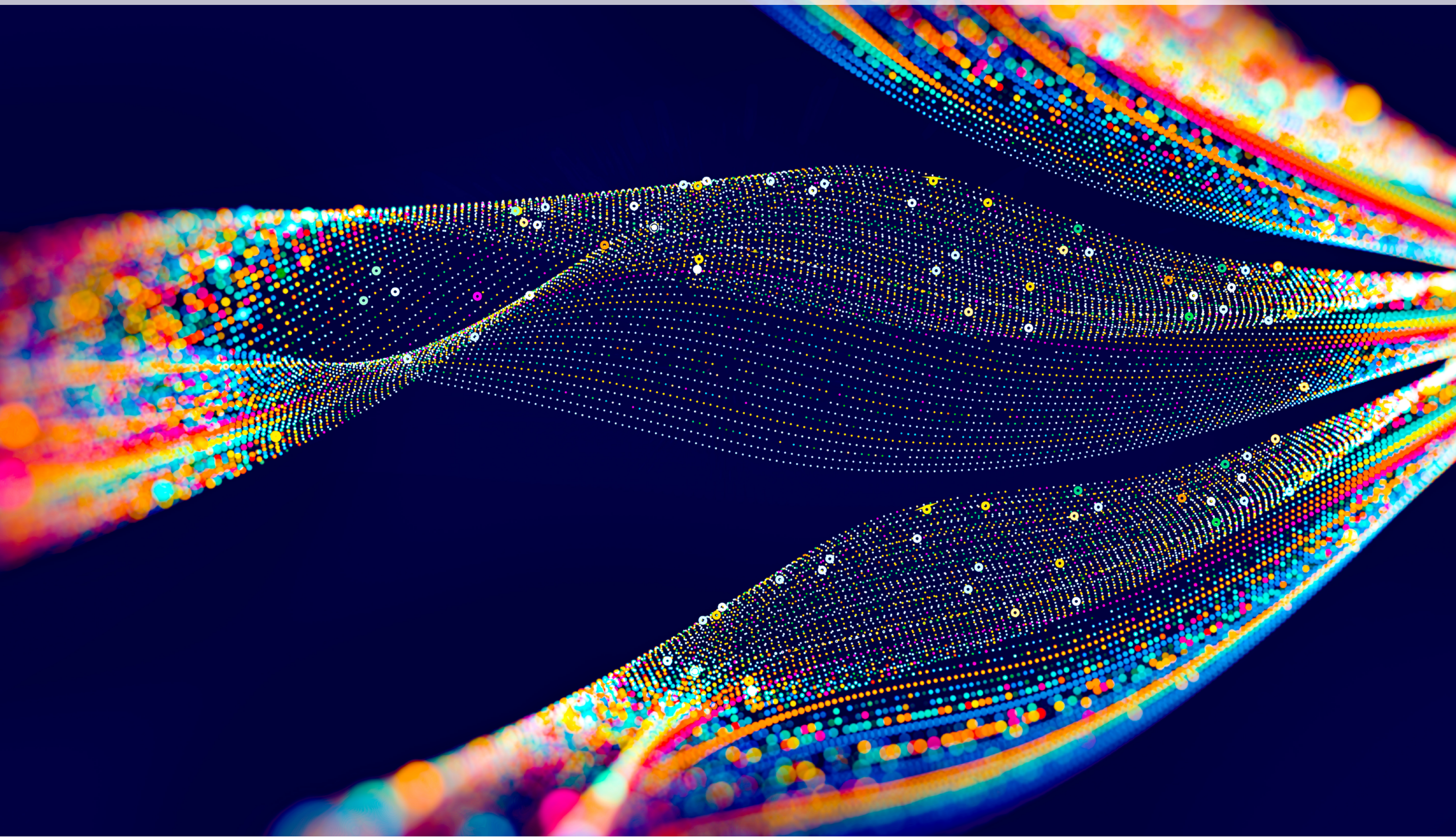
2023 ASPEN ENERGY WEEK



ENERGY TRANSITION & DECARBONIZATION CHALLENGES IN THE UNITED STATES & GLOBALLY

A report from 2023 Aspen Energy Week Forum

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ENERGY & ENVIRONMENT PROGRAM

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Executive Summary

The risks that climate change poses to people, places, and prosperity are increasing, but the global energy transition and decarbonization will be almost inconceivably challenging. Taking climate targets seriously requires an unprecedented level of scale, speed, and transformation. Achieving decarbonization will require making carbon-free technologies cheap and economically competitive, having markets and demand to take up those technologies, having rules and rewards systems that incentivize the right market behavior, having the necessary physical infrastructure in place, and having top-down ambition that ensures widescale action and deployment.

Policy is woven into everything. In the United States, federal laws passed in recent years are investing billions to drive clean energy, clean manufacturing, and climate action. Incentives are going to be the primary U.S. policy driver for clean energy over the next decade. There is a critical complementary role for requirements, regulations, and performance standards, though federal courts are not currently predisposed to provide much latitude to federal regulations. The durability of recent incentives is also in question, and getting as many things built and jobs created (particularly in key districts and states) before the next election could be critical. Longer-term, building broader and more powerful coalitions invested in more aggressive climate action is necessary, but that is made more difficult by the fact that climate action and clean energy are now squarely in the U.S. culture wars. National climate education and marketing campaigns could potentially help reframe the discussion in the United States around the risks of climate change and the opportunities of the clean energy economy, but it is not clear how viable or successful such efforts will be in the current environment. Viewing carbon dioxide as another form of waste to manage could open up more possibilities for support, and there may need to be a massive federal "cleanup" effort to capture emissions and to pull emissions out of the atmosphere.

Infrastructure is critical to achieving a net-zero future. In addition to better utilizing existing infrastructure, a massive scale-up of electricity generation, transmission, and other infrastructure will be necessary, but there are numerous challenges in building new infrastructure at scale. Planning and permitting processes may well be the biggest; it is important to figure out how to clear the way for energy transition projects to happen faster. For transmission, the most effective way to move forward may be to nationalize the system (similar to the interstate highway system), with the federal government designating transmission corridors of national significance, but federal preemption and top-down federal planning may be difficult to achieve politically. Local decision-making is also central to achieving an equitable and just energy system; development must happen with people, not to people. Some planning and permitting delays might be avoided by siting infrastructure in existing rights-of-way, such as interstate highway or railroad corridors, but it is imperative to take social constraints on building transmission lines and other infrastructure much more seriously. There is no way around engaging with communities and people to help them buy into and see themselves as benefitting from the economic opportunities of the energy transition. It is also time to revisit the measuring sticks for evaluating corporate climate ambition and action so corporations can get credit for using their political weight to promote the importance of transmission buildout (as well as for other highly catalytic climate actions).

Development must happen with people, not to people.

Electricity market systems and structures can facilitate clean energy deployment, but the grid must remain reliable and resilient during the energy transition. There are numerous major reliability concerns, including the retirement of traditional generation sources that provide key grid services, disruptions in the natural gas delivery system for electric power, growing levels of demand as more end uses electrify, extreme weather, physical and cyber security, and the lack of redundancy in the grid. There is a need for a single federal-level authority that assesses the risks to the grid and the impacts to national security. There is also an urgent need for Congress to create some sort of natural gas reliability organization to force the interlinked natural gas and electricity sectors to work better together. In addition, while a range of technologies or approaches could deliver reliability and resilience, market forces must do a better job of incentivizing investments in reliability. There is a need to define reliability and resilience standards and to develop market designs that are as tech-neutral as possible, consider resource adequacy across all generation technologies, strike a proper balance of dispatchable and non-dispatchable generation, and take into account location, time, and firm capacity. Markets can be powerful tools to provide reliability at least cost, as well as economic and operational efficiency, optionality, and transparency, and there are real opportunities to design new markets in regions that have not had them, namely the Southeast and the West.

Nuclear energy, a key form of firm capacity that provides huge energy production on a small land footprint, is poised to play a significant role going forward. Existing nuclear stations could extend their licenses for multiple cycles, and new advanced reactors are beginning to secure key contracts and design approvals. There have also been some important federal and state policy supports adopted for both current and advanced reactors. Still, there are significant costs and risks involved in getting new plants through the development and regulatory process; it is imperative to accelerate the learning curve and bring costs down. The Nuclear Regulatory Commission also needs to modernize its analysis and decision-making regarding innovative nuclear technologies. The Commission's risk review for nuclear reactors is extremely conservative (likely more so than Congress intended), and transformative change may require direction from Congress and leadership by the commissioners and staff. In addition, the nuclear industry needs to develop new processes for building nuclear in alignment with a renewed federal focus on environmental justice. Social constraints on building new nuclear can often be mitigated by siting in places with existing facilities that can be expanded or repurposed, including existing nuclear sites and most existing or closed coal plant sites.

Beyond new generation sources, conservation, efficiency, flexible demand, load management, and electrification will all play key roles in decarbonization.

Beyond new generation sources, conservation, efficiency, flexible demand, load management, and electrification will all play key roles in decarbonization. Electrification of end uses (e.g., transportation, buildings) is increasing, though there are challenges related to infrastructure and costs. There is also much more still to be gained from energy efficiency and building envelope improvements, including reduced energy burdens and improved health and resilience in the face of extreme weather events. However, education and engagement of consumers, contractors, dealerships, and others, as well as development of a more diverse workforce and contractor base, are necessary for advancing energy efficiency, demand management, and electrification. In addition, while basic controls and price signals can unlock a lot of load-shifting and demand flexibility, the policy, regulatory, and market rules are lacking to allow the hardware and software necessary for deploying and utilizing these demand-side resources to deliver at scale. In particular, a standard communications protocol and other interoperability protocols and standards are needed to unleash these resources. There are still potential energy efficiency gains in the commercial and industrial sector as well, but energy efficiency projects often do not make the cut in annual budgeting because the corporate dollar is seen as more valuable in other places.

While electrons are very important, the other principal way to carry energy around is through molecules (though, again, systems for the two are deeply intertwined). The biggest overall American energy topic last year may well have been the role played by natural gas in stabilizing Europe following the Russian invasion of Ukraine. However, with its net-zero targets and uncertainty about future demand, Europe has largely been hesitant to sign long-term gas contracts. The United States could help the world by finding contractual arrangements that allow for enough gas infrastructure investment today to meet potential global demand but that have some mechanism in place to accelerate the timelines for retiring or repurposing the facilities. For gas to be part of the climate solution, though, it has to displace coal (not zero-carbon energy), and methane emissions have to be slashed. There has been increasing awareness and aerial and satellite monitoring of methane emissions, and it is long past time to actually solve the methane problem. In addition, because most greenhouse gas emissions from the natural gas value chain are from end-use combustion rather than from emissions upstream or midstream, carbon capture and storage for natural gas combustion is vital to develop.

Decarbonization also requires solving for the mobility landscape, including mobility in the skies. There are innovations being pursued across a range of aviation technologies, including the design of the aircraft itself (e.g., blended wing body technology), propulsion systems (e.g., open fan propulsive systems), and zero-emission engine designs (e.g., hydrogen fuel cells). These innovations would improve aircraft efficiency, and some could provide other benefits such as elimination of high-altitude emissions of combustion artifacts. Public-private partnerships are essential to scaling investment and getting the different technologies up the technology-readiness curve and ready to launch. There will also be a need for further innovation and expansion of technologies that can replace some aviation-miles-traveled, including higher-speed rail and electric unmanned aerial systems and drones. Regulators interacting with innovative aviation companies have shown great interest, but it is challenging to push new models of propulsion and transport for manned aviation through the existing regulatory framework. Globally, most aviation emissions happen outside of domestic borders, which led to the creation of the Carbon Offsetting and Reduction Scheme for International Aviation, which requires airlines to buy carbon credits on the voluntary carbon markets; it needs to be strengthened, but it could help create the right economic environment to drive some of the new technologies. Beyond the planes, airports must also be key areas of focus, both in terms of decarbonizing the airports themselves and enabling the airports to provide low-carbon energy to the new generations of aircraft.

