next few years, the industry and government have a chance to determine what the trajectory of the industry will look like. Aiming big could unlock new technologies, shift markets to low-carbon materials, and provide substantial emission reductions. Tinkering on the edges or thinking small could mean missing the opportunity to turn a massive global industry.

Since the industry is, in fact, global, there are policy needs with an international focus as well. In places like the United States, where there are large, vertically integrated multinationals that own the cement production, the concrete plants, and the aggregates, there is generally uniform support for decarbonization. The U.S. industry recognizes the need for action and is starting to test what it could look like. In some other parts of the world, however, especially places with many small cement plants and a range of concrete suppliers, there has not been much uniformity or commitment to decarbonization. Since the vast majority of additional cement production capacity will be coming in India and Africa (mostly built by China or by large multinationals creating agreements with local companies), there is an opportunity to make sure these plants, which will be around for decades, are built clean from the outset. Energy-intensive sectors are a key area of focus in the nexus between international trade and emissions reductions, and cement was one of the sectors in the abandoned Asia Pacific Partnership, which involved harmonization of performance levels across countries. It would be interesting to see what should be learned and resurrected from those efforts. Multilateral development banks also can play a key role, but their existing guidelines on how to build cement plants are inadequate.

A GLOBAL CHALLENGE

Climate change and the energy transition are global challenges, but the world is currently in a moment of incredible flux, with a hot war and geopolitical realignments. There is a question as to whether global markets and global market governance are equipped to get the world to net-zero. Measures are needed to encourage international partners, especially fast-growing developing countries, to be part of the climate solution.

LOCK-IN & TRANSITIONS ON A GLOBAL STAGE

Global greenhouse gas emissions continue to rise, and the projections over the years of what emissions will be at mid-century have followed suit. Most policymakers do not appreciate the cumulative nature of the issue or the compounding effect of emissions. To get to net-zero, a rising number of annual gigatons of emissions must be avoided or removed, but decisions made now could have long-lasting infrastructure or network effects that lock in emissions for decades. A principal challenge involves the subset of the developing world that is projected to experience significant emissions growth, including Indonesia, Vietnam, India, and South Africa. Their economies need to grow to increase prosperity for their populations, but their current resource mixes imply emissions growth. A global energy transition is necessary.

If developed countries can bring the costs of low-carbon alternatives down far enough that the cost of a new technology is less than the variable cost of the old process ("shutdown economics"), developing countries may voluntarily shut down emitting sources because that is the cheaper route.

The history of energy transitions is that the world has never had one. There have been energy additions, not transitions. Shares of the energy mix have changed, but in terms of absolute levels, humanity has continually added new energy on top of old energy. The world uses just as much biomass as it ever did, and it uses more coal and gas. The growth in renewables has simply been added on top of that. It is not enough to subsidize and build new clean energy; clean energy also must displace emitting energy. To achieve climate goals, subtraction, not just addition, is needed. Things are changing — the European Union is furthest in the transition, and the United States is making progress — but subtraction has not happened yet at the global level.

As complicated and layered as addressing the climate problem will be in the United States, it is even more complicated and layered in many other parts of the world. Industrialized economies are working incrementally from an existing large base of infrastructure. Rapidly developing countries, in contrast, are in the process of building that base of infrastructure, which is a very different capital deployment and market incentive situation. Financing clean energy development in the developing world involves lots of risks (e.g., currency exchange rate risk), but few solutions are usually offered. To shift developing countries away from what is already familiar to them, it is imperative to figure out the key risks and to introduce solutions that address those in ways that incentivize private sector involvement.

One of the most important things the United States can do to contribute to the global solution is to show that it can actually be done. In the process of doing that, the United States needs to drive the cost of alternatives down to close to or less than high-emission options. If developed countries can bring the costs of low-carbon alternatives down far enough that the cost of a new technology is less than the variable cost of the old process ("shutdown economics"), developing countries may voluntarily shut down emitting sources because that is the cheaper route. (Shutdown economics may not work in countries such as China, where the sectors are state-funded and -controlled.) If developed countries live up to their commitments to get to net-zero by 2050, however, that also means there will be a lot of cheap oil, coal, and gas available for the rest of the world.

