2022 ASPEN ENERGY WEEK

TURBULENCE, PROGRESS, & SYSTEMS TRANSFORMATION IN THE CLEAN ENERGY TRANSITION

A Report from
2022 Aspen Institute Energy Forum

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Executive Summary

It has been a tumultuous year in energy, in large part due to the global energy crisis — which was already underway because of the COVID-19 pandemic (and many other factors) before being amplified by the invasion of Ukraine. This is the first truly global energy crisis, affecting all energy commodities and almost every region of the world. This is also the first crisis of the U.S. age of energy abundance, reminding the United States that even as a net exporter of energy, it is still acutely vulnerable to geopolitical shocks. In addition, this is the first crisis of the energy transition, though the crisis was not caused by the transition. In response to the global crisis, the United States has worked to help allies reduce dependence on Russian energy and has become the largest exporter of liquefied natural gas in the world. Demand in these turbulent times must be met while simultaneously ensuring that policy and financial resources are dedicated at scale to systemic change in order to achieve decarbonization. The chaos of the crisis could turn out to be an opportunity to accelerate the energy transition.

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It has been an eventful year for U.S. energy and climate policy, as well. Right of center, House Republicans have been assembling a multipart climate, energy, and conservation agenda. Left of center, there is the Inflation Reduction Act (IRA), the Democrats' wide-ranging budget reconciliation bill that provides $369 billion for climate and clean energy, about half of which is focused on emerging technologies and innovation. In addition, late last year, the bipartisan infrastructure law (the Infrastructure Investment and Jobs Act, or IIJA) was enacted, providing support for a range of deployment activities and technology demonstration programs. Federal agencies — including the new Office of Clean Energy Demonstrations (OCED) in the Department of Energy (DOE) — are now turning to the task of implementation. OCED will have to strike a balance between ensuring success at the portfolio level and being catalytic, and it will have to establish a strong political model to maintain support. One of the high-profile demonstration areas that Congress included in the IIJA is hydrogen, which has led to a flurry of activity in many regions to put together competitive hydrogen hub proposals. On top of all of that, permitting reform is on the table in Congress, and a Supreme Court decision constrained (but did not eliminate) the Environmental Protection Agency's authority to regulate greenhouse gas emissions.

Grid decarbonization and reliability remain essential near-term priorities. It is widely projected that achieving net-zero could require a massive expansion of the U.S. electricity grid, though there are many grid-balancing and demand-side resources that tend to get left out of models. Even with a big focus on the demand side, achieving net-zero requires deployment of clean energy supply. If climate comes up against affordability or reliability, the clean energy transition gets tougher. All energy resources have benefits and flaws for those trying to manage reliable, affordable electricity systems, but the acronym order has to shift from ACRE (affordable, clean, reliable energy) to RACE (reliable, affordable, clean energy). Reliability is paramount, which requires flexibility as the system becomes more decentralized and complex. Transmission buildout is a huge part of enabling a reliable, decentralized grid, and conservation and efficiency are incredibly undervalued in terms of their ability to help enhance reliability.

Power is no longer the largest-emitting sector in the U.S. economy; during the COVID-19 pandemic, the industrial sector joined transportation in overtaking it. Globally, steel is the largest industrial emitter, and the vast majority of steel emissions come from extracting iron from the ore. While recycling can play a role, ironmaking has to be decarbonized, which involves either direct renewable electricity use, a clean fuel (e.g., hydrogen), or carbon capture and storage (CCS), though more options may be emerging. (In addition to increasing supply, possibilities also exist to reduce steel demand in the first place, including through better structural design and substitution.) Decarbonizing steel presents an opportunity to revitalize the industrial Midwest, and bipartisan competitiveness legislation in Congress included provisions to stand up RD&D pilots and programs at DOE to lead the way on decarbonizing steel manufacturing. Demand signals matter too, such as clean procurement efforts. As an energy-intensive, trade-exposed industry, though, there is a need for global or multilateral sectoral agreements on steel decarbonization. It is imperative to rationalize trade policy and carbon policy. While there is growing U.S. interest in carbon border adjustments because U.S. steel has a significant advantage in terms of direct Scope 1 emissions, the picture is not as good when Scope 2 emissions (i.e., where the electricity comes from) are considered. Having steel companies decarbonize their electricity purchases and become clean energy buyers is a good start.

Globally, steel is the largest industrial emitter, and the vast majority of steel emissions come from extracting iron from the ore. While recycling can play a role, ironmaking has to be decarbonized, which involves either direct renewable electricity use, a clean fuel (e.g., hydrogen), or carbon capture and storage (CCS), though more options may be emerging.

For heavy-duty transportation such as aviation and shipping, innovations in liquid fuels will be key to achieving decarbonization goals. Energy efficiency is one of the main strategies for decarbonizing aviation in the near term, but changes in liquid fuel supply are essential over the medium and long term. First-generation biofuels will not provide the carbon intensity reductions necessary; a transition strategy is needed for farmers and fuel refiners who have been leading on those. Many (but not necessarily all) biofuels also have scalability limitations. While biofuels have a role to play in addressing increased sustainable liquid fuel demand, achieving net-zero will require electrofuels (also known as power-to-liquids, e-fuels, and synthetic fuels) to carry a significant portion of the load. Made by combining green hydrogen with captured carbon dioxide (CO2), electrofuel development and innovation require continued focus and support. There has been a remarkable rise in demand for sustainable fuels, including via the First Movers Coalition and the voluntary market, but public-private partnerships and longer, clearer policy support are critical to de-risk the huge and rapid increases in supply needed this decade to meet the growing demand. Direct air capture (DAC) facilities can provide captured CO2 to create electrofuels, and they can also provide nearer-term solutions by providing offset opportunities and enabling oil production with much more favorable lifecycle emissions.

Meeting net-zero goals will likely require enormous amounts of critical minerals. Lithium, for instance, may be essential for electric vehicle batteries, and the economy is investing heavily in it. The push to secure critical minerals for the transition has raised questions of the potential to increase U.S. mining activity, but the same old extraction processes, business models, and governance frameworks should not be used going forward. Efforts to reform U.S. mining law can hopefully establish a better framework for governance, including stronger indigenous and tribal participation and consultation, a more consolidated process for permitting mines, and robust environmental and labor standards. That said, it is probable that the United States will continue to import most of its mineral supply for years to come. While some minerals come from allies, imports of many critical minerals depend on China, which controls a significant amount of critical mineral supply and refining. The United States is also behind in securing ownership of resources in other countries. Security of supply will have to depend on diversification of suppliers, and the Biden Administration has launched some critical mineral initiatives with key partners. In addition to friend-shoring supply, recycling and energy rebalancing can play a role in reducing U.S. dependence on unreliable foreign mineral supplies, as could finding ways to extract critical materials from coal ash and other tailings (though there are questions about scale and economics). Transmission buildout can also be helpful in reducing the number of batteries (and associated minerals) needed on the grid, and pushing harder on the demand side and on materials substitution can likewise make the medium- and long-term need for critical minerals much more manageable.

Because building new infrastructure is difficult in the United States, there has been a lot of focus on the possibility of retrofitting and repurposing existing energy infrastructure systems. Leveraging existing infrastructure and skills can help avoid or minimize constraints that could hinder low-cost, large-scale, rapid deployment. There are several examples of companies already looking at reutilizing former power plant sites, such as for energy storage, advanced nuclear, or offshore wind interconnection points. Beyond the power sector, drop-in liquid fuels can be produced at facilities that previously produced chemicals and can be transported using existing pipelines, and the existing natural gas system needs to be leveraged as much as possible to help support the production and use of hydrogen. For newer emitting assets, repowering and retrofitting will be essential. If new clean fuels can be produced cheaply, quickly, and at scale, they can be used to keep existing assets in place. Technologies such as CCS will also be important for facilities and countries that are expected to be using fossil fuels for a long time. Likewise, the need to build and site new transmission can be reduced or avoided with technologies to re-conductor existing lines. It is imperative to start thinking about how to position the large amount of upfront capital that will be needed to finance the repurposing, retrofitting, and retiring of assets.

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Communities are where the energy transition happens at the micro level — and where tensions could prevent achievement of an energy transition at speed and scale. While some communities are very welcoming of big energy projects and the associated jobs, local opposition to clean energy deployment has been growing, even at the low levels of current deployment and even in the places that have benefitted from it most. Clean energy development must be able to proceed rapidly and equitably within social systems. If transparency and public participation do not improve, the result will be continued public opposition to infrastructure projects. Federal energy offices are increasing engagement with communities and stakeholders and prioritizing applicants for funding that show how they will engage with communities. The difficulty of designing an effective stakeholder process that lets the public feel like it has control over the outcome heightens the importance of building inclusive engagement processes outside of the regulatory context. The work of building trust must start way before there is an opportunity to talk about a particular project. Trust is vital, as is a sense of humanity. It is also essential to educate stakeholders and students, inspire imagination, and let people see themselves in the work of the clean energy transition. As the country moves forward with decarbonization, it is important to emphasize equity and fairness for communities and people that have traditionally been left behind. Communities also must be able to benefit from the ownership of local projects, which can lead to wealth creation.

Companies are increasingly hearing about these kinds of environmental, social, and governance (ESG) issues from investors, consumers, and employees, who recognize them as material business issues and financial risks. Acknowledging the materiality of the issues, many companies and investors over the last few years have been committing to take action to address them, and ESG issues have begun moving from the voluntary to the mandatory. While there is a growing conservative backlash against ESG and "woke capitalism", it may be mostly political and does not change the materiality of the risks at issue or the need to act on them. Companies and investors can be awake without being woke. There is a need for good stories to explain the benefits of ESG for jobs, profitability, and corporate performance. That said, ESG has some challenges to address. While sustainable finance commitments in the United States are huge and growing, investment in the energy transition must scale severalfold from where it is today, and the cost of capital for transitioning companies should be as low as possible. A focus on the right metrics is needed so there can be a commercially viable transition; there are many different ESG frameworks measuring lots of different things, many of which may not be all that related to progress. In addition, there are concerns that the enthusiasm for ESG can have some undesirable consequences, such as when companies sell off emitting assets that are then bought by private equity firms, where they continue operating, but with less oversight, sometimes higher emissions, and less susceptibility to investor pressure.

Private capital that is not seeking profit — philanthropy —plays an important role in the clean energy transition as well. Philanthropies recognize climate change as a critical issue, but the amount of climate philanthropy today is tiny compared to the need at hand, and few in the philanthropic community are planning to increase funding or incorporate a new climate lens into their funding. More money is needed in the field, from new investors and allies. In addition to more climate philanthropy, there is a need for more effective climate philanthropy, which has to be guided by a philosophy and thesis. Some foundations have focused on building platforms for collective action across the range of climate issues, and philanthropy can play a catalyzing role in gathering the breadth of philanthropic funding together to leverage and influence private sector and government investments, including via policy change and partnerships. It is important, too, for philanthropies to invest more in affecting public will, enabling ecosystems in which entrepreneurs can grow, and advancing equity. In addition, philanthropies should invest more deeply in domestic regional strategies, including helping places get prepared to spend the coming influx of federal funds well. Regional, domestic, and global approaches are all important. Collaborative efforts are needed on both big bets and local strategies, because it is imperative to win on everything.

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The First Global Energy Crisis

Climate and energy transition goals cannot be achieved without recognizing the huge energy security and geopolitical issues underlying them. The intersection of energy security and decarbonization has never been more salient than it is now.

Upheaval

It has been a remarkable couple of years for bipartisan clean energy and climate policymaking in Washington. The focus is often on all the partisan discord and disagreement about climate policy in the United States, which is real, but there is too little appreciation of the areas of bipartisan agreement and the strong record of bipartisan progress over the past couple of Congresses.

The very fundamentals of globalization are currently being put to the test, with energy at the core.

Given the short timeframes to address climate change, there are three types of projects that need to be advanced: technology-driven projects pursuing clear technology and cost goals; capital availability projects focused on unleashing the markets to fund needed infrastructure (e.g., by de-risking projects); and sandbox projects to get incumbents, insurgents, and innovators to work together. The focus of the bipartisan push has been primarily on the first of these — innovation in technologies needed to get the global economy to net-zero on any meaningful timeframe. The recent bipartisan progress started with the Energy Act of 2020 (adopted in the December 2020 bipartisan omnibus bill), which was a huge coming-together of several years of policy development. In authorizing huge expansions of funding for several major energy innovation programs, the law represented the largest commitment of funding in the low-carbon energy space ever. The Energy Act of 2020 also included authority for the Environmental Protection Agency (EPA) to phase down hydrofluorocarbons (HFCs), as well as many other provisions.

The very fundamentals of globalization are currently being put to the test, with energy at the core. The old paradigm that economic interdependency translates to security and military deterrence is starting to unravel in ways unseen since World War II. Alliances, including energy alliances, are shifting at a speed no one would have predicted.

Upheavals are rarely the result of one thing. They are the result of many things, each low-percentage, happening at the same time — a cascading series of events and failures. The current global energy crisis is a case in point. The global energy crisis had already been underway due to the COVID19 pandemic and supply chain disruptions— as well as shifts in investment patterns, nuclear shutdown policies in Europe, a roaring economy, increasingly frequent and intense extreme weather events, and many other factors — before being massively amplified by the Russian invasion of Ukraine.

A New Kind of Crisis

The worst energy crisis of the modern era is still in the early stages. It is by no means done and will last for several years, with the worst still to come, especially in Europe. Already in Europe, the situation is dire, with governments trying to keep people from freezing this winter, companies seeking energy for their operations, and people trying to figure out how to pay energy bills. The crisis is not just in Europe, however. It is playing out around the world. This is the first truly global energy crisis in that it is affecting all energy commodities and almost every region of the world. Europe is affected most acutely, but it is an interconnected world. When Europe pulls in more liquefied natural gas (LNG) supplies, Asian demand for coal goes up, and other economies have a harder time affording gas or coal; a part of the crisis that gets too overlooked is that many people do not have access to energy because they are priced out. Oil is also in a state of crisis.

This is also the first crisis of the U.S. age of energy abundance. The United States had become complacent on issues of energy security. It is the largest petroleum exporter in the world and a net exporter of energy, but the United States has been reminded that it is nevertheless acutely vulnerable to geopolitical shocks that are inevitable in a globally traded market.

The crisis was not caused by the transition, but there are structural problems with energy investment, both in fossil and clean energy.