Looking globally, China is the largest current emitter of greenhouse gases, but the relationship between the United States and China has become fraught. These tensions create strong headwinds for the clean energy transition. The Chinese government has invested billions in building the ecosystem around strategic clean energy supply chains. Disruptions to these supply chains are more likely to be inconvenient than catastrophic, but high levels of market dominance create too much market power and too little resilience and diversity. The fragility of U.S. supply chains is a significant political and substantive risk to U.S. climate, energy, and economic goals. The United States must diversify supply chains, which will involve revival of U.S. manufacturing and increased friend-shoring and near-shoring. There are debates about the desirability and efficacy of tariffs and other constraints on China, but there seems to be bipartisan support in Congress for confronting China on a range of issues, even if such an approach leads to higher costs or slower action in tackling climate change. The acceptable levels of cooperation with Chinese enterprises are also not at all clear at the moment. Given the rapid deterioration of U.S.–China relations in recent years, precautions are increasingly being taken to protect U.S. national security, including with respect to sourcing critical infrastructure and limiting the loss of intellectual property. A cooperative partnership with China may no longer be possible, though smaller forms of cooperation and work on common global challenges could still move forward. At this point, some sort of stable competition with China may be more fruitful for producing climate outcomes.

Global tensions and challenges amidst the clean energy transition are an opportunity to remake, rebuild, and reinvigorate the global trading system.

Global tensions and challenges amidst the clean energy transition are an opportunity to remake, rebuild, and reinvigorate the global trading system. Caution and a sense of balance are needed in the near term to avoid locking in protectionist approaches that hinder the export and trade of technologies and services that could help the world decarbonize. At the same time, any type of trading system enabling the clean energy transition must be durable; it cannot come at the expense of precarity in employment and overstretched foreign supply chains. The United States may need to enhance bilateral relationships with countries that can supply critical minerals and metals to meet the needs of the energy transition, although various negotiating realities will make such deals difficult to secure. There are also opportunities for creative tools, such as border carbon adjustments, to leverage market access and incentivize reduced carbon intensity across key sectors. Europe is implementing a price-based mechanism, while proposals in the United States are more performance-based. The opportunities, from the U.S. perspective, are about not just emission reductions but also economics and geopolitics. A border carbon adjustment system has the potential to increase emissions in the importing country (e.g., if it leads to re-shoring of emissions-intensive manufacturing), while its impact on global emissions will depend on whether it spurs countries to reduce carbon intensity or erect barriers against each other that hinder the flow of clean technologies around the world.

Context: The Climate Challenge

Every year except for recessions and the pandemic, use of oil, gas, and coal keeps going up, as do emissions of carbon dioxide (CO2), methane, and other greenhouse gases (GHGs). Atmospheric GHG concentrations continue to grow dramatically. Globally, the summer of 2023 has seen the hottest month on record, the hottest ocean surface temperatures, the least amount of Antarctic sea ice, and other troubling trends. The science is very clear, and the risks to people, places, and prosperity are increasing.

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The economic case for action is strong, with inaction costing the global economy. There is a need for action on multiple fronts, including on reducing emissions, advancing clean energy, and preparing for climate impacts. Political leaders need to get pushed on this from all directions, including from communities, corporations, labor, scientists, and youth.

It is imperative to reduce emissions as much as possible and remove the remaining emissions to stabilize the climate and reduce the worst impacts of climate change. Decarbonizing the U.S. economy will be difficult, and the United States is only a fraction of global emissions. The global energy transition and decarbonization will be almost inconceivably challenging. To take climate targets seriously means achieving a level of scale, speed, and transformation that is completely disjointed from many of the approaches being discussed, whether planning, performance standards, mandates, incentives, or other things. Part of why climate action has been slow is that human suffering is alleviated by affordable, reliable, accessible energy, and currently the most affordable, reliable, and accessible energy for people is often still fossil. Other factors slowing the pace of change include supply chains, pandemic shutdowns, tariffs, concerns about Asian dominance, and the interconnection process. All of these have held up real projects and prevented the retirement of some old, dirty generation. However, if the transition is actually going to be slower and longer, that means climate targets will be missed, and it remains to be seen if people will accept that as the impacts of climate change increase.

Achieving decarbonization will require making carbon-free technologies cheap and economically competitive, having markets and demand to take up those technologies, having rules and rewards systems that incentivize the right market behavior, having the necessary physical infrastructure in place, and having top-down ambition that ensures widescale action and deployment. There is reason for tempered optimism. Private investment is spending big on clean energy and clean transportation. Indeed, there was over $1 trillion in global clean energy investment in 2022, with almost all clean energy sectors hitting investment records (except nuclear, where more investments will be coming in later years), though the investment has not been at all geographically diverse. Public policy has begun to show up too, including the landmark Inflation Reduction Act (IRA) in the United States, which modeling suggests could help the United States achieve 40% reductions in emissions by 2030 (which is radical progress but still not on track for net-zero). Global climate negotiations, however, have not yet delivered a global commitment to phase out unmitigated fossil fuels, and only a few U.S. states have increased their clean and/or renewable energy standards. Several countries and automakers have committed to phasing out the internal combustion engine in vehicles. Net-zero is the aim of the Paris Agreement, the goal of the United States, and the target for many Fortune500 companies.

The targets are only achievable if there is marked progress by 2030 in key energy end-uses that are critical to economy-wide decarbonization. The power sector is the linchpin to economy-wide decarbonization, though progress is needed in many other end-use sectors as well.

Climate Policy

Policy is woven into everything, and it has been an extraordinary year or two for clean energy and climate policy. The durability of that policy, however, is unclear, even as there is still more that policy must do in the future.

Carrots & Sticks

With the recent suite of federal policies — including the IRA, the Infrastructure Investment and Jobs Act (IIJA), and the CHIPS and Science Act — there are billions of new dollars for climate and clean energy. The IRA, in particular, introduced a major new policy regime to drive clean energy and clean manufacturing, including hundreds of billions of dollars in new investments.

Incentives are going to be the primary U.S. policy driver for clean energy over the next decade. Going back to the bipartisan Energy Act of 2020, Congress in recent years has provided important investment and funding across the technology spectrum. The IRA adopted numerous tax credits to accelerate investment in new clean energy technologies, rapid deployment of existing commercial technologies, and a resurgence in domestic manufacturing. For the first time, there are 10 or more years of tax certainty for clean energy technologies, and the investment and production tax credits will become tech-neutral in 2025. Tax incentives to help build the industries of the future include credits for hydrogen and sustainable aviation fuels. Billions in funding are going to the Department of Energy (DOE) and elsewhere in the federal government for early-stage efforts, from research through demonstration, as well as to help build up domestic manufacturing and supply chains.

Incentives for clean energy are helpful and get money flowing, but "carrots" alone are not capable of achieving an energy transition at the necessary speed and scale. Incentives are good at driving the addition of new clean energy, but they are not as good at driving the rapid subtraction of big existing emitting infrastructure; clean energy incentives will not, for instance, produce timely retirements of unabated coal. In addition, at the huge scale of deployment anticipated, subsidies will eventually get really expensive. Regulations, standards, and other "sticks" are also needed.

Recent federal policies have not provided many sticks, but there is a critical complementary role for the regulatory state.

Recent federal policies have not provided many sticks, but there is a critical complementary role for the regulatory state. It is appropriate for the federal government to adopt regulations that drive investment to address barriers to national interests, including ones focused on industries that would not take action on their own due to collective action challenges and other market failures. As a matter of politics and coalition building, an emissions cap of some kind could help mitigate conflicts between industrial and climate policy, and a carbon price could help generate revenues to pay for subsidies. Perhaps more feasibly, performance standards could be constructed in ways that are flexible and market-based, with price incentives on their edges (whether positive like tax credits or negative like carbon prices). Performance standards can also be straightforward, such as the series of appliance efficiency standards that DOE has been issuing. At the state level, the current direction in performance standards seems to be more sector-based than economy-wide, as can be seen with policies such as clean energy standards in the power sector or low-carbon fuel standards in the transportation sector. Regulations are also needed to ensure the necessary enabling infrastructure is in place and to provide the rules of the road that make that infrastructure workable.

There is not truly a dichotomy between incentives and standards. Incentives enable more ambitious future standards, including by spurring cost declines in technologies and thus making the economics of switching easier. Incentives can also grow nascent industries, creating benefits for communities and companies and therefore cultivating powerful interest groups that have at least a chance of overcoming future political opposition to more aggressive climate regulations, standards, and other action. Incentives also often include guardrails and standards (e.g., requirements in tax credits). In addition, regulations can drive demand in the very industries that other policies are incentivizing. For example, DOE has billions to stand up hydrogen hubs, and there is also a huge amount in the 45V tax credit, but without sustained long-term demand-pull for hydrogen, it is not clear that those investments will ultimately bear fruit. This happened in the past with synfuels, where significant federal investments helped meet technical requirements but without market uptake. Regulation, such as the proposed regulations for power plants from the Environmental Protection Agency (EPA), can provide that demand-pull for hydrogen, which can in turn drive private investment. Likewise, there is a large underlying set of rules, expectations, greenhouse gas accounting standards, and other things in the market that very much dictate whether companies pursue carrots or not.

Incentives, mandates, and other mechanisms all dovetail and make it almost impossible to split out what each adds on its own. There have, however, been studies of the interplay of different drivers of clean energy action that have attempted to parse out how much clean energy deployment is due to each particular factor. Looking back to 2000, such studies have found that about half of current wind and solar deployment is due to state-level mandates (e.g., clean energy standards). Other studies have found that, looking back to 2014, about 40% of wind, solar, and storage deployed at utility scale in the United States is due to voluntary corporate procurement. Prior to five or six years ago, the vast majority was probably due to mandates, but that share has declined in recent years as changing costs have spurred more voluntary private procurement. Still, all the mechanisms fit together. State mandates probably would not have been as successful without tax credits, and neither would voluntary private procurement.

Both incentives and complementary regulations are needed, but the federal courts are not currently predisposed to provide latitude to federal regulations. Federal appellate courts are cycling toward a more hard-look era of scrutiny on federal regulations. There is also a new "major questions" doctrine being used by the Supreme Court, which was applied in an aggressive way in *West Virginia v. EPA* to restrict the EPA's ability to regulate greenhouse gases. There are now six justices with virtually unchecked power to determine on any legal question whether Congress has not been precise enough in setting forth agency authority. Some feel the Supreme Court is also likely to eliminate Chevron deference, and some suggest the *Massachusetts v. EPA* decision from 2007 (which found that the EPA can regulate greenhouse gas emissions) could be overturned given the new slate of justices and the new "major questions" doctrine. (The IRA's explicit listing of GHGs under the Clean Air Act might not ameliorate the risk of reversal.) In considering what "stick" policies to pursue, it is imperative to be cognizant of this reality. Ambition will have to be carefully calibrated to legal resilience, and policies may have to be crafted to reach for less in order to survive. Congress will also have to meet its new obligation of precision, which will be difficult.