THE TRADE-CLIMATE NEXUS

In taking domestic action, it is imperative to address the trade-climate nexus. For decades, countries will be at different places in their transitions. Countries at the forefront will pay more, and if their industries are exposed and leaving, the transition will not be viable. It is undesirable for American ambition on climate to mean American industries leave; that sort of global leakage (i.e., emissions go down in the United States but go up wherever the industries relocate) destroys domestic will to act and does not help the climate. To date, U.S. climate policy has not been much of a driver of leakage, in part because there has not been much U.S. climate policy, but that does not mean there could not be more leakage as climate policies get stronger. At the same time, the globalization of supply chains basically decoupled the emissions the United States produces from the emissions the United States consumes. That has created a sort of carbon loophole. For a range of reasons, the need to confront the climate-trade nexus is inevitable.

One of the few areas of bipartisan agreement in the United States is the dislike of trade and globalization as they have recently been practiced. Trade is vital, however, including as the means by which the innovations that are developed in the United States and elsewhere get disseminated to other parts of the world. Disabling or materially impeding trade going forward would be detrimental to efforts to address the global challenges of climate change and the energy transition.

There is a need for trade policy coherence with domestic investments, and there are times the climate, national security, trade, and domestic economic objectives are in tension. In the recent past, the United States invested in solar, and China successfully dumped panels into the economy with the aim of destroying the U.S. manufacturing sector. China's dumping of solar was bad in terms of domestic manufacturing, but it was very helpful for spurring very cheap solar that could help address climate concerns. On the other hand, if a country is exporting cheap technology into another country's market, it is not installing that technology in its own market. Driving down the global price of goods with dirty energy and forced labor also makes it harder for better production of those goods at scale to happen elsewhere. There is a need for more nimble trade remedies, and decisions on those remedies should be technocratic instead of political. Politicians tend to make suboptimal decisions on whether and how to mitigate risks to industries.

National security, access to materials, human rights, and supply chain failures are among several impending supply chain risks around the transition that are linked with China. There is a lot of vilification of China in the United States, but the China situation is very complex. China is committed to hitting its greenhouse gas targets, is likely to peak emissions soon, and is still the largest producer of virtually every critical asset needed for the transition, but it is building new coal plants for economic security reasons. China also is not as much in the world as it was a few years ago. For instance, it seems to have met its commitment to stop overseas coal plant financing, amid a general decline in its overall power project financing, though its reasons for doing so were multifaceted. In addition, China started its long, slow population decline recently, which could lead to decisions and actions that could further cause geopolitical disruption. The United States is creating more separation from China for many reasons.

If the United States is moving away from a global trade system to one in which manufacturing is re-shored or friend-shored, that is a very different trade world. It could mean reversing some carbon leakage by bringing manufacturing back home, but it could also mean the loss of an important source of leverage that could be used to shift policies and emissions trajectories in other countries. A better framework is needed to think about clean energy inputs and goods and determine which things are more or less important to re-shore.

There is some political interest in the United States in pursuing some version of a carbon border adjustment (CBA) mechanism, rooted in a desire to take advantage of the U.S. emissions advantage over Chinese industrial production.

CBAs are a border tax for imported products that taxes either the entirety of the emissions of a product or some portion that is differential to the consuming economy. Some system of border adjustments is necessary for national policies to operate as part of global action.

For a country with a carbon price (including a cap-and-trade system), having a CBA mechanism is economics 101. Adopting a domestic carbon price makes a country's internationally traded products less competitive; carbon prices are primarily effective for products that are not trade-exposed. They are only effective for trade-exposed products if there is some sort of mechanism to level the playing field. The economic tool for that is a CBA mechanism.

The United States does not have a domestic carbon price. It has a big mix of policies that could be translated into a sort of implicit carbon price, but that it is very difficult to do. Some argue the United States does not need a domestic carbon price to implement a CBA, as it could use classic tariff policy and look to carbon performance per unit of output as a metric of comparison. The global trade system is based not on harmonization but on interoperability; that is the basis of the global customs system. The world, for instance, has been doing border taxes for ozone-depleting substances under the Montreal Protocol for decades with no real disputes, in a way that is well-implemented and that conforms with World Trade Organization (WTO) rules. The legal standard for WTO compliance is comparative effectiveness — treating imported products the same as domestic products, such as by requiring products to be produced in a way that is comparative to domestic performance. A carbon margin could meet that standard.