In addition, this is the first crisis of the clean energy transition. The crisis was not caused by the transition, but there are structural problems with energy investment, both in fossil and clean energy. There have been significant reductions in fossil investment, consistent with modeling from the International Energy Agency (IEA) for achieving net-zero by 2050. A great deal of time has been spent trying to elevate ambition for that net-zero end state, and decisions are being measured against whether they are consistent with that goal, including investment in energy supply and infrastructure. There are consequences, however, to curbing investment due to social pressures and anticipated declines in demand. If the world acts like it is on track for net-zero but is not in fact even close to being on track for that goal, then investments will decline and supply will be constrained, but demand will not fall at the same time. The result is either going to be market crunches and price spikes (which are occurring) or state-owned enterprises (e.g., in Saudi Arabia) stepping in to fill the void (which is also occurring).

A more sophisticated conversation is needed, thinking not just about the end state but also about the process of getting there in a world that is far off track. Investments are needed now in assets that will have to become stranded assets later. Failure to manage issues related to energy security and affordability in the face of the various economic and geopolitical costs and risks that arise could undermine the clean energy transition. If energy security and affordability come into conflict with climate ambition, climate ambition will lose.

Responses & Opportunities

There has been a massive U.S. response to the global crisis, including weaponizing energy in response to an aggressive power. The Biden Administration is focused on helping U.S. allies reduce dependence on Russian energy and lower energy prices. For example, the Administration has floated the idea of a price cap on oil to impose pain on Russia without imposing more pain on others. With respect to natural gas, demand is clearly quite inelastic in the immediate term, which means diversification of supply is necessary. The United States has become the largest exporter of LNG in the world, and U.S. LNG exports to Europe have tripled. Addressing methane emissions from upstream oil and gas operations not only would enhance the U.S. competitive advantage in providing more climate-friendly alternative supply, but would also directly create more supply by reducing flaring, venting, and leakage.

The efforts to provide alternative supply are complemented by efforts to reduce demand. In general, there has not been enough focus on demand in this crisis. Being truly energy secure is not just producing more, but also using less, and the conversation may be starting to return to conservation, efficiency, demand response, and flexibility. The United States is supporting Europe in decreasing its natural gas demand and increasing its energy efficiency efforts, and European Union member states agreed to cut their natural gas consumption considerably over the next several months.

In the near term, that will lead to a temporary increase in coal consumption, but it is important to ensure that policy, market design, and finance continue to flow to support long-term goals. If Europe — one of the world's main climate leaders — does not keep meeting its climate goals, the political environment elsewhere for climate policy will get worse. Demand in these turbulent times must be met while ensuring that policy and financial resources are dedicated at scale to systemic change to achieve decarbonization.

Being truly energy secure is not just producing more, but also using less, and the conversation may be starting to return to conservation, efficiency, demand response, and flexibility.

The chaos of the crisis could turn out to be an opportunity; change is sometimes a matter of motivation more than ability. The 1973 oil crisis involved only one fuel but resulted in a tremendous amount of change and innovation, including investments in fuel economy, energy efficiency, renewables, nuclear, and more. There is even more potential (though also more challenges) this time around. For example, there is an opportunity to electrify heating in Europe, which means the United States could provide not just fuels but technologies (i.e., electric heat pumps) to allies. It is possible there could be similar technology export situations in the future with small modular reactors. The crisis could also be interesting for hydrogen, which is cheaper in Europe now than natural gas; it is not clear how long that will remain the case, but it is accelerating deployment. The crisis is accelerating the adoption of electric vehicles as well.

A wide mix of economical clean energy systems is key to addressing the coercive use of energy, but achieving that is not easy. Systemic change across energy takes time and requires many countries and diplomatic efforts. There may also be a need for a bigger role for government in the energy sector and associated supply chains going forward, in order to manage the bumpiness that will occur during the transition.

Policy Developments & Support for Innovation

It has been an eventful year in climate and energy policy, both in terms of partisan policies and bipartisan support for innovation. The funding and programs in these bills could accelerate deployment of technologies to meet near-term climate goals, as well as demonstration of emerging technologies to meet longer-term goals.

Partisan Climate Strategies & the Inflation Reduction Act

For the first time in DC, there are two very partisan approaches to climate and energy on the table. This is the first time there has been competition about who has better policy on these issues, which is a step in the right direction. There is also a lot of overlap between the two approaches.

Right of center, House Republicans have come to the climate debate much later than Democrats, but they are assembling a multipart climate, energy, and conservation agenda. In the short run, there will be support for more nuclear deployment, electrification of dams, diversification of supply chains away from China, more push for domestic production and manufacturing, increased tree planting, and so forth. Looking at the long term, there will be increased support for innovation.

Left of center, there is the Inflation Reduction Act (IRA), the Democrats' budget reconciliation bill. The energy elements of the IRA are wide-ranging. The bill addresses not just power and transportation, but also industrial and manufacturing emissions. It provides tax credits for individuals as well as for corporations and industries, and credits are increased if companies use domestic materials, pay fair wages, and are located in disadvantaged communities. Preliminary analyses of the IRA estimate it could reduce emissions roughly 41%-44% below 2005 levels by 2030 (in optimistic cases), which is much of the way toward President Bident's 2030 goal.

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The IRA bill provides $369 billion for climate and clean energy, about half of which is focused on emerging technologies and innovation. It creates new tax credits for nascent technologies (e.g., clean hydrogen, sustainable aviation fuel, energy storage) that will be crucial in hard-to-abate sectors, helping public and private dollars go further in sparking these emerging industries. There is a direct-pay option for some (but not all) of these credits, which means those technologies can be carried into the market by smaller startups and entities with no tax liability. The IRA also extends existing tax credits for solar and wind for 10 years, creating long-term consistency and confidence. Importantly, the IRA transitions the tax credits starting in 2025 to be tech-neutral and based on carbon intensity, with the credits only starting to phase out once the power sector gets to 75% emission reductions below current levels. These tech-neutral credits will be another boon for innovation, opening the door for new zero-carbon technologies. The credits also provide flexibility for project developers, including the choice of whether to take a production or investment tax credit.

There are many, many more elements of the bill. There is money in the bill for manufacturing tax credits (especially focused on clean energy supply chains), including some targeted just for coal communities. There are investments (though not an investment tax credit), loan funding, state planning grants, and other measures focused on transmission.

With respect to nuclear, there is a nuclear power tax credit in the bill, as well as funds for nuclear-related construction projects and money for high-assay low-enriched uranium (HALEU) to help keep the Advanced Reactor Demonstration Program on track. The Loan Programs Office (LPO) in the Department of Energy (DOE) gets billions more in loan authority under the bill, and the national labs get billions for infrastructure and to refresh tools and capabilities. The IRA also authorizes billions of dollars for energy infrastructure reinvestment, including loan guarantee authority to help facilities retool, repower, and replace infrastructure.

As much as the IRA contains, it does not include as much as some had hoped. Coming to agreement on what the reconciliation bill contains was a long process, constrained by the wants and desires of various senators. Sen. Manchin, for instance, was focused on energy security and reliability, both with respect to international relationships and the reliability of the domestic energy system. The bill involved creative thinking and working within the art of what was possible in the political process. That means, for example, that offshore wind was not included as an industry that can access direct-pay credits; Sen. Manchin had significant concerns about direct pay, so it was not a mechanism that could be included widely in the bill. Support for systemic enablers, including organized markets and transmission, that was in earlier versions of the reconciliation bill was reduced or eliminated. The incentive for sustainable aviation fuels (SAFs) is of a shorter duration than others, partly due to the need to find cost savings in the bill and partly because SAF was identified as something that had longer-term bipartisan support, which might open the possibility of revisiting the incentive in later years.

The IRA also says nothing about retirement of existing assets or disincentives for emitting energy; it focuses almost solely on positive incentives for clean energy. Right now, most of what is getting through Congress can be classified as carrots; regulations from the Environmental Protection Agency (EPA) might provide some sticks, but the Supreme Court decision in *West Virginia v. EPA* constrains (but does not eliminate) the EPA's authority to act in that area in a balanced, rational way. That has huge potential implications.

Part of the deal to bring Sen. Manchin on board with the IRA was an agreement to later pursue permitting reform, which could not be moved in a reconciliation bill.

Bipartisan Infrastructure Law & the Office of Clean Energy Demonstrations

Somewhat forgotten amidst the focus on the IRA is the fact that a massive bipartisan infrastructure law — the Infrastructure Investment and Jobs Act (IIJA) — passed late last year. While IIJA provided support for a range of deployment activities — including related to power infrastructure and electric vehicle charging stations — it also included the largest injection of resources for DOE technology demonstration programs since the Manhattan Project. However, passing a law is only the beginning of the hard work. After passage of the bipartisan infrastructure law in late 2021, things have been handed over to officials at DOE — including the new Office of Clean Energy Demonstrations (OCED) — to implement vast new programs.

Somewhat forgotten amidst the focus on the IRA is the fact that a massive bipartisan infrastructure law — the Infrastructure Investment and Jobs Act (IIJA) — passed late last year.

Historically, the federal government has focused intensely on research and development (R&D), while under-investing in later stages such as demonstration and deployment. It is those later stages, though, that have real-world impact. The IEA has estimated that at least half of the emission reductions that will happen globally by 2070 will come from technologies that are at an early phase today, and many startups really need government help on demonstration and first commercial. With the IIJA and the creation of (and influx of funding for) OCED, the federal government will begin playing a much bigger role in demonstrations.

IIJA had near-term deadlines for many large funding opportunities for demonstrations, and OCED is working to move those out quickly, while also garnering stakeholder feedback on program design related to major provisions. Funding opportunities on hydrogen hubs, carbon capture and storage (CCS), and energy storage should be out by the fall. OCED is staffing up quickly, including bringing in real-world project management experience.

It is hard to strike the right balance, though, between moving with urgency to address statutory deadlines (and the climate crisis) and making sure to plan enough time to do smart design, due diligence of applications, and good project oversight. DOE will have to focus on commercial readiness and financial viability, as well as on deploying the money in a way that addresses equity and affordability. (If too many costs are passed on to customers, there is a risk of losing public support for clean energy goals.)

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There is also a risk management balance to be struck between making sure OCED is successful at the portfolio level and being catalytic. The demonstration program makes sense only if it is doing things the private sector is not yet ready to do, but those are riskier projects with higher chances of failure. That increases the risk of the program becoming a political punching bag. Adding to that risk, demonstrations are large, visible projects located in someone's district and state, which makes them very political and hard to shut down, yet many will fail. OCED will have to establish a strong political model in order to maintain political support and endure; early on, a big part of this effort will be getting influential business and other leaders to proactively and regularly go to Capitol Hill to talk about how important the program is.

DOE should build on OCED to try to create a continuum of support in order to get innovations through to commercialization. Already, DOE has undergone a realignment to enhance working relationships between the applied energy offices and the demonstration and deployment offices, so all parts are working together across the RDD&D continuum. OCED can work with the applied programs to see which technologies are ready for large-scale demonstrations, and developing and maturing technologies is what the DOE national labs in applied energy do well. OCED can also work with the Loan Programs Office to ensure OCED's demonstration support does not preclude follow-on investment from LPO. In addition, DOE's support might change how private investment happens. In general, if a project involves a national lab, DOE, or another federal entity that can backstop the risk (e.g., the Department of Defense), private investors will be more comfortable providing capital. DOE funding can help distribute the finance risk and lead to partnerships around capital building.

Many of the companies that will be ready to accept OCED funding now received initial venture capital (VC) funding years ago. It can take a while to get to the demonstration stage. The technologies that are ready for demonstration today, however, may not be enough on their own to reach 2050 climate goals. Emerging technologies that are needed still must be developed and scaled up over the next decade or two, and companies that received the big injection of VC funds that flowed over the past couple of years will not be ready for demonstrations for several more years. It would therefore be of great value to the innovation ecosystem if the OCED program could exist on an ongoing basis, rather than being a one-time push.

Hydrogen Hubs

Hydrogen hubs are one of the high-profile demonstration focus areas that Congress appropriated billions of dollars to in the IIJA. As a result, there has been a flurry of activity in many regions to put together competitive proposals to get some of that funding. Some states are creating partnerships with other states, as well as with private sector companies, to pursue hydrogen hub funding and create a hospitable market environment. Some states (e.g., New York) are also getting their energy and utility regulators to plan ahead so that they are prepared when demonstrations are ready to begin.

Partnerships and coalitions are important, but it can take time to get the appropriate mix of partners. DOE has an H2 Matchmaker app to connect potential partners. DOE is also trying to get all relevant potential partners at the table and to manage proposals so that, when winners are chosen, there is not a subsequent circular firing squad of opposition, which would imperil political support. All involved need to come together to make sure the winning projects are successful.

As OCED moves forward with the hydrogen hub funding opportunity, there are some elements it may want to consider. For example, the process that DOE has laid out involves many stages that all together add up to many years, but some groups could get to hydrogen production much more quickly; the process should be able to facilitate those who are ready to go faster. In addition, there is good guidance on how to show engagement with communities, but more guidance would be helpful on how to measure benefits to be able to show that 40% of the benefits are going to underserved communities. In addition, the hydrogen hub demonstration projects should be designed so that failed ones do not become stranded assets but rather can potentially be used for future demonstrations. Finally, hydrogen has powerful short-term warming potential, so risk mitigation needs to be built in from the beginning.

Grid Decarbonization & Resilience

There has been a significant slowdown in the deployment of new electricity sources in the United States due to supply chain problems, tariff issues, and other causes, but grid decarbonization and reliability remain essential near-term priorities.

Grid Buildout & Clean Energy Deployment

In the United States, it is widely projected that achieving net-zero — including electrification of transportation, heat, and other end uses, as well as direct air capture, power-to-X, and more — could require a massive increase in the electricity grid. There are huge uncertainties, however, in how much more — or less — electricity U.S. and global decarbonization will require. There are many grid-balancing and demand-side resources that tend to get left out of models. Energy efficiency, storage, load shifting, and other demand-side measures will be incredibly important to avoid the need to build out such huge levels of grid infrastructure. It is an entirely different situation if the grid is forecasting supply and scheduling demand, as opposed to the current, opposite approach.

Even with a big focus on the demand side, achieving net-zero requires deployment of clean energy supply on the grid.

Even with a big focus on the demand side, achieving net-zero requires deployment of clean energy supply on the grid. Renewable energy development often occurs in different places than where the emissions-intensive sources are, but to be most impactful in moving toward net-zero, renewable assets should be deployed in the most carbon-intensive grids. There is a provision in the bipartisan infrastructure law that directs the Energy Information Administration to start collecting grid information on emission intensity, which could unlock opportunity, though utilities may not have all the data.

Advanced nuclear may also be a viable option in the energy system. Advanced nuclear plants will be built globally, and it is important for national security to have the United States active in the area. Some, however, find no operational or business case for nuclear and think the industry has shifted its business model to focus on harvesting subsidies.