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These realities may shift greater attention to technological innovation, incentives, and state-based solutions. The recent federal policies provide significant momentum, but more will be needed. Continued increases in innovation funding are necessary, including to address industrial emissions, agricultural emissions, and carbon removal. (The industrial sector is roughly the same size as the electricity sector in terms of emissions, but the amount of money targeted to the industrial sector in the recent federal bills pales in comparison to the amounts for electricity and transportation.) More demand-pull tools will also be needed to accelerate innovation.

Political Durability & Public Awareness

The IRA will have a material impact in changing the U.S. climate response. Projections of what will be accomplished under the IRA, however, do not matter; all that matters is what is actually done. With the American Recovery and Reinvestment Act of 2009, which aimed to spur shovel-ready projects, a relatively small portion of the allocated money ever got spent. The goal should be to avoid that outcome this time. The durability of the incentives in the IRA, however, is in question.

The IRA process was not bipartisan, and even though some Republican members of Congress may support specific policies within it, they have been politically opposed to the IRA. If control of the White House and Congress flips to Republicans, some of the IRA incentives could be pulled apart. A lot of the IRA funding, though, has gone to Republican states and districts. Dozens of new domestic manufacturing projects have been announced (including many solar supply chain manufacturing projects), and most of those projects are in districts represented by Republicans. There is a difference, however, between an announcement and a job, and getting as many things built and jobs created before the next election could be critical to the durability of the IRA incentives. The range of project headwinds (e.g., the interconnection queue, permitting, transmission) could make that timeline challenging, but there are ongoing efforts to publicize the investments that have already been made and that are in process around the country. Strong voices from all quarters need to tell political leadership that full implementation of the IRA is important.

Longer-term, continued support for ambitious climate action depends on positive feedback loops and people experiencing positive effects of current efforts. Siting of clean energy projects in Republican districts may spread support for the clean energy transition, but support has to translate to votes. Making sure clean energy jobs are good-paying jobs with union representation can help produce the votes and expand the constituency in favor of the clean energy transition, which will be needed to persevere through the price shocks and other troubles the transition will inevitably encounter. Labor has been consistent over the past decade about its perspective on the energy transition: it does not want to see solid, high-paying jobs traded out for lower-paying precarious employment, and it does not want pensions and health care to fall apart. Labor has been pushing this for years, whether in terms of labor and wage standards in energy tax credits (which finally happened in the IRA) or good engagement and community and labor agreements in individual projects. There are rapidly expanding climate and labor coalitions in many states and nationally.

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Climate clearly is not as consensus an issue for Republicans as for Democrats, but there has still been some action. House Republicans' HR1 had provisions on permitting reform (including for clean energy), and the climate subcommittee has been maintained. A conservative Republican senator introduced a plan to have the United States set a goal related to how much GHG abatement globally the United States can claim responsibility for (through a combination of domestic actions and exporting U.S. technologies and services), as opposed to how many emission reductions it can achieve domestically. There have also been some areas of bipartisanship. The Energy Act of 2020, for instance, was robustly bipartisan and, among other things, included significant new regulations phasing out hydrofluorocarbons, in part because things had reached a point where there were economical, cost-effective replacements for them. There is also strong bipartisan consensus that advanced nuclear technologies are an essential part of the solution both domestically and abroad. There is a lot of disagreement in Congress about how to achieve emission reductions, but there is, for the most part, consensus that there should be reductions.

Policymakers, however, have mostly shown a fundamental inability to conceptualize the speed and scale of the climate challenge. They have been freighting the already nearly impossible climate challenge with lots of other important social ambitions, some of which are in tension with achieving speed and scale. There has been a desire to say everything can be done simultaneously, but there are often tradeoffs. Inappropriate expectations have also been created that the transition will be easy for some and good for most, even though the transition is likely to be quite hard (though worthwhile). Failure to be honest about the difficulty of the transition risks not having the political capital needed to do hard things.

While the IRA and the other recent bills are important, managing the risks of climate change will be a multi-decadal effort, which means it will be essential to transform the politics of climate change. Most people do not care much about the climate, and even those who do care are fracturing within coalitions, with fights over various technologies, environmental justice, labor, permitting reform, or other matters. Part of the reason why legislative carrots have moved before legislative sticks is because the addition of energy sources is politically easier than subtraction; the work will only get harder over the next decade, as more people realize the transition is about subtraction as well as addition. Building broader and more powerful coalitions invested in more aggressive climate action over time is a necessary (but not sufficient) condition for achieving net-zero.

Building broader and more powerful coalitions invested in more aggressive climate action over time is a necessary (but not sufficient) condition for achieving net-zero.

That is made more difficult by the fact that climate and clean energy are now squarely in the U.S. culture wars, with active and growing opposition to clean energy and backlash to climate action. There are elements (e.g., good blue-collar jobs, clean air and water, U.S. energy security) that theoretically remain outside of the culture war, providing opportunities for opposing sides to collaborate, and local conservative politicians can be very supportive of climate-related initiatives if met where they are and talked to about what is important to them. Even for those benefits and co-benefits of climate initiatives and projects, however, many audiences may have starkly different views of how to achieve them. The larger issues are very much in the culture war. In recent polls, a huge majority of Democrats see climate as a major threat, and half of independents do, but the vast majority of Republicans do not. Several states representing tens of millions of people declined funding from the IRA, which will hurt those states from a decarbonization perspective. Deep red states are also blocking carbon pipelines needed for carbon capture, utilization, and storage (CCUS). More than technical expertise is needed to address the culture war underway on climate change; social science expertise is needed.

Overcoming the culture war around climate and clean energy could require efforts to make sure people have the same basic education and understanding of the issues, but it is not clear that is possible in the current environment. Ideally, though, such education represents an opportunity to bring more Americans into the fold, including both marginalized communities that have not participated in the clean energy workforce at scale and workers in fossil fuel industries. The summer of floods, fires, and extreme heat seems to have changed some attitudes on the need for action, but many people do not yet necessarily tie the impacts back to climate change. Some experts wonder whether more time, attention, and funding need to be directed to adapting to the impacts of climate change — and whether focusing more on adaptation might make the impacts of climate change more real for people.

Climate advocates sometimes portray the effort to tackle climate change as an urgent war, but most people do not see it that way. Climate change is a chronic, long-term problem, and people do not see it as analogous to World War II (or World War III). Many people just think climate advocates are alarmists yelling fire in a crowded room. While few think of the climate challenge as war today, in a decade or two, with more severe and damaging climate impacts (especially in the poorest parts of the world), social mobilization could be gradual and then move all at once. Things may get to the point where achieving speed and scale actually requires something akin to war mobilization. At the moment, however, the education, awareness, and trust levels are not there to mobilize like war.

There is a need to figure out how to reframe the discussion in the United States around the risks of climate change and the opportunities of the clean energy economy. Some argue that a national marketing campaign is needed to help the transition resonate with the public, including the health, economic, and security benefits. Solving problems requires broad support, and getting people on the same page requires a shared outcome goal. There is a need to design a message that people can get behind, otherwise the partisan and culture war battles will continue, and regulations and other efforts are at risk of being reversed by a new presidential administration or stopped in the courts using the Supreme Court's new "major questions" doctrine. It is worth being cautious, however, about pursuing big national marketing campaigns. People always think their particular initiative or cause would be more successful "if only people understood", but marketing works much better for products than ideas. The United States tends to do a bad job of using marketing to debunk myths and disinformation.

Still, climate education at scale is needed in the United States to have legions of Americans prepared to combat climate change. There is a need to educate young people and incentivize them to get involved. Many schools — middle schools, high schools, colleges, trade schools, and more — have minimal education on climate change, and there are many other issue areas and job opportunities that students can pursue. There is a need to train and seed future leaders. Some clean energy companies are providing students with high-paying internships and school scholarships if they will be ambassadors for action back on campus. For students looking at climate-related careers, reducing or eliminating the cost of college could be a powerful incentive.

Improvements in public education generally are needed as well. During the Obama Administration, the Recovery Act had lots of money in workforce development programs, but many people in disadvantaged communities did not qualify for the programs because the high school education they had did not allow them to pass basic math tests. Today, following the worst of the pandemic, many fourth graders do not read at grade level. There is a need to think about how to finance public education and to better engage school systems. Clean energy jobs, if they are going to be good jobs, require a better baseline education than students, especially those in disadvantaged communities, are getting today.

A New Form of Federal Cleanup

Thinking of CO2 as another form of waste to manage could open up more possibilities for support. A key lever in decarbonization is the ability to pull emissions back out of the atmosphere. All taxpayers are still spending billions a year to clean up the legacy of the Manhattan Project, and billions more are spent on Superfund and on EPA waste cleanups. Cleaning up the atmosphere is too expensive right now, but it will get cheaper. Eventually, there may need to be a massive federal cleanup effort, akin to other cleanup efforts.

There are already solid waste and liquid waste management industries, which could provide models and lessons for a carbon gaseous waste management industry. Both solid and liquid waste management are substantial industries with tens of billions of dollars in annual revenue and lots of employees in well-paying, safe, stable jobs. The solid and liquid waste management industries are considered economically beneficial because of the avoided costs of pollution, better health outcomes, and other benefits (e.g., higher home values when there are not piles of trash on the streets).

One lesson from the solid waste industry is to reduce the flows of waste that must be addressed; for example, it is cheaper to remove trash from the streets than to treat the pollution once it is in the water. Another lesson is to utilize whatever can be utilized, such as by recycling solids into something new, and then to landfill whatever cannot be reduced or utilized. The same will be true for gaseous waste: reduce flows, use what can be used, and sequester the rest. Picking up trash on the street rather than out of the water is akin to point-source carbon capture, preventing CO2 from getting into the atmosphere, though efforts are also needed to remove CO2 from the atmosphere (just as there are to remove trash from the water). If U.S. emissions can be brought down to 1-2 billion tons per year, and if the prices for CO2 atmospheric removals continue dropping to reach around $50-100 per ton, that would suggest a gaseous waste management industry of roughly similar size as the current solid and liquid waste management industries. That is affordable and achievable. Like residential waste management now, it could be paid for via tax bills and utilities, or like industrial waste management, it could involve industry members paying the waste management system to address it.

Federal policy will continue to play a vital role in this area. A decade ago, the federal government put a bunch of money into CCUS projects but without any long-term structure for incentivizing the activity or regulating greenhouse gases. The 45Q tax credit is now highly incentivizing to businesses to pursue deployment of carbon capture technologies, helping to make CCUS technologies economically feasible and profitable, but 45Q ends in 10 years. Without additional policies and incentives, there is a risk of the same outcome as a decade ago — limited deployment and lots of stranded assets. DOE has started doing pilots on CO2 removals, which will help kickstart the industry and help set standards for what counts as removals. Although the DOE procurement program for carbon dioxide removal is still at the beginning stages, it has been included in the normal appropriations process this year in the Senate. The federal government buying removals at scale is not a given, however, which may leave voluntary carbon markets as the only way to drive removals.

Building Transmission & Other Infrastructure

To achieve a net-zero future, the grid likely needs to grow significantly, which means much more generation and transmission will be necessary, as well as other infrastructure (e.g., for hydrogen or captured CO2). Infrastructure modernization is critical — not just for physical infrastructure, but also for digital and social infrastructure — but building infrastructure in the United States is a lengthy, difficult endeavor.