The European Union has adopted the classic CBA approach, with a domestic price and a border adjustment mechanism to avoid leakage. Its Carbon Border Adjustment Mechanism (CBAM) forces companies to pay for every molecule, whether they out-perform EU facilities or not, and penalizes countries that do not have a carbon price. Some argue that the CBAM's approach is not about comparative effectiveness and violates WTO rules by specifying other countries' policy mechanisms. (Although there are debates about whether the EU's CBAM or a U.S. CBA would pass muster with the WTO, many people also seem not to care if they do or not.) The idea that there will be a massive clean energy trade war with Europe is exaggerated, but it is important to think carefully about the protectionist elements of the IRA and the effects of the CBAM on U.S. companies.

A key challenge with the EU's CBAM is that it left developing countries out of the fold, and they are livid about it. For many developing countries, the EU has basically told them that their former colonial power, which put a lot of infrastructure in their countries to extract their natural resources, will now be taxing them on that legacy infrastructure and the exports they produce that they need for foreign exchange. CBAM is a stick to try to push climate action in other countries, but more thinking is needed on how to incentivize, encourage, and facilitate more climate solutions in quickly growing developing economies through both carrots and sticks. To the extent sticks are used, they should be designed with phase-in periods and other technical support and approaches to help countries. Solutions must be found that are developmentally appropriate. Developed countries have an obligation to be part of the effort to help emerging economies grow and grow clean, including by opening (not narrowing) trade avenues. It is important to have a positive narrative about the opportunities arising from the transition to a clean energy economy. Diplomacy, governance, rule of law, financial instruments, and many other elements are essential tools to pursue.

CBAM is a stick to try to push climate action in other countries, but more thinking is needed on how to incentivize, encourage, and facilitate more climate solutions in quickly growing developing economies through both carrots and sticks.

Data is an additional challenge, and the trade-climate nexus is yet another area where carbon accounting will play an important role. There is lots of opportunity to offshore production or otherwise try to game the system. The EU's CBAM approach was pursued in part because a handful of key countries were not moving, not living up to pledges, and not providing monitoring, reporting, and verification (MRV). The EU designed a system with the idea that consultants, lawyers, and others would be able to get from those countries very fine-grained lifecycle analyses down to the production and product level. That is very unlikely to happen, but the terrible quality and spotty availability of energy and emissions data out of big countries such as China are cause for concern. Trade regimes, however, do not generally need to get down to the production and product level, at least at the start. In other contexts, a more generic approach has been taken, starting with a country's average based on sector intensity, not individual producers. Averaged data can get the process started and can create incentives to get product- and facility-level data voluntarily disclosed. The Montreal Protocol, for instance, has generic, sector, and specific layers, and producers have started self-providing data they were not before, providing MRV where there had not been any. Similarly, with respect to fisheries, the approach has been to take known parameters, come up with a generic number, and leave it to countries and producers to provide data if they do not like the generic one.

CARBON REMOVAL

It sometimes seems that people who use the term "net-zero" do not appreciate what the "net" part means. The "net" comes from removals. Although carbon dioxide removal (CDR) is not a taboo subject anymore, removal of carbon dioxide from the atmosphere is not quite as central to the climate agenda as climate science suggests may be warranted. The Intergovernmental Panel on Climate Change (IPCC) and others have been very clear for a long time that, while reducing greenhouse gas emissions is paramount, there will be a need for removals.

It sometimes seems that people who use the term "net-zero" do not appreciate what the "net" part means. The "net" comes from removals.

TYPES OF REMOVAL APPROACHES

There are lots of different approaches to CDR, including engineered removal technologies and natural removal approaches. These approaches need to scale to match the scale that climate science suggests is needed.