Reliability

Electricity is a more critical service than ever. The grid in the United States has been under significant stress for several years, with nationwide credible warnings of rolling blackouts, but stakeholders have zero tolerance for blackouts. The grid is generally quite reliable, with only a small subset of hours where grid reliability is an issue, but consumers and producers are asked to pay a very high price for that high level of reliability. Government interventions should be subsidizing or aiding those most expensive hours, to mitigate impacts on consumers. If climate comes up against affordability or reliability, the clean energy transition gets tougher. Reliability must be paramount. The transition of the power sector is taken for granted, but the acronym order must shift from ACRE (affordable, clean, reliable energy) to RACE (reliable, affordable, clean energy).

All energy resources have flaws or challenges for those trying to manage reliable, affordable electricity systems. The benefit of coal and gas is that system operators can turn them on when needed (except when they are down for maintenance); their on-demand availability is a big benefit. Natural gas supply is difficult in general, however, and it is even more difficult when bottlenecks in LNG exports are the only thing preventing more gas from going from the United States to Europe. The gas is needed both domestically and by allies, creating a very hard situation. Coal supply chains are also experiencing challenges. Wind and solar facilities do not have the same supply chain issues, and their lack of marginal fuel costs is a huge benefit to customers. They are not, however, available on demand, and the variability of wind and sunlight makes them difficult to rely on fully. Batteries can help make those renewables more dispatchable, but a huge number of batteries would be needed if they are only short-duration batteries. On the other hand, all-renewable reliable grid operation has been demonstrated in places, and there are multiple carbon-free grid-balancing resources that are more than ample, with batteries being the costliest. All resource options have benefits and flaws, and it is important for market designs to value them appropriately, though complexity is increasing dramatically in terms of the value propositions of different resource types.

Reliability requires interoperability, grid balancing, management systems, and connectivity technologies. Flexibility is particularly important as the system becomes more decentralized (due to distributed energy resources, demand response, and the like), which increases complexity.

The real world does not reflect modeled predictions. Some utilities do not even know where the oldest infrastructure is on their systems (as the installation pre-dated digital record-keeping), which presents an obstacle in even knowing where the vulnerabilities are. Flexibility in operations and markets is key. Reliability requires interoperability, grid balancing, management systems, and connectivity technologies. Flexibility is particularly important as the system becomes more decentralized (due to distributed energy resources, demand response, and the like), which increases complexity. Microgrids and distributed energy resources help achieve both reliability and gigaton-scale emission reductions. There is still more to explore and exploit at the distribution edge in terms of energy efficiency and distributed energy resources providing flexibility to support the system, but the distribution grid was built for a different purpose, so it will need upgrades.

Conservation and efficiency are incredibly undervalued in how they can help enhance reliability. Some analyses, for example, show that a range of demand measures could substantially reduce the amount of long-duration storage needed; that should inform prioritizations in innovation investments. There has also been a quiet revolution in integrative design, which makes the efficiency resource several-fold bigger than is currently built into any climate model, government study, or industry forecast. Innovations in how to choose, combine, and sequence technologies is at least as powerful as innovations in technologies themselves. Whole system design and efficiency should always come first, in all sectors; it is always cheaper than other options and saves far more energy.

Transmission is also a huge part of enabling a reliable, decentralized grid. Every technology under discussion, whether demand- or supply-side, would be more valuable if there was even a modest buildout of the transmission grid.

Decarbonizing Steel

Power is no longer the largest-emitting sector in the U.S. economy, as transportation has overtaken it. During COVID, the industrial sector in the United States also overtook the power sector, and by some projections, will overtake transportation by 2030. Industrial sector emissions require more attention. Globally, steel is the largest industrial emitter. At the same time, steel is also essential to much of the infrastructure that will be needed for the clean energy transition.

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Decarbonization Options

Green steel has to be developed, at scale, without any green premium or subsidy. If there is any hope of driving global equity and development, there cannot be a premium on something so foundational to the built environment. Cement and steel emissions will scale tremendously in low-income countries, so clean technologies must be low-cost. The technology must be figured out in the developed world so it can be exported and adopted.

Steel decarbonization is iron decarbonization. Virtually all of crude steel is iron; the rest is carbon, which is what gives steel its strength. (That also means there is no “zero-carbon steel”.) The vast majority of steel emissions come from extracting iron from the ore, which is often done today with coal in a blast furnace or a direct reduction method using natural gas, as well as sometimes from recycling steel. Electric arc furnaces (EAFs) have much lower emissions than blast furnaces, but the scrap available in the United States is already being used, and there is not enough scrap in the world for EAFs alone to solve the problem. The auto sector also needs a higher grade of steel than EAF steel recycling may be able to provide with scrap, which can have impurities (e.g., copper contamination) that weaken the resulting steel. However, a method has been developed in the lab to remove the copper; if it can scale rapidly, it could create more value for scrap and recycling.

While recycling can play a role, the fundamental challenge is to decarbonize ironmaking. There are very few options. The choices are basically using renewable electricity directly, using a clean fuel (e.g., hydrogen), or using CCS. Each has its challenges.

The challenge with direct electrification is that very cheap electricity is needed to make clean steel without any green premium, and the electricity has to be even cheaper if someone wants to make a profit. The only way to do that is with intermittent renewables, but steel plants like to operate 24/7. In the international conversation, hydrogen has emerged as a top contender for steel decarbonization, but hydrogen presents its own range of difficulties. For example, hydrogen-based approaches require the highest grade of ore for ironmaking, the hydrogen needs to be super-cheap, and there needs to be a gas network connected to the steel plant (which may be possible in some developed countries, but not where most of the world makes steel). CCS, meanwhile, is technically challenging to apply to a steel plant and imposes a non-trivial cost on production, which puts a significant green premium on the resulting steel. (Carbon utilization may create an opportunity to make CCS a somewhat more economic option.)

More options may be emerging. For example, there are innovators working to develop near-room-temperature iron-making processes powered by intermittent renewable electricity that can use any grade of iron ore feedstock. Much of the cost in steel is profit made on the ore; if different sources of iron could be found and used as inputs (e.g., lower-grade ores, tailings, and waste from mining), such innovation could bring those profit margins to U.S. steel producers or mineral providers.

In addition to options for increasing the supply of clean steel, possibilities also exist to reduce the demand for steel in the first place. Much of the world's need for steel and cement could be saved through better structural design. For example, floor slabs in buildings could use far less cement and steel if they were folded like corrugated cardboard. Substitution is another option, such as with cross-laminated timber for buildings and carbon fiber structures in cars. Over the horizon, graphene (when it becomes possible) could replace some steel and cement. If better design and substitution reduce demand, innovators in producing decarbonized steel and cement could take over a smaller market much more quickly.

U.S. Policy

Steel production in the U.S. Midwest has declined considerably, moving instead to places with worse emission standards than the United States. Decarbonizing steel presents an opportunity to revitalize the industrial Midwest and bring multi-generational, good-paying manufacturing jobs back to the United States, providing both economic and environmental benefits. U.S. blast furnaces also tend to be more labor-intensive and unionized than EAFs, so supporting the success of the existing blast furnaces is important in terms of equity and political economy. The United States used to have a domestic sustainable manufacturing initiative, and the need for a robust, multi-sectoral system within government to address industrial decarbonization has only grown.

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The bipartisan CHIPS and Science Act of 2022 included the Steel Upgrading Partnerships and Emissions Reduction (SUPER) Act to stand up RD&D pilots and programs at DOE to get serious about the United States leading the way on decarbonizing steel manufacturing. The federal government needs to underwrite a big portion of these RD&D projects; private industry cannot, since payoffs are so far in the future. The DOE programs will be coordinated with industry, though, so they are realistic and can develop technologies. Steel is just the first of the industrial sectors that DOE is getting serious about.

Demand signals also matter, such as Buy Clean policies and other clean procurement efforts. It is hard for startups with new technologies that may provide cost or emissions savings to enter the market, especially in big industries such as steel and cement. If data, metrics, and transparency can better account for embodied carbon in products, buyers can help drive the greening of steel. The First Movers Coalition and others are trying to coalesce around a clear definition and provide a demand signal for green steel. Likewise, there is money in the IRA for federal procurement of construction materials with low embodied carbon, as well as a provision on labeling and definitions about what low-embodied-carbon materials are. The IRA provisions, the trillions of dollars to be spent under the infrastructure bill, and executive branch measures to green federal procurement could have a huge combined effect on procurement and consumer demand.

Any policy incentive to advance industrial decarbonization, whether on the supply or demand side, should focus on carbon intensity. Many incentives now focus on process, not the end metric of carbon intensity. CCS, for instance, gets a certain tax credit level, but if someone develops a technology that did not produce the CO2 emissions in the first place (which seems like the less risky route), the tax credit would not apply. That is not a level playing field.

International Policy

While steel is in some ways simpler to decarbonize than some other sectors, with fewer technical levers and fewer industry players, it is also more complicated to decarbonize because it is an energy-intensive, trade-exposed industry. Measures to reduce steel emissions in one place can just lead to production moving to blast furnaces elsewhere. The industry is quite conservative and is working with small margins, so it requires a decisive push to move in the right direction. Confusion around the tech pathways for decarbonizing steel, however, is contributing to inertia in the international arena in terms of agreements and partnerships, hindering much-needed decisive action on steel this decade. There is a need for global or multilateral sectoral arrangements and agreements to work some of this out.

It is politically difficult for a steel-producing country to try to help another decarbonize its production, as it could be helping that other sell more steel into the domestic market. In a globally connected world, it is imperative to rationalize trade policy and carbon policy. The notion of carbon clubs is alive, tied not to synchronization of carbon prices but to carbon performance measured at the industry-specific level, underpinned by domestic regulations. The EU's carbon border adjustment mechanism (CBAM) gets a lot of attention, but in 2021, on the sidelines of the G20, the United States and the EU agreed to provisional relief of tariffs on steel and aluminum, in exchange for working together on some sort of new arrangement for the steel market to address access, carbon intensity, and non-market practices.

In practice, the CBAM would have a small impact on U.S. steel, as most U.S. steel exports go to Canada or Mexico, not across the Atlantic. There is a lot to be done with North American partners to try to advance greener steel.

Early Private Sector Efforts

There is growing U.S. interest in implementing carbon border adjustments because a lot of people, including in Congress, assume the United States would automatically benefit from that. A significant majority of U.S. steel production is already from EAFs, which is why U.S. steel has much lower average carbon intensity than production elsewhere. While U.S. steel has a significant carbon intensity advantage in terms of direct Scope 1 emissions, the picture is not as good when Scope 2 emissions (i.e., where the electricity comes from) are considered. Electric arc furnaces use a lot of electricity, so decarbonizing that electricity is low-hanging fruit for increasing the U.S. competitive position. Many domestic manufacturers use the carbon intensity differential as cover for inaction, but there is a need to incentivize U.S. steel to get even better.

Having steel companies decarbonize their electricity purchases is a good start, and some steel companies are taking steps to become clean energy buyers. Many large clean energy buyers start out buying simple renewable energy credits (RECs) before moving on to power purchase agreements (PPAs) and then other, more impactful procurement strategies. Encouraging steel manufacturers to be clean energy buyers today will accelerate their adoption of other decarbonization solutions as those come online.

In terms of more direct efforts, auto manufacturers are already making bilateral deals with steel manufacturers for lower-carbon steel in the supply chain.

Liquid Fuels

Innovation in liquid fuels, especially for mobile sources that use energy-dense fuels, is a vital part of achieving decarbonization goals.

Shipping & Aviation

The United States is committed to net-zero by 2050. In feasible pathways to that goal, electrification or gaseous fuels (e.g., hydrogen) seem like the predominant routes for decarbonizing fuels. Projections are that the future of liquid fuels may be largely constrained to long-distance aviation and shipping. Clean ammonia and (in the nearer term) clean methanol may be pathways for decarbonizing shipping, and the Biden Administration launched the Green Shipping Challenge, which will be a focus at COP27. Aviation is tougher.

SAFs are essential for the aviation sector to meet its net-zero-by-2050 commitments, but not all sustainable aviation fuel is created equal in terms of carbon intensity reductions.

In the near term, energy efficiency and streamlining the fleet are the main strategies for decarbonizing aviation. Batteries are projected to play almost no role for aviation. Leapfrogs in airplane efficiency are coming into view, including breakthrough aerodynamics that could significantly reduce fuel use and operating cost. Breakthroughs in design, as well as in route architecture (more point-to-point, versus the current hub-and-spoke), could yield big changes in aviation business models and operations in ways that ultimately reimagine the future of flight.

There is skepticism about whether near-term demand-side efforts should also include behavioral approaches to reduce demand for flying. Removing one of the joys of life will not be great for maintaining support for the transition, and flying helps connect the world and enables people to visit other cultures. Demand reduction is also not a viable business model for the industry to get the capital it needs to invest in its net-zero goals.

While the demand side must be the strategic focus in the near term, changes in supply are essential over the medium and long term. That includes sustainable aviation fuels and, in the longer term, perhaps other solutions such as direct air capture (DAC) and hydrogen fuels. SAFs are essential for the aviation sector to meet its net-zero-by-2050 commitments, but not all sustainable aviation fuel is created equal in terms of carbon intensity reductions. The small role to be played by SAFs must be filled by zero-carbon options; as described further below, while this could include some biofuels, power-to-liquids (also known as electrofuels, e-fuels, and synthetic fuels) could be the dominant path, depending on how cheap renewables get.

SAFs provide an option for fuels that can work with the current aviation fleet (unlike, say, hydrogen, which would require new planes, engines, storage, and so forth). SAF price and supply are key challenges. SAFs are much more expensive than jet fuel, and clean fuel policy incentives tend to favor on-road fuels. (On-road fuels have other pathways, such as electrification; aviation may not.) Billions of gallons per year are needed, which means huge and rapid increases in supply through the rest of this decade.

To spur this supply, there is a need to create new markets (domestic and global), which requires both diverse coalitions and policies. There has been a remarkable rise in SAF demand and commitments. The Biden Administration launched the First Movers Coalition to send the largest demand signal in history for needed decarbonization technologies, including near-zero-carbon fuels. Dozens of companies made ambitious commitments to buy the next generation of technologies, and aviation is one of the first sectors that the Coalition will address. The First Movers Coalition has also developed a tech-neutral definition of what clean fuels are, which might provide a basis for aligning markets and reducing trade frictions. In addition, there has been a growing demand signal for SAF from the voluntary market, since many companies with net-zero targets count some portion of the aviation industry's Scope 1 (direct) emissions within their own Scope 3 (value chain) emissions. As more companies set net-zero targets that include Scope 3, there will be more demand for SAFs. Having more buyers interested throughout the value chain means there is potential for sharing any green premium, as long as the timelines of the various buyers are aligned. In the First Movers Coalition, for example, all the commitments are for 2030. Airlines and their corporate customers are already starting to work to structure deals to properly account for and allocate the value of carbon credits for SAF.