Infrastructure Needs & Challenges

Models of the IRA's impact or of decarbonization pathways include huge build-outs of clean energy infrastructure over the next decade. For instance, the power sector must dramatically change the way electricity is produced to meet the U.S. goal of 100% clean electricity by 2035 and 80% by 2030, with the pace of renewable energy buildout ramping up considerably over the next decade — on the order of 60-100 gigawatts of new capacity per year. Modeling of deeply decarbonized systems also shows a need both to retain and expand firm capacity in the system. In addition, carbon management infrastructure needs to scale up dramatically. There will be a need for a lot of pipes to move captured CO2 and a lot of storage to sequester it. There are currently about 5,000 miles of carbon pipeline in the country, and somewhere around 30,000 – 96,000 miles are probably needed by 2050, in addition to hundreds of carbon storage sites (of which there are only 4 now). No matter what the models say and what the financial incentives are, however, there are numerous challenges involved in actually building that infrastructure.

Clean power is finally starting to achieve scale, and the industry is encountering challenges like other big industries do, such as supply chain and labor constraints. Clean energy infrastructure also faces some relatively unique challenges. One, for instance, is interconnection. There are terawatts of clean generation in interconnection queues across the country, but that capacity takes an average of 3.5 years to get through the queue (except in Texas), and only about 20% ever actually gets done. At that success rate, five times more clean energy needs to be in the queues than will actually be needed. Interconnection queue reform is vital. In addition, although community distributed generation improves the distribution grid for everyone and benefits utilities, there are laws across the country that require infrastructure investors to pay for upgrades to the grid; those laws should require incumbents to pay for their grid. (There are also laws that limit community distributed generation to low caps, which increases the unit costs to disadvantaged communities seeking access to renewable power.)

Across different scenarios, somewhere between a 50% and 250% increase in electricity generation is projected to occur globally between now and 2050, depending on the scenario and the degree of climate action.)

The United States is woefully off-track in expanding the grid and transmission to achieve a fully net-zero economy. Some of the needed transmission buildout is business-as-usual expansion, attributable to things like normal changes in population centers, turnover of energy sources, the rapid scale-up of datacenters and artificial intelligence (AI), and the increased value of reliability. The dynamics of what the physical system needs to be able to accomplish are also changing; until the early- to mid-1990s, the entire transmission system was built based on point-to-point (i.e., from where the generation is to where the people are), but system restructuring and changes to the Federal Power Act created a new market for competitive generation that could go anywhere. The majority of the needed transmission buildout, however, is due to the rapid electricity load growth expected from the decarbonization push, including from the electrification of transportation and other sectors, reshoring of clean manufacturing, and the transition of the energy system to be more reliant on energy sources (e.g., wind, solar) that have lower energy densities. (The electrification of the economy is occurring globally, not just in the United States; across different scenarios, somewhere between a 50% and 250% increase in electricity generation is projected to occur globally between now and 2050, depending on the scenario and the degree of climate action.)

DOE estimates that the transmission system will need to grow by more than half by 2035 to hit the levels of growth projected from the IRA. That would be roughly a 5% growth rate every year. The second half of the 20th century saw about a 2% annual growth rate, and it has been closer to 1% over the last few years. Radical thinking is needed about how to build generation and transmission faster, including thinking about how to be creative with the bipartisan backstop authority that the Federal Energy Regulatory Commission (FERC) received, what FERC's appropriate role is, how to implement FERC's new interconnection rulemaking, and how to go beyond that rulemaking. For CO2 pipelines, there will probably have to be a lot more state primacy to get projects moving.

Policy can help drive the transmission buildout. The IRA provides incentives to build non-carbon power, but attempts to get a transmission tax credit into the IRA were unsuccessful. (There is therefore a risk of vastly over-producing clean power in places where it cannot be transmitted, but it is possible that electrolyzers could use the excess cheap clean electricity to produce green hydrogen that can be transported elsewhere.) Members of Congress in both parties have begun to recognize the central role that transmission plays in a secure, resilient, reliable grid, but there is some resistance to paying for it, even though federal spending on a significant interstate transmission system may be well worth it (especially since local communities do not want lots of expensive transmission put into their rate base). Building more transmission, especially longer-distance high-voltage direct current lines, should be something people agree on, whether their priorities are reliability, resilience, cost, decarbonization, local environmental and health impacts, conservation, biodiversity, environmental justice, good jobs, or something else. Transmission is not just about electricity; it is about human welfare broadly.

Still, massive grid expansion and transmission buildout will be incredibly difficult, even just from a materials perspective. A large increase in transmission could require hundreds of thousands of new transmission towers by 2030. Those towers are made with aluminum, copper, and steel, just like electric vehicles (EVs), EV charging stations, wind turbines, and lots of other things in the transition. That will be a huge challenge in terms of manufacturing and sourcing. Transmission is as reliant on the metals and minerals supply chains as batteries but never seems to be part of the conversation in the same way. (The increased manufacturing needed for transmission buildout also underscores the need for industrial CCUS.)

It is important to be prepared for massive transmission expansion efforts to fail. Plans should be considered for how to decarbonize the economy if it turns out that less transmission is built. There is not uniformity among major modeling efforts about whether this would mean a more or less expensive path to decarbonization. National lab modeling has shown that it is possible to get to net-zero with a more constrained transmission buildout but with a very different configuration and a higher cost structure than under an ideal transmission buildout scenario. Other modeling efforts have shown a renewable- and transmission-constrained scenario, which relies more heavily on energy-dense sources and pipelines and less on transmission, as being the cheapest of the decarbonization scenarios on a systems basis. Transmission expansion is a good thing to have and a provider of reliability and redundancy, but it is not the only option.

Beyond expansion, there is a need to think about how to better utilize existing infrastructure, including getting more capacity from existing lines. There is a lot more than can be gotten out of the current transmission system. The majority of lines that exist today will need to be rebuilt anyway, and advanced transmission technologies, dynamic line ratings, new conductors, and other innovations can help get more electricity through the current system. Existing transmission is also underutilized in many respects. There are utilities that have used AI and machine learning to identify locations on their grid that are overloaded and where there is greater risk of failures and outages; such analyses have revealed that while a small portion of the grid was at significant risk, the vast majority of their network was seriously overbuilt to meet reliability criteria, and a small portion of the system was utilized at minimal levels. These kind of analyses can help direct people to connect to underutilized parts of the network, creating huge benefits (and getting ratepayer losses back). Technology for such analyses is available to every utility in the world, but it is being used far too rarely in the

United States. In addition, in the near term, progress could also be achieved by linking grids together, and there is an idea (yet to be fully matured) around minimum interregional transfer capacity.

Planning, Permitting, & Preemption

There seems to be consensus that more transmission and other infrastructure must be built a lot faster, and that kind of huge, rapid buildout has historical precedent. Most of the rural electrification system got built in about 15 years, and that is also true for the interstate highway system. Almost all the historical precedents, however, occurred before the modern permitting era. Current systems for planning, permitting, and paying are woefully insufficient.

Planning and permitting processes may well be the biggest problem in infrastructure. For example, planning and environmental reviews mean long lead times for transmission projects, and it takes years before a single line worker is in the field to actually build transmission lines. It is important to figure out how to clear the way for energy transition projects to happen. The dysfunction has to be removed from the big infrastructure process, without disregarding the environment, such as by doing faster, shorter environmental impact statements. Climate and energy goals will not be achieved if every project takes 5-10 years to get through the process and built. It is imperative to figure out how to get things built in 2 years — to make 2 the new 10.

The challenge of building the reliable, affordable, sustainable grid of the future could be thought of as a tragedy of the parochial regulator. Transmission, for instance, is a private asset with broad national public interests that is owned and operated by utilities mostly regulated at the state and local levels. Unsurprisingly, the system is therefore underbuilt in terms of serving the broader public interest. Even the creation of independent system operators (ISOs) and regional transmission organizations (RTOs), while couched in binding regions together more broadly, is still mostly about optimization, and ISOs and RTOs should not be counted on to solve the problem of transmission expansion without new policy directives.

RTOs and ISOs can do some of the planning for transmission, but there is a strong need for better institutions to provide the national interest direction to guide planning for the deployment of transmission and clean energy technologies. With the range of technologies and the economy-wide efforts needed for decarbonization, there is a need for more multi-sector planning, but there are not obvious regulatory agencies or other bodies with the ability or authority to do such planning.

If the political will can be found (which is far from a certainty), policy would be the most efficient path to address transmission. The most effective way to move forward may be to nationalize the transmission system, with obligations put on states to expand in line with the national interest corridor framework. To the extent states do not move forward, they would lose oversight. This is similar to what happened with the interstate highway system, which was built on the premise of national defense, as well as for the economy and human welfare. The federal government should issue regular reports on transmission corridors of national significance. There is no other way to get everyone to agree. Every governor knows they need transmission, and every governor will say they have to be opposed to it politically. The Interstate Commerce Clause is in the Constitution expressly to give the federal government oversight of interstate commerce. Designation of corridors of national interest for transmission have not happened, however, because DOE got sued and lost last time it issued corridors (because the appellate court decided DOE needed to do a National Environmental Policy Act [NEPA] review for the designation of corridors, even though designation itself is not an action that allows anything to be built). Requiring NEPA review for the corridor designation and then another round of NEPA review during siting to get the permit from FERC is a tough ask, especially with each review taking years. The federal government is trying to figure out how to address that issue, including coordinated action between DOE and FERC so the process only has to happen once and, perhaps, a different corridor process that may engender less opposition.

The most effective way to move forward may be to nationalize the transmission system.

Some argue it may be worth pursuing a blend of the interstate highway system model and the Base Realignment and Closure (BRAC) model for transmission. With respect to BRAC, the Secretary of Defense identified which bases would close, the list went to a commission that took public comment and made appropriate tweaks, and then it went back to the Secretary, who sent it to Congress. Congress, knowing how politically challenging base closure is, set it up so it only had 60 days to do a resolution of disapproval before the plan went into effect. There were three rounds that were so successful that they did not do a fourth. For transmission, it is already known with a reasonable level of assurance what the first set of national corridors looks like; the first round will be mostly correct, and a second round can fix any problems. Settling where the corridors are is the only way to get people to organize to make it work. On the other hand, it is rare for anyone to use BRAC as an example of the right way to do things because it has not been possible to close another base since. In addition, while the interstate highway system could provide a lot of lessons for transmission buildout, it also manifested and cemented a lot of horrifying racial inequality, so it will be important to be careful about conveying the ways that transmission buildout can and should be done differently.

Short of nationalizing transmission, or perhaps in addition, a national tax on grid reliability and sustainability could be useful. Different from a carbon tax, this would fully value the benefits of transmission to national defense and economic interests. The tax should apply regardless of how much anyone individually is directly connected to the grid, while accounting for ability to pay; the current transmission cost allocation process is a huge free-rider problem, where efforts are focused on externalizing costs. A national grid reliability tax should recognize that everyone benefits pretty equally from a robust transmission system, just as everyone benefits from a robust military that protects the country. Even people who live off-grid benefit from all the products and services that are still being produced and delivered by entities that depend on a reliable, affordable, sustainable grid.

Politically, however, both nationalization of transmission and a national tax will be very difficult to achieve. For example, a fatal problem with transmission development, even in corridors, is eminent domain. There are few things worse in politics than exercising eminent domain. Eminent domain is where transmission projects die. More broadly, U.S. federalism is premised on distrusting centralized authority and retaining local authority, which makes sense for human dignity but is challenging for building things at speed and scale. Inaction and inertia are built into the U.S. system of government, with the federalist division of powers and the numerous veto points; speed and scale do not lend themselves to decentralized decision-making. It is worth considering the appropriate role for local decision-making in addressing the energy transition and the decarbonization challenge.