In terms of engineered approaches, there are chemical pathways being explored and utilized to take carbon dioxide out of the air (direct air capture, DAC) or the ocean (direct ocean capture). One DAC option being explored uses saltwater to mineralize CO_2 into carbonates, which would make desalination facilities potential partners (i.e., to help with waste management of brine). There are currently only a few, small-scale DAC facilities that have been deployed (in the United States, Canada, and Europe), but more facilities and pilots are getting built. DAC was initially developed more by venture capital money than by government funding, so it developed as modular systems that enable faster learning, rather than larger systems that have economy of scale.

There are also engineered biological pathways that involve capturing CO_2 through biomass growth, producing power from that biomass, and adding CCS to the system. Bioenergy with CCS (BECCS) is a scalable carbon removal technology, with individual power plants capable of capturing millions of tons of CO_2 per year. BECCS has been in the IPCC pathways for a long time, but there is controversy about how much BECCS can actually scale (i.e., how much supply there is of sustainable biomass). It may end up being on the lower end of the spectrum.

In terms of natural removals, trees (and plants more broadly) are the quintessential carbon removal devices. Plants are a natural way to capture and fix carbon from the atmosphere. Soil is also a great carbon sink, and there is a need for greater focus on soil quality. Agriculture should not be overlooked in terms of sequestration. In general, nature-based removals tend to be cheaper than engineered, but engineered removals tend to have much greater permanence (i.e., the captured CO_2 stays sequestered).

ROLE & VALUE OF CDR

Carbon dioxide stays in the atmosphere for a very long time. Even if all emissions stopped today, there would still be a need for removals. Carbon removal involves cleaning up the mess humanity already made.

If CDR could get to the point where it could be achieved at scale at a reasonable cost, that would make it a backstop technology. If the costs come down, carbon removal could be relatively (but not infinitely) scalable and should be used to remove as many tons as possible. If there was scalable, cost-effective removal technology, it could be used to bring atmospheric concentrations down, whether because of overshoot of the 1.5°C and 2°C targets or to go beyond those goals. Net-zero is not the final goal; CDR is part of the strategy to achieve net-negative emissions. That means billions more tons of carbon dioxide being removed for a long period of time — which means even if carbon removal might not work or might not scale in the near term, it is still important to consider and invest in.

If humanity overshoots climate targets and uses CDR to reduce atmospheric concentrations, it is important to remember that doing so does not mean the climate will necessarily return to what it was. If the Greenland ice sheet melts, it will not re-form once concentrations are brought back down. If humanity crosses climate thresholds, the climate at later-reduced atmospheric concentrations will be a different climate (whether better or worse). Making the task even more complex is the fact that most excess heat is stored in the oceans, which are in dynamic equilibrium with the atmosphere. As carbon dioxide is taken out of the atmosphere, it is somewhat replenished by the ocean.

Although CDR may be used primarily to clean up the mess humanity already made (i.e., to address legacy emissions), it may also be needed as an offset in areas that are really hard to decarbonize and thus where the cost of abating emissions may stay too high. Aviation emissions could be an example. There is a need for a drop-in liquid fuel that is energy dense. The two main pathways are e-fuels (which depend on cheap electricity and hydrogen) and biomass (which has limited availability and lots of competing demands). It might be that doing removal as an offset for continued aviation emissions is a more viable, cost-effective solution in the long term. This would necessitate even higher levels of removals, and there are co-pollutant challenges, but the need may be there nevertheless. If emissions continue but CDR ramps up to the point that it all nets out, that climate math works. CDR could be a valuable flexibility mechanism for the private sector.

Although CDR may be used primarily to clean up the mess humanity already made (i.e., to address legacy emissions), it may also be needed as an offset in areas that are really hard to decarbonize and thus where the cost of abating emissions may stay too high.

For removals to scale to such levels, there will have to be a huge increase in the number of CDR facilities. When communities are approached about siting potential CDR facilities, however, there can be confusion about the technologies, as well as potential opposition. The technologies must be shown to be proven, and communities should be asked if they want CDR facilities sited there, through a process that is inclusive and transparent. There has to be a compelling story for communities about what CDR is, what it means, and what its benefits are (beyond just monetary); the narrative matters. As noted earlier with respect to infrastructure more broadly, CDR developers should also be creating other benefits for communities, and the best outcome might be community-led or -owned CDR facilities. Furthermore, technology transfer to the global South will be key to successful scaling of CDR. All the innovation and research on CDR are in the global North, and intellectual property rights are a constraint in the spread of CDR technologies even in the North, much less for tech transfer to the global South.