The Biden Administration launched the First Movers Coalition to send the largest demand signal in history for needed decarbonization technologies, including near-zero-carbon fuels.

There is a need to de-risk supply projects to meet this growing demand. With limited creditworthiness, it is generally hard for firms working on SAFs and other decarbonized liquid fuels to access DOE's Loan Programs Office. Public-private partnerships can help de-risk projects and get them through the innovation cycle. So too can policy, such as through tax credits and other incentives on the supply side. As noted earlier, the SAF credit in the IRA is a start, but it only provides a market signal for a few years and at a low value. Much clearer incentives are needed for a longer time period for these fuels to be able to compete economically.

2023 will be an important year to think about a bipartisan clean fuels policy package. In addition to the short SAF credit in the IRA that may need to be extended, the EPA will also be setting volume levels for the Renewable Fuel Standard, and the Farm Bill will be up as well. It is important to think carefully, though, about the steps taken to support liquid fuel options; some steps could help all fuels, but care must be taken not to support current-generation fuels in ways that impede the ability to get to future-generation fuels.

It is also important to recognize that new refineries are not really being built in the United States or Europe; many are being decommissioned. China is going to be the largest refiner in the world, which raises some continuing energy security issues with respect to sustainable liquid fuels.

Electrofuels & Biofuels

Over the last couple of decades, understanding has grown regarding the scalability limitations of biomass-based fuels, including because of intersections with the food system. Despite the limited role biofuels may ultimately play, they play a huge role today, especially in the United States. They have significant momentum and support behind them, including appropriations from Congress. There is also still a need for oxygenates in the fuel supply, and the United States is not short on corn. While there is broad recognition that first-generation biofuels will not provide the carbon intensity reductions needed, a sizable percentage of the corn grown now is for ethanol. (Many of the early movers on CCS have been ethanol plants, due to the pure streams of CO2.) Demand destruction for ethanol can come from increasing electrification of ground transport and from e-fuels, so a transition strategy is needed for farmers and fuel refiners who have been leading on that first-generation technology. Farmers will not simply accept having their markets evaporate, and there could be serious deleterious effects on farm economics and on the politics of the energy transition if a big part of farm balance sheets is taken out and not replaced. The United States must find a way to transition farmers to have a role in the economy that supports the greatest carbon reductions.

Biofuels are not just existing ethanol, and are not all the same. Different fuels achieve different lifecycle reductions, and they should not all be lumped together. Industrial forest-based biofuels from sustainably managed forests, for example, could be scalable and carbon-negative, and they also avoid posing a threat to the food sector. Every liquid fuel possibility has to be on the table, and the next generation of SAFs is likely to still include several biofuels. (That said, algae for liquid biofuels has lost steam, though it is not dead.)

While biofuels have a role to play in addressing increased liquid fuel demand, achieving net-zero will require electrofuels to carry a significant portion of the load. E-fuels are made by combining hydrogen (produced from water and green electricity) with captured carbon dioxide (CO_2) to produce a fuel that is chemically identical to what is in use now. Until DAC plants are more widespread and cost-effective, the CO_2 will likely come from wood waste or captured industry emissions. Any form of capturing CO_2 and combining it with green hydrogen to make SAF or e-fuel is displacing a fossil counterpart — leaving it in the ground and sequestering the carbon the same way the earth originally stored it. DAC, hydrogen, and low-cost zero-carbon electricity need continued focus and support. DOE bioenergy technologies have received a surge of funding, but there is not a similar dedicated program for electrofuel development and innovation.

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Before Russia invaded Ukraine, the cost of producing e-fuels was significantly more than fossil counterparts, but with the increase in energy prices, e-fuels are not that far from being competitive. Tax incentives further improve the economics of e-fuels. Incentives for carbon capture (for any purpose in any sector) will help accelerate CCS investment and bring down costs across uses, including for e-fuels. The enhanced 45Q tax credits for DAC in the IRA can likewise provide a huge boost in bringing down the cost of DAC. When the cost of DAC crosses the $100/ton threshold, it will be a gamechanger for e-fuels (and many other things related to carbon capture and offsetting). As the cost of capture is driven down, the cost of e-fuels will follow.

Role of Direct Air Capture

While DAC-captured CO_2 can be used to create synthetic fuels that work in existing engines and generate vastly fewer emissions, DAC plants could also be a cost-effective solution for decarbonizing liquid fuels in two other ways.

First, purchasing offsets from DAC is probably the most cost-effective solution for emitting liquid fuel producers and users in the near term. Offsets are still a dirty word to many, but they should be destigmatized. Some argue that all verifiable offsets should be uncontroversial, but at the least, there is probably agreement by many that DAC-based offsets should be acceptable. The role of DAC offsets, however, will likely be fairly small, given limited DAC capacity and high prices for DAC offsets.

Second, DAC-captured CO_2 could be used in the near term for enhanced oil recovery (EOR). Voluntary market demand seems to prefer that DAC-captured CO_2 be sequestered, but EOR could be an alternative in the near term to provide oil from the ground with much more favorable lifecycle emissions. Social acceptance and accounting measures have to be worked through, though.

Critical Minerals

Critical minerals and ores are the soft underbelly of the clean energy transition. It is imperative to get ahead of the issues, but there are sharp disagreements on the best path forward on critical minerals, even among those committed to decarbonization. These issues will inevitably come to a head in the next few years.

Lithium Supplies

Critical minerals are non-fuel minerals that are essential to the national or economic security of the United States and that have supply chains vulnerable to disruption. There are now 50 minerals on the U.S. Geological Survey list. Not all minerals essential to the clean energy transition are on the list. Copper, for example, is not on the list because there are not significant supply chain disruption risks. Uranium is also not on the list, since it is an energy fuel. Many minerals central to the transition are on the list, though.

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Meeting the IEA's net-zero-by-2050 scenario may require enormous amounts of these minerals. Under the IEA's scenario, critical minerals as a share of global energy-related trade are projected to rise from 10% to 50%. Disruptions for a lot of materials needed for the clean energy sector are anticipated by 2030, and probably sooner. These critical minerals are used by numerous technologies in the energy sector, and there is competition for them with other sectors as well.

In the auto industry today, every major automaker has committed to go electric. Five years ago, the big concern was about cobalt and nickel availability, since batteries used a lot of those minerals. Now, many electric vehicles (EVs) use no nickel, which has been replaced by iron phosphate. Companies are moving away from cobalt too, largely because of child labor issues. For the electric vehicle industry, lithium is currently the critical bottleneck. Lithium supply must increase enormously in order to electrify ground transportation globally.

Most lithium is in naturally occurring deposits of saltwater (brines) in Argentina, Chile, and Bolivia. Over the last 10 years, though, as the EV industry started to scale and lithium prices spiked, it was not large brine resources but rather hard rock resources (mostly in Australia) providing most of the new supply. Hard rock resources are more expensive to produce and smaller in size. To support the transition, more lithium will be needed from brine resources. Traditional methods have involved evaporation ponds, which are hard to permit, but new technologies and processes are being developed. No large lithium brine resources have been identified in Africa, but Chinese companies are investing heavily in hard rock deposits there. Lithium deposits in Afghanistan are thought to be the largest in the world, but the private sector is not focused there, and the political feasibility of accessing those deposits is exceedingly low.

There is a tremendous amount of innovation occurring in battery chemistries, and some battery manufacturers may decide to move away from lithium to things that are more benign and easier to get, such as silicon (i.e., batteries of sand). That said, these innovations in battery chemistries may be better suited for the grid or other functions; lithium may be essential for EV batteries. In addition, while other chemistries are being piloted and prototyped, the economy is focused on and investing heavily in lithium. Lithium has received enormous amounts of investment over the past few years that will not be undone.

The lithium supply concerns are a security crisis. For example, major U.S. automakers have partnered with East Asian battery manufacturers to form joint ventures to manufacture battery cells in the United States. Battery factories, however, take 1.5 to 2 years to bring online, whereas conventional lithium mines take 10 years to bring online. There is a big gap between the timing for a battery factory and the supply of raw materials.

Mining & Communities

There is a tendency to compare the demand for minerals under the current state of technology to the existing economically proven reserves. Reserves, however, are a malleable concept and depend on what is economic, as shale gas showed. Technically recoverable minerals in the earth's crust exist in much greater quantities than the currently proven reserves.

The push to secure critical minerals for the transition has raised questions of the potential to increase mining activity in the United States. Historically, mining has been hard to permit and finance, and the United States does not have the right geology for all critical minerals. There will be a need for industrial policy for critical minerals production and processing. Industrial policy has not been something the United States has focused on historically, outside of defense, but if the United States wants to compete with China, it has to close the large investment gap needed to supply minerals for the energy transition. Policy can de-risk mining projects and processing facilities. There have been some measures taken recently, including invocation of the Defense Production Act, support from the Loan Programs Office, passage of the CHIPS Act, and provisions in the bipartisan infrastructure law and the IRA. The policy progress is reason for optimism, but more may be needed.

The push to secure critical minerals for the transition has raised questions of the potential to increase mining activity in the United States.

For example, the United States is still operating under the 1872 mining law, which has not been meaningfully reformed. The result of the current mining act is that the metals mining industry is the largest source of toxic pollution in the United States, and the communities that suffer most from that are rural, low-income, and Native American. The vast majority of U.S. reserves of minerals needed for batteries are very close to Native American reservations. Likewise, a sizable majority of transition minerals projects around the world are on lands belonging to indigenous people or peasants, many in places with poor political conditions related to permitting and consultation. The same old extraction processes, business models, and governance frameworks cannot be used going forward.

There are efforts underway to reform U.S. mining law, which hopefully can establish a better framework for governance. Reformed governance legislation and a new roadmap for domestic mining projects should ensure early consultation with affected communities, stronger indigenous and tribal participation, meaningful prior informed consent, a more consolidated process for permitting mines, and robust environmental and labor standards, including standards for climate change, tailings, biodiversity, and water. (The industry is already moving in that direction.) Proper consent processes and faster permitting processes are not mutually exclusive; processes such as Smart from the Start can be inclusive of communities, identify the best places for development, and accelerate permitting.

That said, community engagement on critical minerals and mining will be really hard, and people may not be confronting that reality honestly enough. It is probable that the United States will still be importing most minerals in a few years.

International Trade & Security

Concerns about critical minerals are in many ways just the latest in a long line of concerns about resource scarcity. Mismatches in supply and demand trigger reactions. Higher prices lead to more efficient use of the item, increased substitution and innovation, and more diverse sources of supply. While scarcity problems get resolved, that does not happen instantly, so there is urgency in dealing with current challenges in critical minerals supply. More mining in the United States might be helpful, but this is a global challenge. Historically, global trade has been a major force in resolving resource scarcity. What is different now is that U.S. and global feelings about trade are at an inflection point.

The international trade system has proven itself insufficient for the time. Agreements that were meant to be durable have fallen apart over the past couple of years. There is a lot of trade friction at the moment, and it will be a race to the bottom unless fixed. The United States is facing challenges not just with adversaries, but also with friends (and frenemies). The EU, for example, has tariffs on all environmental technologies coming from the United States. The global trade system will be reshaped in coming years.

While the United States imports some minerals from allies (e.g., Canada, Israel), imports of many critical minerals depend on China. China is often the focus of concern, but it is worth thinking hard about what security risks are important to worry about in a world of interdependence. (The idea of energy independence is a fallacy.) The United States is dependent on China for many things. If there are disruptions in the supply of inputs for clean energy goods, that is a different sort of risk than with oil and gas, where the disruption concern is about the flow of energy itself. On the other hand, the automotive sector is central to the U.S. economy, so being beholden to foreign actors for critical inputs is still an important risk to consider. In addition, the critical minerals chokepoint with China may be less about mining and more about processing. The rock has to go to China to be refined; China controls the majority of battery material refining. China could decide it needs what it processes for its own production of cathodes, anodes, batteries, EVs, and other technologies, at which point it would be happy to export its cars to the United States. The U.S. automotive sector is a pillar of the economy and has a highly skilled workforce, but it is starting to realize how dependent it is on supply chains. In terms of the nexus of national security and the energy transition, automobiles (and the batteries in them) are a clear priority. Greater quantitative analysis would be helpful on what the impacts on the U.S. economy (and on particular constituencies) would be if China cut off certain minerals, as would qualitative analysis of what would spur China to induce disruption in the first place. For the most part, China has not taken such steps yet despite a range of tensions, though it did cut off a variety of materials to the United States under the last Administration.

The U.S. automotive sector is a pillar of the economy and has a highly skilled workforce, but it is starting to realize how dependent it is on supply chains.

The United States is also behind in securing ownership of resources in other countries. Chinese government-backed companies, for instance, are outbidding others and winning lithium concessions in South America. More U.S. government support is needed for companies to win concessions abroad.

In an interdependent world, security of supply comes from diversification of suppliers, having strategic stockpiles on hand, and other similar approaches. The Biden Administration launched the Minerals Security Partnership to link up with key partners and support investments in and increase supply resilience of critical minerals. The Partnership is helping to provide architecture to engage with like-minded countries. There is also a Partnership for Global Infrastructure and Investment, which can help attract strategic co-investment.

Recycling, Rebalancing, & Demand

In addition to friend-shoring supply, recycling and energy rebalancing can play an important role in reducing U.S. dependence on unreliable foreign mineral supplies. If the goal is a circular economy, the focus should be less on mining rocks and more on mining society. Better data and planning are needed on the potential critical mineral supply in existing products, when those products' lives end, and what processes can be put in place to "mine" them.

Battery recycling is a naturally regional endeavor, for the same reason that joint ventures on EV battery manufacturing are investing in U.S. manufacturing proximate to automotive assembly — because it is difficult to ship batteries densely due both to mass and to their inherent instability. Countries such as China, India, and the United States are likely to have the economies of scale necessary to develop battery and critical mineral recycling. Other countries that lack economies of scale may be hindered in recycling efforts by the Basel Convention. Starting in 2025, the Convention effectively bans trade in e-waste between developing countries and the United States, which is not a member of Basel. Economies of scale cannot be achieved without aggregation, so Basel's limits on cross-border trade could be a problem for recycling.

If the goal is a circular economy, the focus should be less on mining rocks and more on mining society.

Recycling for lithium may still be a couple of decades away from contributing at significant scale. The United States could make some progress by adopting better policies on recycling, but that would still generate only a small percentage of the total lithium supply needed. Recycling those materials would still be an important and immediate contribution, though.

A middle ground between recycling and greenfield mining is to extract critical materials from coal ash and other tailings using environmentally benign processes. Extraction from coal ash would create a domestic supply, clean up a waste stream, and create economic activity around brownfield sites. The bipartisan infrastructure bill funded new mapping of these waste sites. Processing coal ash and other feedstocks to extract critical materials is challenging, though. There have been several lab demonstrations showing how this can be done, but there are questions of scale and economics. In addition, the waste sites have different feedstocks and different chemistries, and separation processes are highly dependent on the compositions involved.