There are two main ideas underlying federal preemption. First, the federal government is not a plenary government. Rather than plenary powers, it only has the powers enumerated in the Constitution. Second, the Constitution contains the Supremacy Clause, which says that when the federal government acts in a way that excludes state regulation, the federal government action has supremacy. There are three basic ways state action can be preempted: (1) explicit preemption, where a federal statute explicitly says it preempts state action; (2) implied preemption, where a state action would conflict with or inhibit enacting a federal initiative or rule; and (3) field preemption, which is a little squishier, but occurs where the federal government has legislated in such a way that there really is no room left for state regulation. In addition, states are assumed to have no regulatory authority on tribal land and so are preempted from taking action on it unless the federal government allows it.

Federal preemption and top-down federal planning collide with Americans' fundamental embrace of the importance and power of community, but the United States does not really have much community-based decision-making about national security, health care, or national economic policy. There is also precedent in energy for preemption; part of the reason the Berkeley ban on natural gas hookups got stopped was because of express preemption in the 1975 Energy Policy Act, which was adopted during an energy crisis, when it was undesirable for states and localities to dictate what fuels to use. Similarly, the natural gas pipeline system is federally permitted. In the bipartisan infrastructure bill, Congress revitalized authority in DOE and FERC to use preemption for certain transmission lines that are in the national interest.

In public polls, however, there is widespread distrust in democratic institutions, and these institutions may not have credibility with the public to assert top-down authorities. If promised outcomes continue to fail to materialize because they are tied up in processes (e.g., permitting), that further undermines trust in institutions. The COVID experience also exacerbated the trust challenges facing institutions. Much of the country now trusts government less, and many did not listen to any of the guidance issued by the government. It is imperative to learn lessons from what happened with COVID. Furthermore, the nature of the U.S. federalist system means that states are sovereign and that local people and communities have the right to prevent projects and industries in their neighborhoods. It is possible things could be nudged, but changing the U.S. federalist system is hard.

There is a need to build social infrastructure and engage communities. Social scientists should play a bigger role — and should be supported by governments and developers to engage early with communities to guide projects, figure out deployments that will work, and build public support. Local decision-making is central to achieving an equitable and just energy system. The people experiencing the potential impacts have to be part of the conversation. Communities that have long dealt with broken promises cannot have their voices erased. Development must happen with people, not to people. People often have nowhere else to work, and their families work in some of these places. Apathy, disgust with broken promises, and fear of speaking up should not be mistaken for partnership, community engagement, and agreement.

Local decision-making is central to achieving an equitable and just energy system.

It is possible to get around some of the eminent domain and community engagement issues in permitting and siting by using the interstate highway rights-of-way, including for solar, distribution, and transmission. Permitting reform is already included in right-of-way project development, with embedded categorical exclusions for permitting requirements and environmental reviews. The federal government has also issued guidance placing energy and transportation as equals for projects in rights-of-way. Some state departments of transportation (DOTs) have been pioneering efforts to do this, bridging the increasingly intersecting energy and transportation worlds. For example, some DOTs, such as in Wisconsin, have built transmission in their rights-of-way within the past few years, and the Wisconsin Public Service Commission and DOT meet regularly to discuss projects of mutual interest; that can be a model of good behavior for all states. While using the existing rights-of-way can be an expedited permitting strategy for developing new transmission, it is not happening yet because most state DOTs are not very far along in this conversation, and efforts are needed to help them catch up. Bringing in state DOTs from multiple jurisdictions also gets messy. Another option to consider is looking at railroad corridors, which go everywhere; the railroads own the land (so there is a single property owner), there is no intervening state-by-state regulatory authority, and there is no need for eminent domain.

NIMBY & YIMBY

Lots of stakeholders, including policymakers, industry, and communities, are involved in thinking about building transmission lines and other infrastructure. There are social constraints on all sorts of energy development, and the friction is slowing projects down. It is imperative to take social constraints on the decarbonization challenge much more seriously.

There is a need to try to transform not-in-my-back-yard (NIMBY) culture into something where communities are excited to have clean energy (i.e., yes in my back yard, or YIMBY). There is a lot of NIMBYism; people do not want transmission lines or clean energy infrastructure in their communities. Modeling may show there is enough land for various energy sources, but strong local opposition to large-scale projects is growing, whether because of land use requirements or other concerns. For instance, there has been an onslaught of moratoria and setback requirements in Iowa that is restricting the available land for new wind. Recent studies have found that the total number of wind energy ordinances at the county level increased six-fold over the last four years, and if the median ordinances were extrapolated across the country, it would reduce the total amount of wind energy potential in the United States by almost three-quarters. The issue is getting

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worse, and the number of communities passing ordinances limiting the growth of renewable energy is increasing. The opposition to infrastructure is broader than just renewables, but because solar and wind are so land-intensive, there are a lot more people affected, more people whose consent is needed, and more likelihood of opposition movements. A scenario with lots of renewables also requires lots of transmission, and transmission lines, because they cross so many jurisdictions, are even harder to get built. There will be a lot of places where communities feel they have reached a saturation point with any type of energy development. There is a need to be thoughtful about where different types of energy infrastructure should go and to have very early engagement with communities.

There is a key question of whose consent has to be sought and obtained for projects to move forward. Objections to energy infrastructure siting often are not from the community but rather from the larger circle of interests. For instance, there are many times that transmission planning meets resistance from people not along the transmission routes and with no property impacted by a proposed line. Likewise, even in places where landowners have realized that they can get more income more easily by having a solar array in one field than by farming it, the surrounding communities that value the natural setting and way of life are opposing the solar arrays. These are often the loudest voices of opposition, and it only takes one person or organization to object to a permit. Even if the vast majority of the community is supportive of a project, one objection can lead to a decade of uncertainty for a project.

The weakest link will stop a project, whether that is a denied permit, a lawsuit, or something else. The bigger and more expensive a project is, the easier it is to say no to it and the more time and money it takes to get it approved. Hundreds of billions of dollars of investment opportunities could fail because of permitting snafus, lawsuits, or other obstacles. In addition to preemption (discussed earlier), lawsuit reform could help get things built by addressing the increasingly sophisticated and well-financed ability to strategically slow projects through lawsuits.

Still, there are real reasons why frontline communities, rural conservatives, farmers, and others are concerned about some of these projects. There is no way around engaging with communities and people where they are. Black and brown communities, for instance, have the memory and reality of negative impacts (on health and other things) that come with infrastructure. Native communities, too, have lots of hesitation about new infrastructure because they are used to being used as a dumping ground. The need to build lots of infrastructure is challenged not only by perceptions and by environmental and community opposition, but also by what has historically been accurate: large promises to underserved communities by huge energy industries that come in and pollute. Those who want to build anything in those communities have to fight the legacy of dirty infrastructure. They have to help people understand that these are unprecedented opportunities for economic development, including jobs, business growth, and access to emerging technologies. The benefits should also include equity investment and wealth creation in communities that have been exploited. Underserved and other communities need to be included in the process and have the benefits explained to them; a national conversation and campaign, bringing together clean energy and environmental justice interests, are needed on the importance of the transition — but it will be important to actually live up to the promises this time.

Programs such as community-based energy efficiency, electrification, and solar for all can be great gateways for low-income communities to start to see the benefits of clean energy, including with respect to career pathways. Wraparound services, including transportation, child care, and mental health support, are essential. For example, one of the top barriers to equity in construction apprenticeships is mobility; to advance in the apprenticeship, it is necessary to keep working, but construction work moves from place to place, so reliable access to transportation is vital. Workforce development training also needs to be paid; many people cannot afford to go a month or two without a salary. Some of the most successful diversification initiatives in construction apprenticeships have been built around smartly designed local-hire and geographic preference in low-income communities, combined with wraparound services from state departments of labor and workforce boards. Such initiatives require leadership from states, municipalities, labor unions, and community stakeholders to be successful and to ensure that benefits materialize for impacted communities.

Likewise, it is imperative to connect with people on the ground and invest in parts of the country where emissions are high, where there has been chronic under-investment, and that may not be politically aligned with climate and clean energy. The economic drivers will be very important for places that are under-resourced. Efforts and investment are needed to help people in these places buy into the economic opportunities of the energy transition, bring economic prosperity to their regions, and feel included in the conversation. It is important for people to see themselves as part of the transition and as benefitting from its opportunities. In some rural, conservative areas, people are really excited about the economic development potential from bringing in new industries and innovative technologies. For example, communities with retiring coal plants have competed to be the sites for new advanced nuclear plants, based on the economic and workforce benefits. Likewise, there could be good jobs within the oil and gas sector to help build a new, robust carbon capture, transport, and storage sector. There could also be a role for utilities to get creative in letting local power companies deploy more new renewables, allowing communities to see the positive economic impacts of bringing in new solar and helping them feel part of the energy transition. Training, jobs, and resources have to be brought to where people are, and the economic opportunities could spur people to move into the YIMBY camp. The challenge is to make the opportunities clear in ways that make sense to them. The goal should be to figure out where the benefits are so compelling that communities will be fighting to get clean energy as opposed to putting up walls.

There are debates about how realistic YIMBY is (whereas NIMBY is very real and prevalent). YIMBY may be possible, if folks engage with communities and figure out what they want. Businesses often do not engage communities early and frequently, and they often do not respect what they hear. There is a critical need for robust community engagement and to highlight examples of the real good these projects can do in communities.

Moving people to a YIMBY frame of mind will be very challenging, however. It will require more consistent public messaging about the benefits of and need for clean energy infrastructure, but to reach people, those messages have to come from sources seen as trustworthy, which is very difficult in an environment where everything is seen as political.

There is no way around the need to organize. Regardless of what marketing or messaging is done, there is a need to build trust in the communities that projects are going into. There is a fundamental distrust of the private sector coming into a transaction, and the same is true with respect to government. Speed and scale are essential, but so are building trust, building relationships, and building credibility on the ground.

While it is unlikely that supermajorities of YIMBYs will be created for transmission and other infrastructure, there needs to be more of a bias for action. Government systems currently overweigh highly visible, direct, local environmental impacts, and there is a need to bring some of the diffuse effects of climate change into the conversation in a better way. For example, bird advocates that might traditionally oppose project development need to recognize the importance of building more transmission, since climate change puts many bird species at risk of extinction.

Role for the Private Sector

Private sector energy buyers could play a key role in getting infrastructure, including transmission, built. Consumers that have been buying lots of wind and solar should move beyond talking about renewable energy exclusively and start walking the talk about reliable decarbonization. Large customers with public decarbonization commitments could talk with regulators and service providers about transmission being just as, and maybe more, important. They could demand that utility partners, utility commissions, and economic development authorities support new interstate transmission build.

Congress also needs to hear from a diverse array of people and perspectives about why there is an urgent need to build more transmission faster. Rank-and-file members of Congress are nowhere near as informed on this as they need to be. In highly technical areas like this, experts who live and breathe it sometimes forget how little most people know and how important it is for them to hear it over and over again from a variety of perspectives. Most members of Congress do not know that electricity demand has been mostly flat for a while but is about to spike. Most Democrats in Congress do not appreciate how essential transmission is to addressing climate change, and most Republicans in Congress do not appreciate the reliability, cost, geopolitical, and competitiveness pressures that will arise if transmission buildout does not occur. There are only a few months to turn around some of the complacency setting in in Congress about permitting reform, after which there may not be another opportunity for the foreseeable future.