If CO2 emissions cannot be reduced and removed at a sufficient rate, humanity may be driven to an option that involves greater interventions that could have difficult implications. Geoengineering, including solar radiation management, may be a few years away from becoming a mainstream topic of conversation, but it may soon become a necessary option to stop planetary systems from irreversibly declining. There is a need for care and good regulations about potential impacts from such planetary system interventions.

POLICY & FUNDING SUPPORT FOR CDR

For the most part, the scale of private buyers for carbon removal will not be large enough, which means policy and government involvement are essential. There are multiple roles for public policy in CDR. Innovation policy and RD&D funding help bring the technologies down the learning curve. There are also other forms of government support, such as contracts for differences in the United Kingdom and the 45Q tax incentive in the United States. There has been relatively little attention paid to the IIJA provision specifically for CCS and DAC that provides tax-exempt project financing (private activity bonds) for carbon capture projects, to complement the 45Q tax credit. Policy could also include price incentives and resolution of the permitting and siting challenges that could hinder buildout of the necessary infrastructure.

Fundamentally, however, removing carbon at scale is a pure public good and will require public procurement — a publicly provided service to the country and the world. Carbon removal could be thought of as an atmospheric cleanup project, and the financing needed is comparable to the size of the current global waste management industry. The public already pays for Superfund, the cleanup of the Manhattan Project, and other similar efforts, and there are bipartisan, bicameral bills in Congress to start spending on CDR procurement as a public good.

Until CDR gets to the point of being widely financed as a public good, CDR advances and deployment have to be funded. Some of that support could come through subsidization or through performance standards (e.g., California's Low Carbon Fuel Standard, which includes CDR as an approved pathway). Other kinds of compliance markets could also provide support, such as carbon trading markets in Europe. All of these should help lower the cost of removal.

Beyond compliance markets, CDR can be supported through voluntary carbon markets. The voluntary carbon market will not provide the scale of financing needed for all necessary removals, but it could still provide meaningful support. Companies adopting climate commitments are willing to spend to meet them (as long as their efforts align with the rules used to determine whether they met them). CDR companies are already raising hundreds of millions in private equity and selling credits in voluntary markets. Nature-based and engineered removal approaches, however, may need to be decoupled in the marketplace and treated as separate things with different ends and economics. Nature-based projects have a variety of benefits and goals, including land conservation, agricultural production, and support for indigenous communities. Engineered approaches, in contrast, are focused squarely on removals. There are different incentives and models involved.

Removals should not be allowed to crowd out reductions. Reductions need to happen now, and removals need to be prepared for now. It is important to clean up the existing mess, but it is also imperative to stop putting more mess up in the atmosphere. It is not one or the other.

Among some of those working on voluntary carbon markets, removals are glamorized and favored over reductions. Both are needed. Removals should not be allowed to crowd out reductions. Reductions need to happen now, and removals need to be prepared for now. It is important to clean up the existing mess, but it is also imperative to stop putting more mess up in the atmosphere. It is not one or the other.

Another way to help bring costs down is to utilize CDR approaches that generate value-added co-products. Co-generation can alter the equation by producing things of great value, whether carbonates, hydrochloric acid, green hydrogen, freshwater, or something else. Co-products can reduce CDR costs and potentially even make it profitable. However, if the economics of a carbon removal approach rely on one or more co-products, that means scalability can only occur at the same rate as the co-product(s). Given the scale of removals needed, co-product markets can get saturated quickly. Power production would be an exception, suggesting that BECCS might be more scalable.

The captured CO_2 itself could be one of those valuable products. One route for improving CDR (or CCS) economics is to use the captured CO_2 for a commercial purpose. Putting too many constraints on what captured CO_2 could be used for could make it harder for CDR to get the funding and financing needed in the early days.