Reducing U.S. dependence on critical minerals should also involve rebalancing. There is a wide set of generation technologies, many of which have less reliance on critical minerals to deliver energy. In terms of the amount of material needed to generate a set amount of power capacity, solar and wind look pretty good, but in terms of delivered energy, the need for batteries increases the minerals dependence considerably. Nuclear has a low materials burden. The United States should consider rebalancing toward more zero-carbon baseload power (e.g., nuclear, geothermal), with variable renewables used more for peaking (which reduces the need for batteries). Recycling and rebalancing combined could reduce U.S. demand for materials such as copper, silver, and tin to less than 1% of global demand, which creates space for better trade agreements and friend-shoring arrangements.

In addition, how many batteries (and how many critical materials for those batteries) are needed for the grid depends heavily on how much transmission gets built; robust transmission buildout dramatically reduces the amount of storage needed on any part of the grid. Likewise, models projecting the massive future need for minerals for batteries do not factor in the potential for efficient vehicles with less mass and drag, thereby reducing the batteries needed to achieve the same range. There are more efficient mobility systems that could be implemented as well. Digging harder on the demand side and on materials substitution can make the medium- and long-term need for critical minerals much more manageable.

Retrofitting & Repurposing Energy Infrastructure

Trillions of dollars in the United States are already invested into existing energy infrastructure systems. There is a lot of excitement, or perhaps hyperbole, about the possibility of retrofitting and repurposing some of it.

Importance of Leveraging Existing Infrastructure

Building new infrastructure is really hard. The global energy crisis presents opportunities to improve federal policy, including expedited permitting to enable building more climate and energy solutions. It is not clear, however, that the federal government can solve the permitting issue sufficiently, due to the state, local, and individual opposition hamstringing projects of all kinds. That is not to say that there is no hope in pursuing greenfield infrastructure, but it will be very helpful to have a big contribution from brownfield infrastructure development. The difficulty of building anything in the United States suggests a need to focus on leveraging existing infrastructure as much as possible.

Some question whether it is worth trying to build the energy system of the future on assets and systems that are already not working for everyone, as opposed to just letting the old infrastructure go. There is a need to transform the power structure as well as power systems, and starting with existing assets could narrow thinking and hinder innovation on the possibilities of the future. However, while it is important to build new values into the new system, that does not preclude reusing existing infrastructure. Indeed, relying solely on new assets for the transition would cost trillions of dollars that could not be spent instead on social equity.

The difficulty of building anything in the United States suggests a need to focus on leveraging existing infrastructure as much as possible.

Entirely replacing the global fossil fuel infrastructure and doubling or tripling it to meet rising energy demand is too slow and risky. Building new energy infrastructure and replacing all storage, transmission, and so forth would be too difficult, too large, and too high-risk to enable the needed investment within the timescales demanded by the climate crisis. The quickest and most efficient way to meet future energy demand and achieve the energy transition involves leveraging existing global infrastructure and investments.

While reusing existing infrastructure will be vital in many places and circumstances, it is important to recognize that leveraging that infrastructure is not a value in and of itself. Reusing infrastructure is a means to an end only if it delivers better outcomes. In geothermal, for instance, much capital has been squandered trying to reuse infrastructure, but the rocks and wells in geothermal are different than in oil and gas. In addition, every time an asset is repurposed to do something it was not originally designed to do, that involves a boutique design, which is hard, expensive, and not scalable. The real question is not so much which infrastructure to reuse or not, but how to get information out there so people can make optimal decisions without bias for any particular solution.

Existing assets to leverage go beyond the built environment. Human skills are another key resource to think about, as a way to create jobs and a just transition while delivering critical infrastructure and energy needs. Offshore wind, for example, is relying on workers from the oil and gas sector who have experience building vessels, platforms, and the like. Some emerging industries may be able to find workers with the right skills and desire, but others may not. While repurposing expertise makes a lot of sense, some companies are really struggling to find skills they had thought would be readily transferrable. Public-private partnerships and community colleges can be helpful in creating training programs. The IRA also offers bonus credits for projects located in historically energy-related communities.

Existing Infrastructure Used in a New Way

The deeper one goes into devising full-scope, system solutions for an industry or state, the more important it is to see what building blocks already exist and what needs to be augmented. Leveraging existing infrastructure and skills can help avoid or minimize other constraints — such as supply chain availability and space requirements — that could hinder low-cost, large-scale, rapid deployment.

There are several examples of companies that are already looking at reutilizing former power plant sites. Energy storage is a great application to locate at former power generation sites, and companies are looking into those opportunities. Companies are also looking into locating advanced nuclear projects at retiring coal plant sites. Offshore wind facilities on the East Coast are connecting into existing onshore legacy assets (e.g., former coal or nuclear plants) as interconnection points with the grid. The offshore wind industry can buy old power plants, shut them down, and convert them to energy hubs that have collector stations for offshore wind and batteries. States such as New York are providing preferences for offshore wind developers that can repurpose fossil plants and infrastructure, to try to capture some of the benefit of the sunk costs. (More broadly, offshore wind can also breathe new life into ports and industrial communities.) All energy ventures want retired power plant sites that have good interconnection. On the other hand, that means any retired plant sites that are not already built on probably have other issues that are hindering reuse.

Whether in the power sector or other parts of the economy, legacy infrastructure can be repurposed into symbols of the clean energy future, not just left as relics of the past.

As thought is given to what to do with former or retiring power plant sites, it is important to recognize that plants in urban areas are often literally walled off from the communities where they are located. Walling off parts of the city limits economic opportunity in those communities.

The focus on repurposing infrastructure must go beyond power sector opportunities. For example, power-to-X technologies can repurpose existing assets to bring new e-fuels to decarbonize heavy transport and industry. Drop-in fuels, such as SAFs, can leverage existing infrastructure and pipeline capacity; they can be produced at facilities that previously produced chemicals and can be transported using existing pipelines. Likewise, the existing natural gas system needs to be leveraged as much as possible to help support the production and use of hydrogen.

Whether in the power sector or other parts of the economy, legacy infrastructure can be repurposed into symbols of the clean energy future, not just left as relics of the past.

Repowering & Retrofits

There are important regional differences in existing assets that must be taken into account. Developed countries generally have older assets, which could potentially be repurposed, but developing countries generally have much newer assets that will not be retired any time soon. There are many new coal plants, for instance, in India and China, and the transition in the United States will look very different from the transitions there. Even in developed countries, there are relatively new emitting assets that are expected to have long lifetimes. Shutting down relatively young assets is not viable, particularly as populations and industries rely on that energy; that elevates the importance of repowering and retrofitting those assets. The owners of those assets will not just roll over and abandon them.

There is a need to repower existing fleets and to develop clean synthetic fuels. Drop-in substitutes allow for continued usage of existing storage, transport, distribution, and end-use infrastructure. That lowers the scale of investment needed, reduces the amount of new infrastructure (e.g., transmission) that has to be built, and leverages global capabilities, infrastructure, and skills that are already operating. If new clean fuels can be produced cheaply, they can be used to keep existing assets in place — say, burning ammonia and hydrogen instead of gas and coal. Very low cost is key so that drop-in substitutes have comparable costs to existing energy sources; like Impossible and Beyond Burgers, substitutes need to achieve comparable costs to scale. In addition to very low cost, fuels also have to be delivered at a rate and scale that matches levels of consumption. There is a need for very low cost, very repeatable, very large-scale solutions.

There is a need to repower existing fleets and to develop clean synthetic fuels.

In addition to using new fuels in existing infrastructure, assets can be retrofitted. Technologies such as CCS, for example, will be particularly important for facilities and places that are expected to be using fossil fuels for a long time. Likewise, the need to build and site lots of new transmission can be reduced or avoided with technologies to re-conductor existing lines; new types of wires can profitably carry much more power than present conductors. There are lots of interesting technology opportunities in transmission that did not exist even a few years ago.

Repowering and retrofitting may not be complete answers for some infrastructure, though. Cement plants, for example, produce less than half of their emissions from burning fossil fuels, so repowering facilities with clean fuels will only solve part of the problem. Retrofitting cement plants with CCS, meanwhile, involves a huge capital expense that will make the plants less profitable.

In addition, when deploying new infrastructure, it is important to be thoughtful about deploying the right stuff so it will not have to be retrofitted, repowered, or rebuilt later. Distributed inverters, for instance, should be resilient and able to work with or without the grid. Car charging infrastructure needs to be bi-directional (or at least ready to be).

Capital

It is very hard to terminate assets that are not already retired. Existing assets generally have long-term contracts associated with them (e.g., for the fuel, for the offtake), and it is costly to terminate those contracts. Those with long-term contracts are also unlikely to cancel them because they are providing a hedge in the market. The owners of those assets are not usually the ones that are developing the technologies to replace them. Policy has a role in promoting retirement or repurposing of assets early, before they would otherwise be ready from a financial perspective. Capital comes from ratepayers, taxpayers, or the markets, and there is a need to get a handle on how the costs will be mitigated and spread, otherwise the issue of recovery of expenses will slow the transition and impact energy prices.

More broadly, it is important to start thinking about how to position the large amount of upfront capital that will be needed for the transition and how to finance the repurposing, retrofitting, and retiring of assets. Offshore wind, for example, is building a new domestic industry from scratch and will require big investment to retrofit, expand, and adapt infrastructure, workforce, and supply chain capabilities. Every new plant and every repurposing of infrastructure requires money now that will be paid off over time. One should expect innovation and finance smartly.

Energy Democracy, Communities, & Equity

The intense focus of many years on setting ambitious climate mitigation goals, while still needed, may have to shift more to a focus on implementation. Implementation within a complex set of systems requires a focus on society. Human beings live in systems. Communities are where clean energy is being built and emitting energy is being shut down. There are complex environmental justice and energy justice issues, to ensure the most marginalized folks in the world are fairly benefitting from and not unfairly burdened by the energy transition. Communities are also where there can be strong local pushback, whether to closing a facility or building something new. Communities are where the energy transition happens at the micro level — and where the tension points could prevent achievement of an energy transition at speed and scale, both domestically and globally.

The very fundamentals of globalization are currently being put to the test, with energy at the core.

Local Opposition

Large-scale energy models are great at figuring out the idealized, least-cost path of deployment to achieve gigatons of emission reductions, but they do not account for things like local opposition and how much can actually get built on the ground. It is essential to consider all the upstream work that has to be done to get to the point where the gigaton reductions can occur. Frameworks need to account for all the non-energy constructs that are critical to success but not yet measurable in a tangible format in models. Iowa, for example, is a state that models presume will have high wind energy deployment, and it has historically been favorable to wind. Even at the low levels of wind deployment today, though, local opposition is growing in Iowa, with counties enacting more prohibitive ordinances and moratoria on wind. In addition, half or less of the land presumed to be available for wind leasing in models may actually be available for building and siting, and there is no room for new wind projects beyond what is already in the queue unless new transmission is built — and opposition to transmission projects is increasing too. Likewise, a project in Indiana gave royalties to community members, yet the county still passed a moratorium on new wind. Even in the places that have benefitted the most from wind, opposition is growing.

The challenges of local opposition are not unique to wind. The same concerns are hitting many other kinds of infrastructure. Transmission projects, as noted, have faced a lot of community refusal, especially when the electrons did not go to those communities. Opposition to pipelines is the same whether they are carrying natural gas or captured CO_2 for sequestration. Environmental justice community groups have been relatively unified in the sentiment that hydrogen (regardless of how it is made) and decarbonized fuels are false solutions; there is deep distrust of some of these technologies, which creates challenges for local acceptance. Infrastructure projects to advance the clean energy transition are not necessarily seen differently by communities than conventional energy infrastructure projects.

Issues about community support for transmission, wind, or other technologies will never even get a chance to be resolved unless the issues around mining and critical minerals are addressed. Mines are a challenge to site around the world; there is always a reason to say no to a mine. If it is not possible to get to yes for any mine, though, the mines will be pushed to where there are more authoritarian and corrupt governments that might just forcibly relocate communities.

Communities should have a role in saying what energy is sited there. If projects are not backed by long-term community support, they tend not to be good investments; they will lack social license to operate. If models suggest the cheapest path to net-zero is a huge buildout of wind and other infrastructure, but communities will only allow some of that to get built, other solutions will be needed. For example, models tend to shortchange the demand side, which is why they project that so much stuff needs to get built. Improved consideration of energy efficiency potential in the models, as well as other ways of balancing the grid besides big thermal plants, would lead to very different modeling results and fewer projects that will engender local opposition.

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Energy efficiency, demand response, community solar, and other smaller-scale efforts involve teams of people that go into communities and help people learn about energy. These types of programs pave the way for later engagement on bigger projects by bringing basic understanding and positive experiences related to energy, so new projects may not seem so scary. These programs also often hire from the communities and help small firms in the communities build their workforces.

It is important to recognize that some communities are also very welcoming of big energy projects and do not see them as burdens. Communities are not monolithic, though people fall into the trap of talking about them as if they are. Communities with retiring coal plants, for example, competed fiercely to be the site for an advanced nuclear project, which was seen as a source of jobs and opportunity. There are hundreds of communities that like energy infrastructure and want the associated jobs. There are many other communities that need to be brought into the conversation to help them see solar, wind, DAC, and other decarbonization infrastructure as workforce and economic development opportunities.

Public Participation & Community Engagement

Taking a systems approach to address climate change involves not just physical systems, but also economic, regulatory, policy, social license, and a range of other things that need to work together. Discussions about the energy transition often focus on going fast. There is a proverb that to go fast, go alone, but to go far, go together. The energy transition must go fast, but it is also important to remember that there is a long way to go, and it is imperative to go together. The human climate support structure needs just as much attention, investment, design, and buildout as the clean electricity system does.

Clean energy development work has to be able to proceed rapidly and equitably within social systems. Trust in government is at an all-time low, but public interest in energy is at an all-time high, from the personal to the geopolitical. It is imperative to find a constructive way to consider, respond to, and incorporate public input if the country is going to be successful in rapidly deploying infrastructure. If transparency and public participation do not improve, the result will be a continued litany of lawsuits, protests, and public opposition to infrastructure projects after permitting decisions have been made. Communities immediately react negatively to things they feel like they have no choice about. When impacted communities and constituents are engaged from the start and feel their concerns have been heard, the process tends to go more smoothly and quickly, and the results tend to be more readily accepted. (This is not unique to domestic efforts; the same challenges arise when U.S. agencies go to other countries with models for solutions and receive pushback about not knowing what is really going on there.)