Companies have made public decarbonization commitments that encompass operations and supply chains, and transmission expansion that decarbonizes the grids that companies and their supply chains connect to would be an impactful and cheaper alternative to the other means at companies' disposal. A way must be found, however, for large consumers to get credit for the investments they are making to the system. There is no real accounting mechanism today that would allow companies to get credit against their decarbonization commitments for the investments they might make to support transmission buildout.

There are rules and rewards systems — some regulatory and governmental, some quasi — that guide corporate behavior. These include everything from the Federal Trade Commission's Green Guides, by which a big corporation could be sued if it says the wrong thing, to quasi-regulatory frameworks like RE100. These systems govern what corporations that are using their demand-side power to drive the carbon-free energy system can and cannot say and get credit for, which in turn incentivizes certain behaviors and ways to engage. Historically, they have very successfully incentivized a pretty narrow set of ways to engage, primarily power purchase agreements (PPAs) matched on an annual basis for wind and solar. It is arguably even worse in the voluntary carbon market, where incentives are for corporations to buy the lowest-cost carbon credits. Corporations and other large off-takers (e.g., universities, cities) have not been incentivized to directly procure nuclear, to engage in public policy conversations, or to use their political weight to promote transmission. A small but growing number of energy buyers are engaging in conversations around systemic change anyway, but a far greater number could be incentivized to do so if they could somehow talk about it in a way they could get credit for. It is time to revisit the measuring sticks being used to evaluate corporate climate ambition and action so corporations can get credit for climate actions that are highly catalytic.

Grid Reliability & Electricity Markets

Market systems and structures can facilitate clean energy deployment, but the grid must remain reliable. As market design evolves and market expansion proceeds, reliability is the most important thing for the power sector to focus on.

Importance of Reliability & Resilience

Reliability is really important, very hard, and generally underappreciated. Reliability is an absolute, physical measure and can be defined. Resilience is a relative measure and is harder to define; it is about the ability to rebound from some external occurrence. Maintaining reliability and resilience of the grid is essential during the energy transition. A grid hiccup during the transition could have serious public repercussions on the pace and form of a path to a zero-carbon economy. Grid hiccups can cause backlash against carbon-free energy sources, whether they are actually at fault or not; this is already being seen in the culture war.

There are numerous major reliability concerns. One is the transition of the resource base and the retirement of traditional generation sources. Coal and natural gas plants do a lot of magic on the grid beyond just providing kilowatt-hours. For instance, they also create inertia (helping maintain frequency on the grid) and reactive power (helping maintain voltage on the grid). On an alternating current (AC) grid, these plants provide essential reliability services. Power electronics, through inverters, are incomplete replacements for spinning generation. At the same time, another reliability concern is the fact that as coal (and, to an extent, nuclear) plants retire, the grid becomes more dependent on natural gas, and there have been several recent disruptions in the natural gas delivery system for electric power. As described more below, it is imperative to rethink that gas-electricity interface, which is particularly crucial in cold weather events. These changes in resource mix are occurring while more end uses are beginning to electrify, which creates its own reliability challenges, since the grid is not currently set up to handle the levels of demand in growth forecasts, and grid infrastructure is already quite constrained.

Extreme weather poses reliability concerns as well. The broader, deeper, longer, more extreme weather systems that are now occurring more frequently put greater stress on grids, affecting generation, transmission, distribution, and load. These events also affect the ability of grids to rely on neighboring systems for support. As various locations have learned from recent winter storms and summer heat waves, reliability and resilience have a cost, but the lack of them has a cost too.

A fundamental challenge to grid reliability is the security of grid infrastructure, with respect to both cyber and physical. For the most part, the clean energy transition is seeking to replace technologies that are high-emitting, analog, and simple with ones that are low- or non-emitting, digitally interconnected, technically complex, and supply-chain diffuse. The interconnected and digital nature of the transition will empower interesting technologies and opportunities, but every connected device put on the system creates a new cybersecurity threat vector for adversaries to attack and disrupt critical U.S. infrastructure. There are also rising physical security issues on the grid, such as people shooting up substations.

Assessments of global threats have found that there are countries capable of and intent on being able to cause local disruptions to critical U.S. energy infrastructure. As the grid becomes more digitized, and as more fundamental aspects of life become increasingly reliant on electricity, having a reliable grid will be even more of a true national security imperative. Already today, there are military missions and installations that require uninterrupted access to critical infrastructure, especially electricity, to operate remotely piloted aircraft and perform active reconnaissance and surveillance to support missions around the world.

While more interconnection in national grids could provide a risk of wider impacts, the greater ability to move electricity around and to have other grids backstop whatever is being targeted could lead to greater resilience. A dramatically expanded transmission system is far easier to protect from being taken down and to recover if parts are taken down (whether maliciously or by accident). Redundancy is essential; it is present in telecom, but not in the power system. Studies have suggested that if a couple dozen large transformers are taken out, the entire grid collapses. In addition to redundancy, the grid would be even more reliable and protective if there were an overlay direct current (DC) network, as opposed to just an expansion of the AC network. A DC backbone could help recover parts of the AC system that are taken down. There is a clear national security imperative around transmission acceleration.

Utilities already spend a lot of time coordinating at the highest levels with the federal government, including the Department of Homeland Security (DHS) and the National Security Council, on grid security. There are regular meetings of the Electric Security Coordinating Council to focus on grid cyberattacks and other aspects of grid security. There is plenty of conversation happening, but there is not clarity on who owns it — whether the Department of Defense (DOD), DHS, DOE, utilities, or someone else. Everyone thinks someone else is managing the grid security risk, and there is not adequate conversation about the future of transmission and what is needed for a secure grid because there is not a central place for having that conversation. There is not a single federal-level authority that assesses the risks to the grid and the impacts to national security. That does exist for climate change, in the form of the multi-agency National Climate Assessment reports; a similar National Assessment of Grid Security is probably needed (most likely with classified and unclassified versions).

Gas-Electricity Interface

A fundamental reliability problem is the gas-electricity disconnect. Driven by the increase in domestic supply and reductions in price caused by the shale revolution, natural gas has become a much bigger presence in the U.S. power sector over the last couple of decades. Coal as a percentage of U.S. capacity went from about 50% in 2000 to about 20%, while natural gas went from around 15% to around 40%. (Renewables went from under 1% to 10%.) In terms of actual usage, the capacity factors of coal plants over the past couple of decades have decreased, while natural gas capacity factors rose. Each gas plant (apart from peakers) is being used more. The decrease in coal and the increase in renewables has shifted the functioning of the U.S. electricity grid to be quite reliant on natural gas as a flexible, dispatchable resource. Recent studies have shown that natural gas demand is now relatively inelastic to price; last year, as the price of natural gas basically quadrupled, the power sector demanded the same amount of natural gas. (Not only is electricity production becoming more reliant on gas, but gas production is also growing more reliant on electricity; for example, one of the major ways that upstream and midstream natural gas companies get their methane and carbon dioxide emissions under control is by electrifying stations, production fields, and the like.)

Natural gas is now the largest fuel used for power generation, and power generation is the largest customer of the natural gas industry. The natural gas system was not designed for this. Today's standards were established before the 21st century, when natural gas for power generation was much smaller. Interstate pipelines are basically unregulated in terms of what must be done for deliverability to generation plants. More fundamentally, everything about gas and electricity do not fit together, from the regulatory oversight to contractual arrangements to risk allocation to even the daily schedule. Gas-electric coordination may be the Achilles' heel of the energy transition.

There is an acrimonious relationship between the natural gas and electricity industries when it comes to natural gas generation units. At some point, there has to be an arbiter that forces them to work together because their systems are interlinked. The future for both industries is better if they can find a way to coordinate. A lot more natural gas combined cycle plants are coming online over the next few years in the United States, and with the increase in winter storms and changes in load (e.g., peaks in both summer and winter), gas-electric coordination is becoming more existential to the reliability of the grid. Congress needs to act to create an agency to compel gas-electricity coordination. There may be a need for a natural gas reliability organization, as was done with electricity almost 20 years ago. It will be harder with natural gas, since the industry is much more diverse in types of companies and services, but this is a crisis-level issue and should be as much of a priority as transmission, interconnection, permitting, and supply chains.

Ideally, such an organization would be created within the next year or two, but that appears unrealistic. A key hurdle is the structure of the electricity market itself, which must be updated to be able to provide revenue assurance to gas generators. The electricity industry and electricity generators are not firm off-takers for the natural gas industry. They are not a customer class to which the natural gas industry is responsive. Some electricity generators have been reluctant to sign long-term natural gas contracts, and natural gas companies have not been commercial enough in how they set pricing. State-regulated utilities can sign long-term contracts for pipeline space and pass costs on to ratepayers, but merchant power (which makes up half the power in the United States) does not have the ability to do that because capital markets (i.e., shareholders of those companies) will never support them signing such a long-term contract. (The ability of regulated utilities to get natural gas and use it over the long term means the emissions from the U.S. power sector will eventually be quite concentrated in regulated markets, which are mostly in the South.)

Designing for Reliability & Resilience

Reliability and resilience are valuable, necessary, and expensive — or, at the very least, there is a proportional relationship between cost and the level of reliability. A range of technologies or approaches could deliver reliability and resilience, including bigger reserve margins and operating reserves. Transmission is essential; there is a need to invest in transmission to enhance resilience, redundancy, and the ability to unlock areas where there is a lot of clean energy potential. Likewise, there is a need for pipeline infrastructure to ensure reliable natural gas delivery to the electric power system during the transition. There is also a need to de-constipate the interconnection queues and get resources online — especially batteries, though technologies beyond lithium-ion will be required. A robust system requires balancing resources (i.e., some amount of firm energy), which currently usually means natural gas, which can ramp up and down quickly to fill voids when other resources cannot. If there is a desire to move away from natural gas, some form of clean, zero-carbon, firm electricity is needed; there are lots of potential moonshots out there, but at least one of them has to come to fruition to fill the gap. Demand-side management, virtual power plants, and other approaches can also be important market mechanisms that can improve reliability and resilience and avoid some of the politics inherent in potential supply-side solutions. In addition, it is important to have a robust, reliable energy supply chain, in terms of both equipment and fuels.

Transmission is essential; there is a need to invest in transmission to enhance resilience, redundancy, and the ability to unlock areas where there is a lot of clean energy potential.

In part because the Electric Reliability Council of Texas (ERCOT) is a single-state ISO, with a coordinated and smooth process from legislation to the Public Utilities Commission through implementation, some of these approaches are already making progress in Texas. ERCOT's interconnection queue is already de-constipated; the time from application to physical interconnection for technically ready and adequately financed projects (especially those that are dispatchable) is significantly shorter than in other ISOs and RTOs. Texas has or will soon have the highest wind penetration, solar penetration, and storage deployment in the country. For transmission, the processing time from identification of need to flowing electrons takes less than half the time of other jurisdictions. Multi-state RTOs are more stymied by the need to deal with multiple state regulators; there is inherent friction when implementing critical policies.