USING THE REMOVED CO_2

If CDR is accomplished via DAC, BECCS, or some other engineered approach, the captured CO_2 must be stored or utilized. To sequester carbon dioxide, it can either be put into geologic formations or be mineralized; both work well. (There are also people looking at how to do mineralization while recovering critical minerals.) Alternatively, captured CO_2 can be utilized for a range of products, including concrete, vodka, diamonds, and fuels. Using captured CO_2 for these products, however, is likely more expensive than alternative approaches, except perhaps in the case of enhanced oil recovery (EOR).

There is strong skepticism about CDR from some young climate activists, who see it as providing cover for oil and gas companies. Using policy to support EOR with captured carbon could reinforce that view and guarantee political opposition to CDR from portions of the left. On the other hand, there are those who argue that EOR should be central to domestic oil and gas strategy, as capturing CO_2 and injecting it underground for EOR is one way to actually square increased production and lower emissions. EOR production leaves injected CO_2 in the ground; done in particular ways, EOR could be carbon negative. Taking EOR off the table also tells the Permian Basin, Wyoming, and other producing regions that there is no role for them in a net-zero future. In addition, EOR is already a widespread practice, and the main source for it currently is CO_2 that is mined out of the Earth — CO_2 that is already geologically sequestered. That reality has to factor into the calculus too.

APPENDICES: PARTICIPANT LIST

Shannon Angielski, Principal, Governmental Issues, Van Ness Feldman LLP

Donnel Baird, Founder, BlocPower

Roger Ballentine, President, Green Strategies Inc.

Rahim Bapoo, Managing Director, BMO Capital Markets

Kathleen Barron, Executive VP and Chief Strategy Officer, Constellation Energy Corporation

Adam Barth, Partner, McKinsey & Company

Jeff Bladen, Global Director of Energy, Meta Platforms, Inc.

Drew Bond, Co-founder, President & CEO, C3 Solutions

Brandy Brown, Chief Innovation Officer, Walker-Miller Energy Services

Bill Brown,Chairman and Founder, 8 Rivers

Mark Brownstein, SVP, Energy Transition, Environmental Defense Fund

Neil Chatterjee, Senior Advisor, Hogan Lovells

Amy Chiang, Vice President, Global Sustainability, Global Government Relations, Honeywell International, Inc.

Stephen Chriss, Director, Energy Services, Walmart

James Connaughton, Chairperson, Nautilus Data Technologies

Lara Cottingham, VP Strategy & Climate Impact, Greentown Labs

Jon Creyts, Chief Executive Officer, Rocky Mountain Institute

Tanya Das, Senior Associate Director, Energy Innovation, Bipartisan Policy Center

Joseph DeSimone, Professor, Stanford University

Jennifer Diggins, Vice President Public Affairs, 8 Rivers

Kerry Duggan, Chief Executive Officer, SustainabiliD

Tim Digiuglio, Head of Sustainable Finance Advisory, Wells Fargo & Co.

Katie Dykes, Commissioner, Connecticut Department of Energy & Environmental Protection

Jonathan Elkind, Senior Research Scholar, Columbia University Center on Global Energy Policy

Patrick Falwell, Vice President, Green Strategies

Cody Finke, Chief Executive Officer, Brimstone

Peter Freed, Director of Energy Strategy, Meta Platforms, Inc.

Will Gardiner, Chief Executive Officer, Drax Group

Caroline Golin, Global Head of Energy Market Development and Policy, Google LLC

Dave Grossman, Principal, Green Light Consulting

Maureen Hinman, Co-Founder and Chairman, Silverado Policy Accelerator

Brett Isaac, Founder & Executive Chairman, Navajo Power

Nat Keohane, President, Center for Climate and Energy Solutions

Melissa Klembara, Director, Portfolio Strategy, Office of Clean Energy Demonstrations, Department of Energy

Tim Latimer, Chief Executive Officer, Fervo Energy

Robert Leland, Director, Climate Change Security, Sandia National Laboratories

Jeff Lyng, Area Vice President, Energy & Sustainability Policy, Xcel Energy

Ian Magruder, Director of Private Sector Engagement, Rewiring America

Roger Martella, Vice President & Chief Sustainability Officer, General Electric

Robin Millican, Senior Director, U.S. Policy and Advocacy, Breakthrough Energy

Jeannette Mills, Executive Vice President & Chief External Relations Officer, Tennessee Valley Authority