Federal energy offices are taking note. To empower and promote public voices in Federal Energy Regulatory Commission (FERC) proceedings, the Office of Public Participation was created under the Federal Power Act in 1978, but it was not stood up until 2021. The new office's efforts include direct outreach to community justice organizations, landowners, members of tribal nations, and consumer, environmental, and community groups. The office also works within FERC to improve existing processes to be inclusive, fair, easy to navigate, and responsive to public input. Similarly, DOE's Office of Clean Energy Demonstrations is engaging with communities and stakeholders, and its funding opportunities will be prioritizing applicants that can show how they will engage throughout the project with the communities around them.

It may not be realistic, though, to expect people to show up to a policy process and give deep, substantive feedback. It is hard to get the public to understand highly technical matters. At utility proceedings, the seething frustration among public participants is palpable; people hate utilities and want money taken from them and given to communities. There is a lot of frustration in the public about lack of transparency. Even when everything is posted in a public docket, most members of the public have not had decades of training to understand what has been posted. Members of the general public do not have that kind of time to put into a regulatory proceeding. It is really difficult to design an effective public stakeholder process that lets the public feel like it has any control over the outcome, but a transparent decision they feel they have had some control over is what they want.

Rather than parachuting into communities when trying to push a particular project, companies need to do a lot of work to lay the foundations of trust.

If it is impossible to do effective engagement within a regulatory process, that heightens the importance of utilities (and others) also building inclusive engagement processes outside of the regulatory context. If companies are trying to engage with communities when they are trying to get something sited, they are probably starting too late. Rather than parachuting into communities when trying to push a particular project, companies need to do a lot of work to lay the foundations of trust. That is hard to do and hard to find the time and funding for, but if companies want to be effective in disenfranchised communities, the work of building trust has to start way before there is an opportunity to talk about a particular project.

Trust is essential. In Iowa, for example, a key indicator of whether a county enacts a moratorium on wind is whether the community has trust in the developer and feels the developer is fair. The actions of one developer also affect all others. How one developer of a project engages with the community will impact the next project that comes along. Everyone in the field has a duty to engage and to engage well. Third-party validators could be important. One opportunity might be if state universities created energy extension programs similar to their agricultural extension programs. These would not be funded by companies, would be part of communities, and would be there before, during, and after any particular project development.

Rapidly and equitably deploying clean energy solutions requires people to acknowledge and value community and equity. Communities feel hurt, angry, and ignored. They want action, not talk about studies or things that, in their view, do not matter. Focusing on gigatons is technocratic; many people in the world have no conception of a gigaton and never will. It is vital to achieve gigaton-scale reductions while meeting others where they are, which often is not in the same technocratic realm. People have to go into community meetings and into their work as people, not as professionals. Being human together is something that has to happen more; bringing people in and changing hearts (not minds) requires vulnerability, authenticity, and a sense of humanity. The same skills that got people through the Depression — building neighborhoods and relationships with neighbors — need to be incorporated into decarbonization work. Societies with some source of renewal stronger than the disillusion and conflict that are always present are the ones that ultimately remain vital, and that source of renewal may be at the individual level.

Education of Stakeholders & the Future Workforce

There is a large chasm between the level of understanding of people immersed in the industry and the stakeholders that affect projects at a local level, including elected judges, sheriffs, and county commissioners. Education is vital, in terms of both communicating now and planting the seeds in schools, from K-12 up to community colleges and trade schools.

It is imperative to invest in young people. Climate protests make clear that there is a high level of anxiety among young people. They do not understand all the complexities of the energy system or all the tradeoffs involved in decisions about the transition. There is a need to prioritize and accelerate investments in energy education in K-12, community colleges, and HBCUs. As students share what they learn with their families, the energy system, clean energy, and decarbonization can become normalized and understood, and people's interest in the field can be piqued at a young age.

Getting students interested in and prepared for careers in clean energy can start to chip away at the current lack of a diverse workforce and diverse worker pipelines.

Scaling DOE's Solar Decathlon could be a powerful opportunity. The Decathlon is a competition for college students, in cross-discipline teams, to design and build low-carbon homes. It is an educational opportunity for students that helps them build skills for the job market. Attached to the event are hands-on education days for K-12 students to teach them about the technologies and empower them to be part of the future of work that is needed. The homes built are also given to the unhoused. Scaling this one event and making it a roadshow that goes to the communities most in need can help solve multiple problems by educating students, empowering future clean energy workers, and providing housing.

For the general public, young people, and American entrepreneurs alike, the key is to inspire imagination. People must see themselves in the work of the clean energy transition. With a divided nation, and in a potentially divided future government, it is important to figure out how to unite the country behind a national vision.

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Prioritization of Equity

As the country moves forward with decarbonization, it is important to emphasize equity and fairness for communities and people that have traditionally been left behind. Equity involves several elements. One is access, including to technology. Another is having benefits and burdens distributed equitably; historically, burdens have lived in certain communities, while the benefits flowed elsewhere. Participation and engagement are also key; people have to be able to participate and be involved in (and have the ability to sway) decision-making. Representativeness is important as well; the people engaged in the process have to reflect the larger community. Ultimately, objectives should include improving environmental health outcomes in underserved communities across the country, bringing a more diverse workforce into clean energy jobs immediately, building more infrastructure in communities that need it, and preparing underserved communities for climate disasters.

Community solar is an important model for providing clean energy access, improving regional air quality, and generating jobs and taxes that benefit communities, particularly in dense urban areas. Climate resilience is another great opportunity to put more infrastructure in underserved minority and rural communities in a way that enables people to see the energy future and how they can be part of it. Infrastructure can also go in schools, Boys & Girls clubs, and other places that people go regularly (not just when there is a disaster); these places can become clean energy model centers, where people learn about solar, test drive an electric vehicle, and more.

It is important, too, to build diversity, equity, and inclusion into the innovation ecosystem from the beginning. In the past, the benefits of industrial policy have not gone to marginalized communities, and the venture capital and science and technology worlds have not been very diverse. Tiny percentages of the venture capital flowing into climate tech have gone to women or to black or brown founders. Now is the time for the government to be supporting PhDs and students who might not otherwise take the risk to step out of the lab and create companies.

Community Ownership & Wealth Creation

Communities are often best positioned to solve their own problems; they know what climate solutions they want in their communities, and they have to be empowered to develop projects in their own backyards. Including local developers to help build clean energy infrastructure (e.g., in the distributed generation space) can enable a new, more diverse workforce and foster community wealth creation.

Communities are often best positioned to solve their own problems; they know what climate solutions they want in their communities, and they have to be empowered to develop projects in their own backyards.

Communities have to be able to benefit from the ownership of local projects. Opportunities for equity ownership of projects and assets need to be available to everyone; equity ownership and investment lead to wealth creation. The vast majority of Americans are uncredited investors and have been unable to invest in private companies, which means they historically have been left out of the equity side of building wealth. It is important to democratize development and ownership of clean energy projects so everyone has the opportunity to own a piece, no matter how small, of the clean energy economy. There are models for project deployment that can be replicated to enable inclusive growth and democratized ownership across the country. In a proposed large-scale carbon hub project in Canada, for example, indigenous communities are 50% equity partners.

Ownership also comes with burdens, though, and people need to be set up for success. For example, there are great programs to put solar on homes for free, but thought also has to be given to maintenance, energy efficiency opportunities, and energy education and literacy (e.g., how utility bills work, the role of technology in reducing carbon footprints). There is also trauma in some communities associated with legal documentation and contracts, and education is a critical part of overcoming that trauma. People need full descriptions of how financial products and investments work, as well as what the burdens and opportunities of ownership mean. Boosting financial literacy alongside energy democracy requires a great deal of intentionality.

Investment, ESG, & Shareholder Power

It is remarkable how far the environmental, social, and governance (ESG) investing space and shareholder activist efforts have come in the past few years, but there is still a need to better align the environmental and financial systems of success.

Materiality

Twenty years ago, the environment was mostly a nonprofit-only issue. There has been a cohort of long-standing shareholders with deeply held views on environmental and social performance, but for a long time, these views were not getting picked up by the majority of investors. Even a few years ago, most investors did not ask companies a single ESG question.

Companies are now hearing about these issues from investors, consumers, and employees. These stakeholders want values-driven company efforts, and sustainability is now a material financial capital markets issue. These issues, along with equity, have moved in relatively short order from minor considerations to essential aspects of being private sector leaders. The issues are material to the real economy, in every sector. For instance, companies cannot make great profits if they run out of water or are continually affected by droughts. Likewise, some asset managers are recognizing that it is a material concern for their companies, clients, and beneficiaries to live in a world where potentially hostile foreign powers can hold them hostage on energy. There are new and different ways to measure performance that matter to the bottom line, and some companies simply need to perform better. Those are material business issues and financial risks.

ESG issues have begun moving for the first time from the voluntary to the mandatory.

Recognizing the materiality, the private sector has committed to take action to address these issues. Over the last few years, the number of companies committing to a net-zero future has gone from a handful to thousands. The same trend has been seen with investors. A few years ago, there were few net-zero and equity commitments by investors, but now there are hundreds of asset managers and asset owners committing to net-zero, and asset owners are putting pressure on asset managers on climate change. (It is imperative, of course, to ensure those commitments are grounded in specific short-, medium-, and long-term measures with accountability and transparency.) There are also new investor initiatives that have been formed to pressure companies on biodiversity loss and nature-based solutions.

ESG issues have begun moving for the first time from the voluntary to the mandatory. Investors have pushed for a long time to get the U.S. Securities and Exchange Commission (SEC) to issue a rule on climate risk, and the SEC has issued a draft rule recognizing climate risk as a material financial risk. (The SEC draft rule has already led to a ripple effect of interest in other countries in doing something similar, though the regulatory requirements can vary broadly.) Europe is pursuing a different approach with a sustainability taxonomy, and various things are being explored in Asia. Central banks are also very focused on climate risk, particularly the potential impacts of physical and transition risk.

Some have called for the S and G to be cut from ESG, but others argue that those matter a great deal. Governance, for instance, is critical. Having a board committee focused on the transition has an impact on the CEO, investor relations, preparations for earnings calls, and more. The pace of the decarbonization journey, meanwhile, will be dictated by how well companies navigate the S, as the S issues are growing in importance. The better companies navigate issues such as affordability, justice, and just transition, the faster the transition will go.

Shareholder Pressure

Hundreds of ESG-related shareholder resolutions have been filed with companies, many of which led to successful negotiations where companies changed practices to get the resolutions pulled. There have been commitments from several companies to set specific goals because shareholders believe those will make the companies more stable and profitable. Investors are not necessarily seeking to advance particular technologies; rather, they are seeking to protect their long-term interests from risks and pushing companies to have continuous capital formation that both yields profitability and de-risks itself. The last couple of proxy seasons have clearly demonstrated the focus of the investor and shareholder communities on enterprise risk management broadly, and the heightened investor focus on risk will only continue.

Shareholder power was perhaps most visible in the shareholder activist effort in 2021 to install different board members at ExxonMobil.

Some companies welcome the investor pressure and conversation, seeing ESG as being about mitigating risk and creating value for companies, customers, and communities. Others have not been so welcoming. Shareholder power was perhaps most visible in the shareholder activist effort in 2021 to install different board members at ExxonMobil. The push was centered on getting energy experience on the board of a company that had underperformed compared to its peers, experienced significant value destruction, and lacked a strategic plan for the energy transition. (All three of the elected directors in that effort have since been re-elected.)

While there has been an uptick in the volume of shareholder proposals, support for environmental proposals has declined somewhat this year. Some of that is due to the fact that companies have made progress, proposals have gotten more specific and prescriptive, and the context has changed, with energy affordability a bigger issue. Some are wondering if some recent proposals are going too far.

Backlash

Where there is shareholder activism, there has also been counter-activism. That has been true for a long time. Currently, there is a growing backlash against ESG and "woke capitalism". Conservative states are pushing back against financial firms they see as being pro-ESG and anti-fossil fuels. Some conservative politicians are fundraising successfully on the anti-ESG message, while conservative champions for the energy transition are experiencing unexpectedly severe waves of pushback on ESG. If control of Congress changes after the midterm elections, there will likely be more scrutiny by Congress of proxy advisors about whether they are pushing an activist agenda.

Some view the backlash as being mostly political. The numbers, actions, and risks regarding ESG issues are compelling enough that the backlash is unlikely to prevail, and climate impacts and pressure to act on climate are only going to grow going forward. Companies and investors recognize that these are real material risk issues that need to be acted on appropriately. Companies and investors can be awake without being woke.

There is a need for good, clear stories to defend the movement. One cannot just assert to a member of Congress that these issues are material; there is a need for stories about how ESG considerations protected jobs, increased 401(k) values, changed corporate performance for the better, and so forth. ESG investments outperforming traditional indices, companies that lead sustainability rankings outperforming the market, and other such metrics are also great counters to pushback.

Unlocking Capital

Investment in the energy transition must scale severalfold from where it is today; sustainable finance commitments in the United States, while huge and growing, are still far less than what is needed for the energy transition. It is essential to focus on unlocking capital flows, including for the hardest-to-abate sectors to transition their businesses over time. (It is also important to figure out how to funnel much-needed funding to adaptation.) The transition will succeed or not based on dollars being deployed outside of things deemed to be "sustainable finance". Companies that are transitioning should be celebrated, and the cost of capital for transitioning companies should be as low as possible.

There is an inflationary effect of ESG in the current environment, though, leading to higher costs of capital. Analysis suggests, for example, that investors globally are pricing in a carbon price for new carbon-intensive investments; the cost of equity capital for high-carbon sectors implies a carbon price for long-term hydrocarbon investment. The markets are moving much faster than policy, which can lead to structural underinvestment. Utilities likewise are experiencing some challenges in raising capital and are seeing some risk being priced in. The enthusiasm for net-zero can lead to higher costs of capital for companies that are looking to transition. If they have trouble accessing capital or if it is at higher cost, that makes the transition harder and more expensive.

It is essential to focus on unlocking capital flows, including for the hardest-to-abate sectors to transition their businesses over time.

There has been a lot of focus on which sectors are "good" and which are "bad", but many companies need to transition. Metals companies, for instance, tend to be under-owned by ESG indices partly because they are very toxic, but they also play a key role in clean energy supply chains. European investors are divesting from oil and gas and carbon capture, while U.S. policy is actively supporting carbon capture.