Regardless, wholesale markets need constructs to deliver reliability and resilience. Market forces tend not to reward investments in reliability. For example, investments in winterization have proven controversial in the merchant sector, and there is not really a funding mechanism to reward them for such investments. Similarly, there is not yet a good market-based solution for how to build transmission. Resources that provide reliability tend to do so without compensation, whether pumped storage facilities jumping in when nuclear stations go offline in the middle of the day or hydropower facilities saving water during daytime (when solar generation is high) in order to increase output during shoulder hours during a heat wave. Hydro — which provides less than 10% of electricity generation but about 40% of black start on the grid — has a tremendous amount of spinning reserves and inertia that are not adequately compensated. (The existing hydro fleet is at risk; half of the non-federal fleet is up for relicensing within the next decade, some facilities are voluntarily surrendering their licenses, and the IRA provided no incentives to preserve existing hydropower.) Customers that had batteries in datacenters that were responsive to frequency issues on the grid likewise received no compensation for their useful grid stability services. It is imperative to look deeply into market design to deliver incentives to industry participants and capital providers to provide reliability, resilience, and reduced environmental impact (including land, water, air, and atmospheric impacts). If those attributes are added together properly, good market design can deliver the most affordable outcomes with the highest reliability and lowest practical environmental footprint.

It starts with defining a reliability standard, which should include not only frequency, but also duration and geographic impact. Concurrently, there is a need to define the value of reliability. There are lots of ways to look at it, including the cost of load shedding if reliability is lacking. Valuing reliability is about the economic, social, political, and other impacts avoided. Most folks have an extremely low tolerance for any threat to reliability; there is more tolerance for higher costs, but that is not without limit. There is a similar need to define a resilience standard and a value for resilience, which can be more difficult, though there are experts with better metrics about what true resilience means and how to price it into infrastructure. Talk about flexibility must be clarified, including what it means, how much is needed, and when it is needed. Appropriately defining the metrics is vital; if it is not clear what has to be provided, it will be impossible to know how to price it or when enough has been provided. Once definitions are determined, it can be easier to assess which generation sources and other measures to choose, and a market design can be built to fit them.

The Public Utilities Commission in Texas took the approach of saying certain electrons have more value because they come from reliable, dispatchable sources, and participants should receive compensation for that value because the resources are there when needed to create a reliable, resilient energy supply. Others that want to participate in the Texas market that cannot meet the reliability standard have to buy performance credit mechanisms that then go to the providers that provide reliable energy.

There is a need, however, to think about resource adequacy and the likelihood of resources showing up across all generation technologies. The conflation between fossil fuels and reliability in the public mind is real, and grid problems are often blamed on renewables when they are not at fault. For example, in some places, people have experienced blackouts because coal or gas plants have frozen; dispatchability depends a great deal on how weather-hardened particular technologies have been. It is important to have the proper balance of dispatchable and non-dispatchable generation — and to strike that balance based on facts and not based on a culture war around clean energy generation.

Part of what makes resource accreditation and market design hard is that figuring out the ability of a resource to provide capacity is a function of the rest of the portfolio, the load, the net load shape, and more. There are lots of interactive effects. There are many load probability models that measure expected output from different resources and identify periods of relative resource insufficiency. Forecasting how much wind and solar generation will show up at any given moment is proving to be challenging; the issue for system operators is less the variability than the unpredictability. These types of models and tools should be done not just to estimate renewables output, but also to look at the ability of thermal generation, as a function of fuel security, outage rates, and other factors. This becomes even more important as climate change impacts on both the load and resource sides increase. For example, many climate models suggest thermal generation will become highly unreliable in extreme high-temperature events in future summers.

Efforts to promote reliability and resilience should be designed to be as tech-neutral as possible. It should not be about fuel type, but about the ability to provide a certain service. In addition, the focus has to be on more than just capacity; reliability requires a more refined and impactful metric that takes account of time and location. For example, adding new solar and wind in locations where the grid is already saturated with solar and wind does nothing to help with either decarbonization or reliability. Incentives are needed for developers to build resources that take into account location, time, and firm capacity. There is a suite of technologies that can support reliability across different market types and market constructs, which means there will probably be different solutions in different parts of the country.

There is debate about whether ancillary services markets can solve the problem of supporting reliability. Short-term operational reliability needs of the system can probably be addressed in ancillary services markets, if reliability can be clearly defined and measured. Longer-term needs tied to resource adequacy and the need to build new generation probably cannot be solved with ancillary services markets. Those are two different operational time horizons that should not be conflated.

There are similar debates about whether vertically integrated systems can do a better job with reliability and resilience. Indeed, some sitting FERC commissioners have recently expressed sentiments that reliability and decarbonization may suggest a need to move away from competitive markets. RTOs are meant to optimize cost and maintain short-term reliability; they are not designed to deliver long-term, 20-year grid reliability. Nothing about vertically integrated markets, however, makes them inherently more reliable than an RTO. Indeed, there are many things about an RTO that might make it a more reliable system, including a broad geographic set of resources and a high level of transmission interconnection; these have proven valuable during recent winter storms. In addition, in a lot of markets, fuel procurement risk management is on the market participants, so they have an incentive to make sure that risk is managed; in vertically integrated markets, there have been at least a couple of cases in the past year where utilities went back to state commissions asking for recovery of fuel costs. The ability to do that does not give utilities incentive to procure fuel any better. Performance-based ratemaking may be needed to introduce competition among the utilities and assets in vertically integrated markets.

Markets tend to work well at delivering lower costs and better products and services; in electricity markets, they have also worked better at lowering emissions. Looking at wind, solar, and storage alone, over 80% has been deployed in wholesale organized markets. On the other hand, markets are generally where nuclear plants closed because they could not compete. Wholesale markets are premised on reliability at least cost; they are not designed to achieve decarbonization. That will not change until the Federal Power Act changes or there is a clear federal climate policy that FERC feels statutorily compelled to achieve.

Some feel ISOs and RTOs have governance models that favor current participants and incumbent technologies, raising the question of whether sufficient market rule innovation and reform are possible without governance reform. Many of the stakeholder processes in RTOs were created by market participants, and one has to be a defined market participant to really participate in the process. Incumbents (both generation and transmission owners) have a lot of sway, whereas customers with large loads have very limited say; incumbent utilities should not have a monopoly on representing load interests in the stakeholder process. State consumer advocates and environmental advocates, too, are often relegated to sidebar, backroom conversations. The RTO governance system is seen as fundamentally flawed, and reform may have to start with FERC. Still, while there is a lot of work to do on governance, the alternative to RTOs is an often opaque planning process driven by incumbent utilities. Overall, markets provide greater transparency and opportunities for stakeholders to provide input.

If it is not possible to work through how to create the right price signals for all desired attributes in markets, it may be that markets should not be relied upon to do everything. Markets may not be suited for co-solving for clean, resilience, affordability, new transmission, reliability, and other attributes and needs all at once. It is worth thinking about where market failures are being created and what other solutions might be. More planning, regulatory processes, and standards may be needed to provide the right incentives.

Market Expansion

Markets provide customers with reliability at least cost, economic and operational efficiency, access, optionality, transparency, governance, and stakeholder discipline. Markets generally tend to avoid boondoggles and can help drive down the cost of procuring clean energy resources, such as through operational efficiency and competitive procurement. Although RTOs were never designed to factor in, solve for, or accommodate public policy or private sector energy objectives, access to and optionality for resources have allowed RTOs to be leaders in carbon-free energy integration. Large energy customers, however, cannot access carbon-free energy everywhere across the United States, despite exceedingly high demand. There are large swaths of the country that do not have meaningful market access, particularly the Southeast and the West. Now there are real opportunities to design new markets in regions that have not had them.

The West, for example, is considering expanding to be a fully interconnected Western region. Conversations about a Western market are further along than they have been in years (or ever). Governance really matters, though, and the West is not a monolith. The Western market will have to deal with the big gorilla in the region, which is the California ISO (CAISO); others have to learn to work with CAISO, and CAISO has to learn to work with others. There may be some momentum in CAISO in terms of being willing to adapt to a different governance structure.

Likewise, the Southeast has launched the Southeast Energy Exchange Market (SEEM). SEEM will have a steep learning curve, as many market participants have to learn to adapt to a regional market instead of a single-state regulated market. The exact contours of SEEM remain unclear, since the courts remanded SEEM back to FERC because it failed on a number of substantive issues needed in a market construct. Still, there is lots of room for opportunity and growth in SEEM.

Some view markets as requiring states to cede some level of authority, but states retain complete and total authority over competitive resource procurement. There are substantial benefits to customers from markets, and to the extent it happens on a regional basis, the benefits are greater. RTOs or other competitive market constructs can provide market access and allow energy customers to transparently, affordably, and immediately procure clean energy at scale. There have been recent state-led studies showing the benefits of creating a West-wide organized wholesale market, including billions in annual energy cost savings, maintenance of grid reliability, enhanced local and state economic development (attracted and retained by lower energy costs), and the creation of hundreds of thousands of permanent high-paying jobs. There have been similar studies in the Southeast, with similar results.

Creating a market does not have to mean complete deregulation. There should be a role for sophisticated buyers to directly access the market and procure clean energy resources to satisfy their needs, but it does not necessarily follow that there is a need to fundamentally deregulate the market all the way down to retail customers. Corporate buyers can have a lot of influence when they talk with utilities and commissions as markets are opening. The buyers, who create lots of jobs in communities, should have a seat at the table for collaborative conversations.

It is important to learn from the past, as there is not a single approach to creating a market. Different things can work in different places, but some core policies should drive market expansion in the West, Southeast, and elsewhere. First, there should be geographically broad regional energy imbalance markets that allow for reserve sharing, spot energy market transactions, and regional optimization — the basics of wholesale power markets. The Western energy imbalance market is a good example of that. Second, it is important to have transparent and coordinated regional transmission planning that better incorporates public policy objectives. Planning in local silos will lead to unnecessary costs and overbuild. Third, generation is not a natural monopoly, and new generation should be procured via a competitive procurement process that enables all suppliers to compete.

In considering market expansion, it is worth clarifying what the goal of such expansion is. Current markets were designed to solve the problem of lots of power plants being run inefficiently with incentives to build new ones instead;

a new incentive structure was created to run existing plants well before building new ones, and it worked well. There seem to be many other problems now, including how to provide reliability, how generators should be paid, how to decide what to build and what to retire, and how to decide who gets access to build. Sometimes people looking to markets to solve a problem are talking past each other because they have different problems in mind.

In thinking about market expansion (and reform of existing markets), it is worth remembering that today's markets were built based on the incumbent resource fleet, but creating markets for tomorrow should involve thinking about the resource fleet of tomorrow. RTO markets, with locational marginal prices and capacity constructs all wrapped up in things like accreditation methodologies, are not amenable to the resource fleets of the future. They work better than the previous alternatives to optimize fleets, but that does not mean they would work better than something that has not been tried yet for future resource fleets that are, for example, variable in when they produce. There may be a need to move to a foundationally different kind of market construct if markets are to be used for the fleets of the future, rather than try to continue to optimize based on a thermal fleet design. For instance, it may be necessary to move away from constructs that rely on marginal performance as a means of providing most compensation — and to move toward constructs that are driven by contributions to reliability.

Nuclear

Nuclear energy is at a significant inflection point, for both the current fleet and the potential future fleet, but there are regulatory and equity issues that must be addressed.

Current & Future Nuclear Fleets

Nuclear currently provides about one-fifth of U.S. electricity and about half of U.S. carbon-free power. Utilities' nuclear officers expect more than 100 gigawatts of new nuclear will be needed to meet emission reduction goals, which is basically a doubling of the current U.S. fleet size. That is only a fraction of the overall picture, as utilities represent less than half of electricity generation, and there are many nuclear uses beyond the grid (e.g., hydrogen, industrial heat, water processing). Some estimate that around a couple hundred gigawatts will be needed by 2050. Globally, all credible scenarios have nuclear increasing, though some show nuclear going up only a little, while others show huge increases.