Thomas Montag, Chief Executive Officer, Rubicon Carbon

Esther Morales, Executive Director, Clean Energy Leadership Institute

Jason Muller, Senior Director, Low Carbon and Climate Advocacy, Equinor

James Murchie, Chief Executive Officer, Energy Income Partners, LLC

Richard Newell, President & CEO, Resources for the Future

Calli Obern, Director of Policy, Capture6

Todd Parfitt, Director, Wyoming Department of Environmental Quality

A.-H. Alissa Park, Lenfest Earth Institute Professor of Climate Change, Columbia University

Mosby Perrow, Partner, Van Ness Feldman LLP

Mark Peters, Executive Vice President for National Laboratory Management & Operations, Battelle Memorial Institute

Tremaine Phillips, Commissioner, Michigan Public Service Commission

Rich Powell, Chief Executive Officer, ClearPath

Heather Quinley, Managing Director, ESG & Sustainability, Duke Energy

Dan Reicher, Senior Research Scholar, Stanford University

Katie Sarro, Senior Director, Business Roundtable

Chris Schraeder, Senior Vice President, Stakeholder Engagement, Wells Fargo & Co.

Jonathan Sohn, US Director, Capital Power

Steph Speirs, Chief Executive Officer, Solstice

Martha Symko-Davies, Senior Laboratory Program Manager, National Renewable Energy Laboratory

Christina Theodoridi, Policy Advocate, Natural Resources Defense Council

John Wagner, Laboratory Director, Idaho National Laboratory

Cynthia J. Warner, Board Member, Chevron Corporation and Sempra

Jeff Weiss, Executive Chairman, Distributed Sun

Heather Zichal, Global Head of Sustainability, JP Morgan Chase

ASPEN INSTITUTE STAFF

Greg Gershuny, Executive Director, Energy and Environment Program, The Aspen Institute

Timothy Mason, Assistant Director, Energy and Mitigation Policy, Energy & Environment Program

Maria Ortiz Pérez, Managing Director, Energy and Environment Program, The Aspen Institute

Tanzia Redi, Program Coordinator, Energy & Mitigation Policy, Energy & Environment Program

Francesca Reznik, Program Associate, Energy & Mitigation Policy, Energy & Environment Program

APPENDICES: AGENDA

FRIDAY, MARCH 3, 2023

Arrivals and Check-In | *Joe's Stone Crab, 11 Washington Ave, Miami Beach, FL 33139*
Opening Reception
Opening Dinner

SATURDAY, MARCH 4, 2023

Breakfast

Welcome Remarks

SESSION 1 | **Briefing Room: Briefing Room: Unprecedented Federal Investment**

2022 witnessed the largest public investment in fighting climate change in history. In 2023, a key focus is how will we "move the money?" Will it go to the highest and best uses? What are the obstacles to maximizing impact? Are the politics of this new-found federal investment sustainable?

Moderated by Roger Ballentine and **Jim Connaughton**

Discussants:
Katie Dykes, Connecticut Department of Energy & Environmental Protection
Todd Parfitt, Wyoming Department of Environmental Quality
Dan Reicher, Stanford University
Melissa Klembara, United States Department of Energy

SESSION 2 | **An Even Bigger Pot of Money: Capital Marks and Decarbonization**

Leading estimates suggest that multiple trillion dollars of investment per year is needed to decarbonize the global economy on a pace to achieve net zero emissions by mid-century. Governments alone cannot meet this challenge. Private capital has an out-sized role to play. Across investment banking, asset management, and private equity, decarbonization or climate change is increasingly a topic of discussion, but how is capital actually flowing and to what? Is capital seeking decarbonization alpha? Eschewing embedded climate risk? Or just moving the deck chairs around? What are the drivers and obstacles to creating a real decarbonization bias in the capital marks and how does this scale dramatically? Are high-profile financial sector climate pledges and initiatives delivering impact?