A focus on the right metrics is needed so there can be a commercially viable transition; divestment just pulls capital away. If companies cannot execute on the energy transition in a financially viable way, that will slow the transition. Metrics for the energy transition need to evolve so businesses can be successful both in terms of quarterly results and in terms of making sure the planet remains sustainable for human and other life. Metrics to measure progress are needed; there is a need to coalesce on how to measure and communicate what companies are doing on the transition. Much work has been done in the space, but lumping E, S, and G together makes them hard to execute against. There are many different ESG frameworks measuring lots of different things, many of which may not be all that related to progress. Greenhouse gas accounting frameworks also are not designed for investors and companies to take action; Scope 3, for example, is defective, deficient, inaccurate, faulty, and lacking integrity — but it still matters. Those issues have to be rectified to reform accounting; measuring things accurately can amp performance. The key is to reward actual decarbonization — real, measured emissions of companies over time. (The investor community also needs to grapple with the issue of offsets.) The data has to be simple, transparent, and standard for capital markets to unleash gigaton-scale financing. Such data will be valuable not only for investors, but also for banks making decisions about companies.

One metric improvement to inform capital flows would be to add the market value of price volatility into energy sources with volatile costs, such as natural gas. That would make comparisons to other energy sources with constant price streams (e.g., renewables, efficiency) fairer.

Because of the massive amount of capital needed across a range of areas, public-private partnerships will play a critical role. For instance, as much as some investors might want asset managers to take on risks to bring new technologies and ventures to deployment, that is where asset managers run the risk of being criticized for "woke capitalism" and conceding returns. There is a lot asset managers can do on decarbonization with their portfolio companies that is consistent with their fiduciary duties, but there are some harder areas, including new technologies. Those are areas where public-private partnerships are important, so finance can play its role to support new technologies without bearing all the risks. Public-private partnerships help take away the moonshot risk.

Companies and equity capital are not the only relevant elements in deploying dollars for the transition. The public debt side of the capital markets ecosystem is also critical, such as water bonds or for utilities. Municipalities, for instance, play a big role in decarbonization efforts, and they are largely driven by tax-exempt debt. There is very little to no relief on interest rates for green projects, though.

Potential Undesirable Implications of ESG

There are concerns that the enthusiasm for ESG is failing to fully consider some of the potential undesirable implications. For example, the SEC reporting requirements, and all the different ESG frameworks and rating systems, may be exciting at a macro level, but at the tactical level, there is a concern that the experts that ought to be delivering solutions for emission reductions will instead be spending time with accountants and lawyers doing compliance reporting. Reporting is important, but reducing emissions is far more important.

There are concerns about achieving net-zero on paper only, not in the real world.

Likewise, there are concerns about achieving net-zero on paper only, not in the real world. For example, one of the easiest ways for a company with fossil fuel assets to achieve the net-zero target that investors are pushing them to reach would be to sell those assets. Those assets, however, are often bought by private equity firms. The assets are off the books of one company, but they are still operating, with less oversight, sometimes higher emissions, and less susceptibility to investor pressure. Public markets are an important but small piece of the puzzle.

Climate Philanthropy

Private capital that is not seeking profit — philanthropy — plays an important role in the clean energy transition.

Increasing Philanthropic Effectiveness

Philanthropies are recognizing climate change as a critical issue. A survey of U.S. philanthropic leaders found that most thought climate was extremely important, with many of those identifying it as one of the top issues to focus on now. Climate philanthropy is increasing, with funding for mitigation more than doubling over the past five years. Major players are engaging in a big way, with pledges from billionaires and collaborative commitments from groups of foundations. Some foundations are focusing all their work on climate change.

Unfortunately, the amount of climate philanthropy today is small compared to the need at hand. Global climate mitigation funding makes up a very small percentage of philanthropic giving, and the percentage is even lower in the United States. Even though climate change is overwhelmingly recognized as a crisis, not many in the philanthropic community are planning to increase funding or incorporate a new climate lens into their funding, whether because it is not part of their mission, their board has limited interest, the problem is too big, or other reasons. Too few foundations are having climate conversations with their boards and grantees, yet it is obvious to most that climate change impacts every kind of social issue, whether health, education, inequality, poverty, crime, or protecting democracy. It is not that climate change is more important than those issues, but rather that it is inextricably connected to everything else — which means failing on climate means failing to achieve and sustain other goals.

A survey of U.S. philanthropic leaders found that most thought climate was extremely important, with many of those identifying it as one of the top issues to focus on now.

More money is needed in the field, and it needs to be new money, not existing funders being asked to give up their other priorities to take on climate. Philanthropies can help other foundations start thinking about how to incorporate climate work into their existing portfolios (e.g., related to economic and community development), but more on-ramps are needed for new investors and allies. Philanthropic dollars are more than just foundations; there is a lot of potential money out there from individuals as well. There is a need for a system map, increased knowledge, and communications to help people identify where their philanthropic dollars should go in this hard-to-navigate space.

The Climate Leaders Initiative (CLI) does some of that. CLI was established as a platform for other foundations to align funding with climate strategies without having to pool funding or be part of an institution. CLI was built on the university fundraising model, but with a focus on finding people with concern for the cause (instead of loyalty to a university) and helping them find the climate-related philanthropic opportunities that matter to them. It has helped bring in new funding. Other initiatives like CLI will be needed on a global scale, so private donors will add their philanthropic funding to the effort with confidence that they are aiming in the right direction with some chance of success.

Increasing Philanthropic Effectiveness

In addition to more climate philanthropy, there is a need for more effective climate philanthropy. Surveyed foundation executives were generally unenthusiastic about their own efforts. Climate change is a hard systemic challenge, and foundations are still struggling to find effective philanthropic approaches.

Some foundations that have been deeply committed to climate funding for a long time have focused on building platforms for collective climate action across the range of climate issues, including energy, transportation, agriculture, forests, oceans, and adaptation and resilience. Climate action is best as a team sport; it takes collaboration and partnerships to address.

Philanthropy can play a catalyzing role in gathering the breadth of philanthropic funding together to leverage private sector and government investments. The clean energy transition will require trillions of dollars in investment annually, and that will not come from philanthropy. Philanthropy must focus on moving government and private markets to invest in different, new ways — on changing the structures, incentives, and contexts in finance. Philanthropy can support achievement of the policy change required around disclosure and transparency to allow for proper pricing of carbon in investments, adoption of policies and other measures to create secure investment environments in countries, implementation of initiatives to develop projects worth investing in, and other kinds of "infrastructure" to support the kinds and scales of investment needed. All of these are classic philanthropic types of investments that could make a big difference.

Philanthropy can play a catalyzing role in gathering the breadth of philanthropic funding together to leverage private sector and government investments.

There is a need to bring different players and capital together to rethink how to build capital stacks and create markets. The public-private LEAF Coalition is an example of the potential for philanthropy to catalyze new investment and finance models; a few million dollars of philanthropy will probably unlock more than $1 billion in corporate and sovereign payments to reduce tropical deforestation.

When the philanthropic community wants to affect policy, the bulk of its efforts go into advocacy, but the national labs offer a different channel, as more of an inside player that can affect policy by providing credible, objective, and independent policy-relevant technical expertise. More broadly, philanthropic support for U.S. government climate programs can be catalytic. On the global stage, the dollars that Congress appropriates for international climate programs are a rounding error (and come with constraints), so outside support for efforts such as the First Movers Coalition and the Net Zero World Initiative can be quite impactful. It takes a long time to spin up funding for initiatives like these, so startup funding from philanthropy can be vital to hitting the ground running.

Any policy strategy has to be accompanied by a strategy focused on public will. Most Americans know that climate change is happening but feel incapacitated to do anything about it, in part because climate change is often talked about in ways that make it feel impossible to influence. It is important for philanthropies to invest more in affecting public will — in getting people, particularly those most affected and with the greatest need, to believe they can make a difference on the issue.

Foundations are also exploring how philanthropic capital can help companies drive the transition (e.g., get technologies to market) and enable ecosystems in which entrepreneurs can grow and succeed in pursuit of solutions to difficult problems, all while benefitting communities. For example, the national labs host some successful philanthropically funded programs, such as ones focused on de-risking technology innovation by giving grants and technical assistance to early-stage companies and leveraging the labs' capabilities to bring more successful startups into the ecosystem.

As philanthropies focus on creating a new clean energy economy, they should also work to ensure that the new economy does not exclude people the way the old economy did. Philanthropies can target their capital to help advance the notion of racial and social equity while moving climate solutions. In addition, philanthropies could think about indirect multiplier effects, such as supporting the education of women and girls and different ways of helping small businesses access credit; these are not about climate, but they will have effects on climate solutions.

There are many things philanthropic capital can do, but if it is not guided by a philosophy and thesis, philanthropy can be an impediment rather than an accelerant. There should be a specific philosophy of capital placement, whether that is seeking to seed wildflowers or cultivate and curate a rose garden, and the thesis could be to catalyze self-propagating chain reactions of impact. Time is of the utmost importance, particularly for motivated change agents; a fast no is much better than a slow yes. Philanthropies should hone their strategies to allow for accelerated results. That said, the transition is both a sprint and a marathon. Philanthropies should look to near-term priorities and actions but with an eye on effecting durable change.

Philanthropic convening power has to be a key part of the theory of change as well. Philanthropies can be a fulcrum of rationalism, bringing parties together that might otherwise be screaming at each other because they are not understanding the commonalities and linkages. Philanthropic platforms have enormous and underutilized convening power.

Foundations are uniquely positioned to take risks, and they should. That can include the idea of finding competent partners, giving them money, and letting them use that money in the way they think it needs to be used; the lack of trust between philanthropies and their partners/grantees is a problem. It can include taking more risks with their financial balance sheets as well. Foundations can align their full assets to advance the mission they are trying to achieve, such as by making a net-zero commitment on their endowments. The vast majority of most foundations' assets is in their corpus; grants are a small percentage. If their investment pool is not aligned with their mission, their work is being undermined by their capital before a single grant has been made.

Regional Strategies

It is imperative for philanthropies to invest more deeply in regional strategies domestically, especially in places that seem to be the hardest politically and economically. If the Midwest and Southeast were pulled out of the country, they would be among the largest emitters in the world. These tough places are challenging but can also be part of the solution, as evidenced by some Midwest states that are leading on equity, efficiency, EVs, wind, and other areas. Approaches are needed to help change regional economies, or climate goals will not be met.

If the Midwest and Southeast were pulled out of the country, they would be among the largest emitters in the world.

Given the large flows of federal funding that will be coming from the bipartisan infrastructure law and the IRA, and the lack of local and state infrastructure in place to make sure that money lands effectively and equitably, there is an important role for philanthropy in filling early gaps, helping places get prepared to spend the money well, and helping communities understand that democracy and climate policy are delivering for them. Philanthropies can directly engage with local economic development officials, few of whom understand climate change and incorporate it as an opportunity or challenge. People in regions often feel alone, not included in the broader climate philanthropic movement, but philanthropies can have impact in driving the transition by acting regionally.

Gigatons are made up of many little tons, and getting the little tons right is critical; there is a need to celebrate small wins. Focusing regionally, however, should not come at the expense of big, collaborative bets on potentially transformational efforts on a larger scale. Smaller systems sit within bigger ones. Global, domestic, and regional approaches are all important. Collaborative efforts are needed on everything, at all levels; groups of funders need to collaborate on both big bets and local strategies. Multiple efforts are needed at once, because it is imperative to win on everything.

Appendices: Participant List

Tonya Allen, President, McKnight Foundation

***Sarah Allendorf**, Director of the Chemistry, Combustion, and Materials Science Center, Sandia National Laboratories

Doug Arent, Executive Director, Strategic Public-Private Partnerships, National Renewable Energy Laboratory

John Arnold, Founder & Co-Chair, Arnold Ventures

Bryn Baker, Senior Director, Market and Policy Innovation, Clean Energy Buyers Association

Miranda Ballentine, Chief Executive Officer, Clean Energy Buyers Association (*Co-Chair*)

Roger Ballentine, President, Green Strategies Inc

Kathleen Barrón, EVP & Chief Strategy Officer, Constellation Energy Corporation

Damian Beauchamp, President and Chief Development Officer, 8 Rivers Capital LLC

***Brooke Beebe**, Senior Vice President, Advocacy & Engagement, Hemlock Semiconductor (HSC)

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

Alyssa Boggs, External Relations Strategy and Engagement Lead, Worldwide Sustainability, Amazon.com, Inc.

Jason Bordoff, Founding Director & Co-Founding Dean, Center on Global Energy Policy, Columbia Climate School

***Savita Bowman**, Policy Analyst, ClearPath

Samuel Brothwell, Director of Research, Energy Income Partners LLC

Bill Brown, Executive Chair and CTO, 8 Rivers Capital LLC

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

Josh Burkholder, Director of RTO Policy, American Electric Power

Gilbert Campbell, Founder & CEO, Volt Energy Utility

***Paul Camuti**, Executive Vice President, Chief Technology & Strategy Officer, Trane Technologies

Amanda Peterson Corio, Global Head of Data Center Energy, Google LLC

Kandice Cohen, Director, Electrification of Heat, Trane Technologies

Will Conkling, Head of Data Center Energy, Americas and EMEA, Google LLC

Matt Crozat, Executive Director, Policy Development, Nuclear Energy Institute

***Kelly Cummins**, Acting Director, Office of Clean Energy Demonstrations, United States Department of Energy

David Danielson, Managing Director, Breakthrough Energy Ventures

***Kyle W. Danish**, Partner, Van Ness Feldman LLP

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

***Tom Dower**, VP, Public Policy, LanzaTech

Lisa Epifani, Head of Policy (incoming), X, the Moonshot Factory

***Ignacio Fernandez-Stearns**, Data Center Energy, Americas, Google LLC

* *participating remotely*

** *affiliation listed for identification purposes only*

*__Shelley Fidler__, Principal, Governmental Affairs, Energy and Environmental Policy, Van Ness Feldman LLP

Cody Finke, CEO, Brimstone Energy

*__Emily Fisher__, General Counsel, Corporate Secretary, and Senior Vice President, Clean Energy, Edison Electric Institute

*__Alex Fitzsimmons__, Senior Director, ClearPath

*__Mike Francis__, Program Manager, Renewable Energy, Amazon.com, Inc.

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

Meg Gentle, Executive Director, Highly Innovative Fuels Global

*__Diana Glassman__, Director-Engagement EOS, Federated Hermes

*__Kirsty Gogan Alexander__, Co-Founder & Managing Director, TerraPraxis

Kristen Golden, General Counsel, Grid United

*__Representative Anthony Gonzalez__, United States Congress

Susan Gray, Global Head of Sustainable Finance Business and Innovation, S&P Global Ratings

*__Dave Grossman__, Principal, Green Light Consulting (*Rapporteur*)

*__Emma Hand__, Partner, Dentons US LLP

*__David Hardy__, CEO, Ørsted Offshore North America

Bruce Harris, Vice President, Federal Government Affairs, Walmart Inc. Inc.