Moderated by Roger Ballentine

Discussants:
Thomas Montag, Rubicon Carbon
Chris Weber, BlackRock, Inc.
Heather Zichal, JP Morgan Chase

SESSION 3 | Oil and Gas

What does a decarbonization pathway really look like? Over what time frame? Different majors taking different approaches – expansion into other sectors like renewable energy; diversification in liquid and gaseous fuels; operational footprint changes; and others. Are there multiple pathways? How do we manage a decadal low carbon transition in light of socio-political economic exigencies and geopolitical tensions?

Moderated by Jim Connaughton

Discussants:
Mark Brownstein, Environmental Defense Fund
Andy Karsner, X, the Moonshot Factory
Cynthia (CJ) Warner, Chevron Corporation and Sempra
Jason Muller, Equinor

Forum Reception and Dinner

SUNDAY, MARCH 5, 2023

SESSION 4 | Taking Stock of the Progress to Net Zero in the Electricity Sector

The proliferation of strong decarbonization commitments of the electric power sector has been dramatic. Today, three-fourths of U.S. electricity customers are served by a utility with a 100% carbon-reduction pledge or a utility owned by a parent company with a 100% carbon reduction target. What is the state of progress against these commitments? What are the obstacles to greater progress? How do market structures impact the decarbonization pathway? How far can the sector go without significantly new technologies or policies?

Moderated by Roger Ballentine

Discussants:
Jon Creyts, Rocky Mountain Institute
Vishal Kapadia, Walmart Inc.
Jeff Lyng, Xcel Energy
Jeannette Mills, Tennessee Valley Authority

SESSION 5 | Decarbonizing Cement

Along with maritime shipping, steel production, and aviation, cement is considered a “hard to decarbonize” and highly carbon intensive sector – accounting for approximately 7% of global emissions. What are the most viable pathways for decarbonizing cement? What combination of efficiency, alternative energy, advanced technologies – and substitution – make the most sense? What levers – policy and demand-side market pressures – are needed to accelerate change?

Moderated by Jim Connaughton

Discussants:
Cody Finke, Brimstone Energy
Rob Leland, Sandia National Laboratories
Christina Theodoridi, Natural Resources Defense Council

SESSION 6 | Carbon Removal

Even the more optimistic global decarbonization pathways call for carbon removal – natural and engineered – as part of achieving a net-zero mid-century economy. As the more optimistic timelines for emissions reductions slip further from reach, the role of/need for removals increases. Is enough attention being paid to removals – or too much? What are the solutions? Are the finance and market structures in place to scale removals? What new policy pieces are needed?

Moderated by Roger Ballentine

Discussants:
Will Gardiner, Drax Group
Calli Obern, Capture6
Alissa Park, Columbia University
Nat Keohane, C2ES

SESSION 7 | The Carbon Bomb: Leakage and Lock-in

When it comes to decarbonization, are we actually succeeding, or are we making things worse? As we work to bring our emissions down, what's actually happening is that emissions are going up due to the very significant differential in carbon intensity between developed and developing nations. As developing nations build out their energy production and industrialization infrastructure, to the extent that they are predicated on fossil fuels, they may be locking in emissions for a generation or more. As more efficient and clean end use technologies are being developed and mandated in the developed world, are we dumping the old technologies into developing markets? Is this a function of the "green premium"? What are the right trade, energy, labor policies to minimize leakage and lock-in?

Moderated by Jim Connaughton

Discussants:
Jonathan Elkind, Columbia University Center on Global Energy Policy
Maureen Hinman, Silverado Policy Accelerator
Richard Newell, Resources for the Future

Forum Reception

MONDAY, MARCH 6, 2023

SESSION 8 | Wrap Up – Putting it All Together

Forum Adjourns

THANK YOU TO OUR 2023 SPONSORS!

Google

8 RIVERS

Meta

WELLS FARGO

Arnold Ventures

Capital Power

CLEARPATH

DUKE ENERGY

Constellation

Energy Income Partners, LLC

INL Idaho National Laboratory

Sandia National Laboratories

BATTELLE

NREL Transforming ENERGY

Van Ness Feldman LLP

Distributed Sun