Richard Hess, Director, Program Development, Idaho National Laboratory Energy & Environment Science & Technology Directorate

Maureen Hinman, Chairman and Cofounder, Silverado Policy Accelerator

Franz Hochstrasser, CEO and Co-Founder, Raise Green Inc.

*__Colette Honorable__, Partner, Reed Smith LLP

Brenda Hopewell, Vice President, Energy Solutions, APTIM

*__Anne Hoskins__, Policy Advisor, Brimstone Energy

*__Sarah Hunt__, CEO & President, Joseph Rainey Center for Public Policy

Ramsay Huntley, Climate Strategy and Innovation Lead, Wells Fargo & Company

*__Christine Irvin__, Director, Oxy Low Carbon Ventures

*__Brian Janous__, General Manager of Energy & Renewables, Microsoft Corporation

*__Nick Johnson__, Wind Technology and Design Manager, Sandia National Laboratories

Robert Johnston, Senior Research Scholar, Columbia University Center on Global Energy Policy

*__Jyotsna__, Corporate Strategy & Planning, International Solar Alliance

Andy Karsner, Senior Strategist, X, the Moonshot Factory

*__Elin Katz__, Director, Office of Public Participation, Federal Energy Regulatory Commission

Randall Kempner, Senior Advisor, The Aspen Institute

*__Mariah Kennedy__, Director, Data Center Energy Strategy (Global), Microsoft Corporation

*__Nathaniel Keohane__, President, Center for Climate and Energy Solutions

*__Briana Kobor__, Global Regulatory Lead for Energy Markets and Development, Google LLC

David Kolata, Executive Director, Citizens Utility Board

*__Maria Korsnick__, President and CEO, Nuclear Energy Institute

Peter Lake, Chairman, Public Utility Commission of Texas

Tim Latimer, CEO, Fervo Energy

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Elizabeth Lewis, Managing Director and Deputy Head of ESG, Blackstone Inc.

Nancy Lindborg, President and CEO, The David and Lucile Packard Foundation

David Livingston, Senior Advisor, US Special Presidential Envoy for Climate

Amory Lovins, Co-Founder & Chairman Emeritus, RMI; Adjunct Professor of Civil and Environmental Engineering, Stanford University

***Mindy Lubber**, CEO and President, Ceres

Mark Lundstrom, CEO, Radia Inc.

Kara Mangone, Global Head of Climate Strategy, The Goldman Sachs Group, Inc.

Maria Martinez, Manager, U.S. Policy & Advocacy, Breakthrough Energy

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***Jason Muller**, Sr Advisor, Government Relations, Capital Power Corporation

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Richard Newell, President and CEO, Resources for the Future (RFF)

Sandeep Nijhawan, Founder and CEO, ElectraSteel

John O'Leary, Deputy Secretary for Energy & Environment, Office of Governor Kathy Hochul

Mark Peters, Executive Vice President, Battelle Memorial Institute

Ian Philp, Program Officer, Environment, The Bernard & Anne Spitzer Charitable Trust

Renee Pirrong, Director, Strategy Tellurian Inc.

Rich Powell, CEO, ClearPath (Co-Chair)

Sagatom Saha, Cleantech Competitiveness Specialist, U.S. Department of Commerce**

Melissa Simpson, Director for Global Government Affairs, Sempra

***Anna Shpitsberg**, Deputy Assistant Secretary, U.S. Department of State

***Nicole Sitaraman**, Deputy Director, Office of Public Participation, Federal Energy Regulatory Commission

Varun Sivaram, Senior Director for Clean Energy and Innovation, U.S. Special Presidential Envoy for Climate

***Antonio Smyth**, SVP, Grid Solutions, American Electric Power

***Jen Snook**, Senior Manager, Decarbonizing Industrial Supply Chain Energy, Clean Energy Buyers Association

***Dave Snydacker**, CEO, Lilac Solutions

Jon Sohn, Director of US Government Relations & Policy, Capital Power Corporation

Xin Sun, Associate Laboratory Director, Oak Ridge National Laboratory

Nancy Sutley, Executive Secretary, Los Angeles Department of Water & Power

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

David Szmigielski, Vice President, ESG Solutions, Wells Fargo & Company

***Scott Tew**, Vice-President, Sustainability & Managing Director, Center for Energy Efficiency and Sustainability, Trane Technologies

Alexa Turner, Director, Public Policy & Government Affairs, Sempra

***Clint Vince**, Founder & Chair, US Energy Practice and Co-Founder & Co-Chair, Global Energy Sector, Dentons US LLP

***Doug Vine**, Director of Energy Analysis, Center for Climate and Energy Solutions

Libby Wayman, Partner, Breakthrough Energy Ventures

Michael Webber, Professor, The University of Texas at Austin

Jeff Weiss, Executive Chairman, Distributed Sun

Tracy Wolstencroft, Senior Advisor, TPG Rise Climate

***Lisa Wood**, Vice President, Customer Solutions, Edison Electric Institute

Cherie Wilson, Vice President of Government Affairs – Sustainability, Delta Air Lines

Adria Wilson, Manager, U.S. Policy and Advocacy, Breakthrough Energy

***Lauren Wright**, Executive Director, Conservative Climate Foundation

Abby Wulf, Vice President and Director, Center for Critical Minerals Strategy, Securing America's Future Energy

***Riddhima Yadav**, Sustainable Investing Strategy Lead, The Goldman Sachs Group, Inc.

Laura Zapata, CEO & Co-Founder, Clearloop Corporation

***Audrey Zibelman**, Vice President, X, the Moonshot Factory

Appendices: Agenda

SUNDAY, JULY 31, 2022

Arrivals and Check-In

Opening Reception

Opening Dinner
Presented by Google

MONDAY, AUGUST 1, 2022

Breakfast
Welcome: Greg Gershuny, The Aspen Institute

Introduction:
Rich Powell, Clearpath
Miranda Ballentine, Clean Energy Buyers Association

SESSION 1: Briefing Room: Upheaval in the Energy System

Moderated by Rich Powell and **Miranda Ballentine**
The Russian invasion of Ukraine in February plunged world energy markets into a time of radical uncertainty - at a moment when energy systems were already struggling with a stressed grid due to increasing extreme weather, more intermittent resources, and gas being called upon for ever more uses simultaneously. The United States and its allies consequently have a renewed focus on issues of energy security and independence, leaving vast implications for the energy transition. How should policymakers balance the need to pursue energy security for the US and allies, and resilience within existing power grids, with the continued pressing threat of climate change?

Discussants:
Adria Wilson, Breakthrough Energy
Jason Bordoff, Columbia University Center on Global Energy Policy
Peter Lake, Public Utilities Commission of Texas
Anna Shpitsberg*, United States Department of State
Michael Webber, The University of Texas at Austin

SESSION 2: Critical Minerals and Metals

Moderated by Miranda Ballentine
Critical minerals are both a key enabling resource for modern energy systems and a potential new source of natural resource-related geopolitical competition. Yet, the United States does not have a coordinated national strategy to ensure that its mineral supply system will be available and affordable in sufficient quantities to meet demand (and in a sustainable way). What policy solutions should exist to help combat anticipated critical minerals scarcity? What role might domestic mining play in this system? Can innovation pathways help ease constraints? What is the role of recycling?

* *participating virtually*

Discussants:
Maureen Hinman, Silverado Policy Accelerator
Robert Johnston*, Columbia University Center on Global Energy Policy
Amanda Maxwell, Natural Resources Defense Council
David Syndacker*, Lilac Solutions, Inc.

SESSION 3: Transportation: Decarbonizing the Liquid Fuels System

Moderated by Rich Powell

Unique challenges in the transportation sector position liquid fuels as a probable continued keystone technology to meet energy demands. Yet, questions remain about how to decarbonize the liquid fuels supply in a sustainable, scalable, and economically viable way. What sectors within transportation are priorities for clean liquid fuels? What tradeoffs exist between the pursuit of sustainable biofuels versus synthetic fuels? Is there such a thing as sustainable biofuels? What are the key barriers to scaling and deploying synthetic fuels?

Discussants:
Christine Irvin*, Oxy Low Carbon Ventures
Maria Martinez, Breakthrough Energy
Varun Sivaram, Office of the US Special Presidential Envoy for Climate
Cherie Wilson, Delta Air Lines, Inc.

Forum Reception and Dinner

TUESDAY, AUGUST 2, 2022

Breakfast – Davis Commons, Aspen Meadows Resort

SESSION 4: Innovation and the Infrastructure Investment and Jobs Act

Moderated by Rich Powell

The past few years have seen a flurry of congressional action on promoting energy innovation. In particular, the bipartisan Infrastructure Investment and Jobs Act passed in 2021 has led to a number of new programs and initiatives - definitively putting the U.S. energy innovation system back into the business of major technology demonstrations at a scale not seen since the Manhattan project. What is the status of implementation at DOE, and how is DOE transforming itself and its systems to respond to this vast challenge? What technologies have been prioritized, and how are public and private players aligning to both take advantage of major projects and then to develop "hub" systems for new clean infrastructure? What federal actions might yet come, particularly in a potentially divided government ahead?

Discussants:
Kathleen Barron, Constellation Energy Corporation
Kelly Cummins*, Office of Clean Energy Demonstrations, United States Department of Energy
Dave Danielson, Breakthrough Energy Ventures, LLC
Xin Sun, Oak Ridge National Laboratory

SESSION 5: New Energy Symbiosis and Systems Thinking

Moderated by Miranda Ballentine

Tens of trillions of dollars of "hard" traditional energy, electric transmission and distribution, and industrial infrastructure are in the ground today across the United States. The gas pipeline network alone is $5 trillion in replacement value. Similarly, tens of millions of workers continue to work, and have engineering and project expertise, in traditional energy industries. Numerous efforts are underway to repurpose the existing energy infrastructure towards a clean energy economy. How can the world put today's energy and industrial system to work towards tomorrow's clean electro-molecular economy? What does all of this mean for the business models of today and tomorrow?

Discussants:
Bill Brown, 8 Rivers Capital, LLC
Kirsty Gogan*, TerraPraxis
David Hardy*, Ørsted Offshore North America
Audrey Zibelman*, X, the Moonshot Factory

SESSION 6: Industrial Decarbonization: Steel

Moderated by Rich Powell

Decarbonizing the industrial system will be a crucial yet complex step in the energy transition. In particular, decarbonizing the production of steel will be a necessary challenge to overcome given the hugely energy intensive nature of the sector, and the continued, potentially even greater, requirements for enormous quantities of steel in transition technologies. Yet, very few technologies currently exist for low-carbon steelmaking. What is the current landscape of decarbonization strategies, especially given the need for cheap natural gas for direct reduced iron (DRI) in EAF steel-production, as well as the infancy of current CCS? Where does the industry stand with innovative alternative breakthrough technologies? When will the renewable energy capacity exist for green hydrogen to serve as the magic bullet? How can waste streams be repurposed to recycle heat and steel? How will growing worldwide demand for steel be met equitably and efficiently? And how are policymakers responding to this challenge?

Discussants:
Rep. Anthony Gonzalez*, United States House of Representatives
Sandeep Nijhawan, ElectraSteel
Jen Snook*, Clean Energy Buyers Association

SESSION 7: Shareholder Power

Moderated by Miranda Ballentine

The public corporation / public investor / financial regulatory system is in transition given the increasing pressure from shareholders, institutional investors, and asset managers to address climate change and other sustainability imperatives. In particular, several recent high-profile shareholder actions have garnered news headlines, and some anticipate that this trend will continue to gain prominence in the years ahead. Is the recent rise of shareholder power a passing trend or a new normal? What impact will shareholder activism have on management decision making regarding climate and sustainability? What role will the new Securities and Exchange Commission and other financial regulatory measures and pressures in this space play? What role will asset managers play? What will become of the emerging conservative backlash against certain ESG initiatives?

Discussants:
Andy Karsner, X, the Moonshot factory
***Mindy Lubber**, Ceres
Kara Mangone, The Goldman Sachs Group, Inc.
Katherine Neebe, Duke Energy Corporation

Forum Reception | Forum Dinner

WEDNESDAY, AUGUST 3, 2022

Breakfast

SESSION 8: Energy Democracy, Communities, and NIMBYism

Moderated by Miranda Ballentine

Decarbonizing the United States necessitates building many clean energy assets at a monumental scale and at great speed, something the United States has not done in decades. Often, impacted communities have concerns about the effects these assets may have for those living nearby, or those who might be displaced. How can clean energy development work rapidly AND equitably within social systems? Can clean energy assets be built quickly while also furthering environmental justice imperatives? What is the right way to balance community input and decision-making against national or regional energy system priorities?

Discussants:
Brandy Brown, Walker-Miller Energy Services
Gilbert Campbell, Volt Energy Utility
Elin Swanson Katz*, Office of Public Participation, Federal Energy Regulatory Commission
Spencer Nelson, Clearpath Foundation

SESSION 9: Climate Philanthropy: Emerging Opportunities and Partnerships for Change

Moderated by Miranda Ballentine and Rich Powell

This is a special joint session with the Aspen Program on Philanthropy and Social Innovation's Aspen Philanthropy Group.

All sectors – public, private, non-profit, and philanthropic – have a critical role to play in addressing the climate crisis. Given the massive amount of investment necessary and the narrow time window for action, leaders must find ways to prioritize the most impactful investments and to leverage innovation and collaboration to improve the likelihood of success. How can foundations use all their tools-grant making, investments, and policy/advocacy-to drive climate action? What are the opportunities and gaps for climate philanthropy? What existing cross-sector partnerships are working well and why have others failed? What models for cross-sector climate efforts should be expanded?

Discussants:
Tonya Allen, The McKnight Foundation
Doug Arent, National Renewable Energy Laboratory
Randall Kempner, The Aspen Institute
Nancy Lindborg, The David and Lucile Packard Foundation

Optional Trip: White River National Forest - Maroon Bells Scenic Area

No formal dinner is planned for this evening to allow participants to gather in small groups and explore Aspen.

THURSDAY, AUGUST 4, 2022

Breakfast

SESSION 10: Wrap Up – Putting it All Together

Moderated by Rich Powell and Miranda Ballentine

Forum Adjourns

Lunch

A HEARTFELT THANK YOU TO OUR 2022 ASPEN ENERGY WEEK SPONSORS!

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BOUNDLESS ENERGY™
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Meta
Arnold Ventures
CLEARPATH

Constellation.
Blackstone
Energy Income Partners, LLC

INL
Idaho National Laboratory
Walmart
Microsoft

Sandia National Laboratories
NEI
NUCLEAR ENERGY INSTITUTE
DENTONS
Capital Power

BATTELLE
CEBA
Clean Energy Buyers Association
EEI
Edison Electric Institute

NREL
Transforming ENERGY
Van Ness Feldman LLP
TRANE
TECHNOLOGIES
Distributed Sun