All energy sources have their benefits and challenges, and to solve the climate crisis, many technologies will be needed. A benefit of nuclear is its huge energy production on a small land footprint. (There are debates about how much land is actually needed for a substantial wind and solar buildout, as well as what the public acceptance and regulatory restrictions will be regarding the available land, but the fact remains that nuclear has extraordinary energy intensity relative to the size of the facility.) On the other hand, nuclear also has a spent fuel issue, which requires some kind of national resolution that has proven elusive. The spent fuel volumes, however, are not very large.

With respect to the current generation of nuclear technology, Plant Vogtle finally got under real commercial operation this past year. Existing nuclear plants can safely run for decades. They are licensed for 40 years, and most of the fleet has already renewed or will soon renew for another 20. As part of the process, operators rebuild plants part by part over time; the nuclear stations operating today are essentially new facilities, operating more efficiently and productively than when they first came online. Because of the continual rebuilding process, nuclear stations could extend for multiple license cycles.

Advanced nuclear has very different sizes, shapes, and uses than old nuclear. Advanced reactors range from microreactors of a few megawatts to somewhat larger reactors (e.g., small modular reactors or SMRs) that have capacity for a few hundred megawatts; in the long term, it is possible there could be a return to even larger reactors. Advanced nuclear is very safe, because safety is dependent on passive physical processes. The past year has been a watershed year for newer forms of U.S. nuclear, with deals and contracts to develop SMRs (both domestically and internationally) and approvals for advanced reactor designs. Power purchase agreements were signed for SMRs and for future fusion. Progress has also been made in getting U.S. high-assay low-enriched uranium (HALEU) production up and running. (HALEU is the fuel for many advanced reactors.) Developers of small and advanced reactors have lots of hurdles still to overcome, though, and more progress needs to be made on designs, regulatory processes, and commercialization opportunities.

Advanced nuclear is very safe, because safety is dependent on passive physical processes.

While climate may now be a culture war issue, nuclear has a broad base of bipartisan support. Polling suggests nuclear may be the only carbon-free electricity generation technology that Republicans favor more than Democrats, by a decent margin. Over the last couple of years, there have been some important policy changes for both current and advanced reactors. For example, the IIJA and the IRA had benefits for current fleets to sustain operations and stem the tide of plant shutdowns, and the IRA's tech-inclusive clean energy tax credits will provide new options for production and investment tax credits for new nuclear.

Until the IRA, there was no long-term revenue certainty for companies' nuclear assets. As natural gas prices fell and low-marginal renewables (supported by policy) ramped up, nuclear plants were increasingly challenged to recover their costs. State policy helped prevent the retirement of the nuclear fleet; about half of the merchant nuclear fleets in the United States are under state support agreements that preserve their operation, and a little over half of the rest remain under investor-owned utility ownership and are protected by state regulation and cost recovery. Most nuclear plants operating today therefore are only doing so because of access to state regulatory structures that cover their operating costs.

The IRA was transformational. With the 45U tax credit, the industry went from fighting to preserve assets to being able to look forward and invest. The clock, however, has already started ticking. The 45U credit expires at the end of 2032, right around when the industry will be going through a wave of Nuclear Regulatory Commission (NRC) proceedings to extend existing plants' operating licenses. (This means the NRC will have to prepare for a wave of license renewal applications occurring in parallel with the wave of new license applications coming from small and advanced reactors.) The regulatory process for extensions takes about 3-5 years to complete, and investments and upgrades (which are needed to get through that process and be ready to operate for another 20 years) have to start before the application is filed. The 45U credit expiration means operators of existing reactors will have no line of sight to revenues to support continued operations.

This is part of the reason that operators of existing plants, for the most part, are not the ones building the next generation of reactors. They are not investing heavily in new nuclear because they cannot justify to their investors taking on the cost and risk of getting new plants through the development and regulatory process when markets and policies do not sufficiently value or protect the existing fleet. Instead, existing operators are lending their expertise and support to SMR and advanced reactor developers through service agreements and other partnerships, including licensing support, experience with safety protocols, and marketing expertise. There is significant reluctance to enter into actual project development until the technology has been demonstrated and proven to be able to produce energy predictably, reliably, and cost-effectively.

Getting over the cost curve will be a challenge. In the long term, the tax credits provide a foundation, but early movers incur extra costs and risks without any commensurate benefit from going first. It is a challenge to get projects going at a scale that will stimulate the supply chain, bring costs down, and demonstrate the various technologies. Advanced nuclear is striving to reach liftoff.

It is worth looking at other countries' experiences to address the issues that the industry and infrastructure financiers will be concerned about, including cost overruns, long-term operations and maintenance costs, regulatory uncertainty, and the need for offtake. Countries that have built nuclear (e.g., South Korea, China, Russia, United Arab Emirates) have shown that when a country builds, it gets better at it, costs go down, and the process becomes more predictable. The United States needs to get back to that if nuclear is to play a significant role. Creating a pipeline of plants or an order book is important, as opposed to just building plants one at a time.

It is imperative to accelerate movement down the learning curve. Countries around the world are looking to nuclear to have a role in their energy mixes. Russia is a key supplier of enriched uranium and dominates the supply chain for a number of different nuclear components. China is talking about building numerous nuclear plants abroad through the Belt and Road Initiative. If the United States does not have technologies that have been demonstrated domestically, it will not be in the game to provide technologies to other countries. The United States will continue to cede that market to China and Russia, which gives them 100-year energy relationships with countries (from starting to build through decommissioning).

Nuclear Regulatory Commission

Once advanced nuclear technologies have been demonstrated, there will likely be a rapid rise in demand. The ossified regulator needs to modernize in order to be ready. There has been active, ongoing dialogue in Congress with the Nuclear Regulatory Commission and with the private sector about how to improve the NRC's analysis and decision-making regarding innovative nuclear technologies.

Nuclear energy's story is similar to many others in the big decarbonization push, in terms of the need for permitting reform (here, to build more advanced reactors). There has been a remarkably bipartisan push for reforms to the NRC to get it to do a better job of permitting new reactors. In 2019, Congress enacted the Nuclear Energy Innovation and Modernization Act (NEIMA), which directed the NRC to come up with new risk-informed, performance-based, technology-neutral regulations for advanced reactors. Thus far, the NRC staff does not seem able to do it, issuing a very long draft rule that seemed to double-down on a lot of requirements that will force applicants to demonstrate that they are reducing health risks from a reactor to incredibly minute levels. It is not clear if the commissioners feel the NRC staff's proposed rule could go forward. Some experts think the NRC also does not seem to be carrying out its own goal of making sure that it is considering the risks from the alternatives if it does not license and permit a given reactor, which in most cases will be a fossil-fuel-fired generator.

The NRC faces many challenges as an agency, including a need for more resources and workforce reform, but a big part of the problem is how it operationalizes risk review in its regulations. Some would argue it has ended up in a very extreme place, though it is not clear that Congress intended for the NRC to be so extreme in its standards. A useful comparison can be made between the NRC risk regime and the regime that the EPA has in place under the Clean Air Act (Section 112) for facilities that emit toxic pollutants. The EPA's regime is very stringent, as it is meant to deal with dangers such as chemical plants, toxins, carcinogens, and other things that generally cause far more deaths and cancer than nuclear plants have. Congress used nearly identical language in Section 112 in directing the EPA to set a health standard as it did in the Atomic Energy Act in directing the NRC to develop a standard for nuclear energy; if anything, the language directing the EPA's standard could be read as being more stringent. Over time, the EPA developed numerical risk levels to carry out its mandate, and in the 1990 amendments to the Clean Air Act, Congress essentially blessed those. In addition, recognizing that it gave the EPA and the NRC overlapping authority over the same toxic pollutant (radionuclide emissions) from nuclear facilities, Congress directed the EPA to be the regulator unless the EPA found in a rulemaking that the NRC approach would meet the Section 112 standard. The EPA found that the NRC cleared that mark by a mile and in fact was restricting radionuclide emissions at a level at least an order of magnitude lower than what the EPA had determined. The NRC is somewhat out on a limb in its risk regime for nuclear reactors, going much farther than Congress intended when it created the NRC (and farther than what Congress recently directed in NEIMA). What the EPA has done provides one possible blueprint for a different approach. (It could also be interesting to compare the NRC and the Defense Nuclear Facility Safety Board, which has, some might argue, also ended up in a very conservative place.)

No one wants to minimize safety, but the NRC processes need to be faster and more efficient. The NRC has lots of headroom to recalibrate and come up with a different approach to risk regulation, but the NRC may need to bring in new people and create some organizational change. If the organization cannot escape its current regime and structure, Congress may need to enact a new law that says specifically what it wants the NRC to do. Truly transformative change at the NRC will require direction from Congress; otherwise, the NRC commissioners will not feel like they have the legal top cover needed to make big changes. Even after direction from Congress, overcoming the cultural barriers to reform will take huge individual leadership by the commissioners, as well as a lot of leadership from and investment in the talent of the commission staff.

While NRC reform is essential, there is already some rhetoric and pushback arguing that calls for reform are just the industry pushing to deregulate and get unsafe projects built. It is important to be careful in how NRC reform is talked about; if it is seen as cavalierly cutting back on regulation, there could be a public backlash.

Siting & Environmental Justice in Nuclear Energy

There have been many innovations in nuclear technology, great advances in commercial products, companies moving through licensing, first-of-a-kind demonstrations planned, and construction on some projects starting soon. A similar set of innovations and advancements are needed on the softer side — in business plans, financing, demand-pull policies, siting, community engagement, and the like — for new nuclear projects to be both financially successful and supported by the public, thereby enabling nuclear to scale up to meet the challenge of deep decarbonization. (Lots of soft and hard innovations are also needed in the fuel cycle.)

Environmental justice has been thought of as consisting of three different types: restorative justice, procedural justice, and distributive justice.

New processes must be developed for how to build nuclear to align with federal mandates and a renewed federal focus around environmental justice (EJ). Environmental justice has been thought of as consisting of three different types: restorative justice, procedural justice, and distributive justice. These are not areas that the nuclear industry is used to thinking about, but it needs to start. Nuclear advocates often assert that nuclear is inherently an EJ technology, since it has zero emissions, no air or water pollution, and fewer justice concerns than something like a coal plant or oil refinery. That, however, is oversimplifying. EJ is not just about where polluting facilities are sited; it is also about full inclusion in the decision-making process of all aspects of a project that could affect local communities' health and environment.

The big thing that needs to change — and that advanced nuclear companies are already starting to change — is how nuclear plants are sited and how local communities are engaged and involved in project development. In the 1960s and 1970s, utilities decided where they needed power and where cheap land was located, and then they announced it. The model, which came to be known as define-announce-defend (e.g., against lawsuits), led to lots of public backlash against projects and against nuclear broadly. New siting processes are being developed that focus on finding communities that are excited to host a nuclear facility and that are interested in and invested in a project. The vendor or nuclear company has to work with the community to co-develop a project that meets everyone's needs and gets long-term community buy-in. A huge nuclear buildout in the United States only requires a few hundred sites, and there are probably already that number of communities that want them.

For nuclear operators, the communities they operate in are some of the strongest partners they have; any pushback and concerns often are not coming from those communities. Still, any social constraints on building new nuclear can often be mitigated by siting in places with existing facilities that can be expanded or repurposed. Existing nuclear sites could be a good fit. Most (but not all) of the existing or closed coal plant sites could also be converted to nuclear, subject to regulatory approval and other matters. In addition, because nuclear has such a small land footprint, and with new regulation that allows a closer boundary for the site, new advanced nuclear could be placed relatively close to where it is needed, such as on a university campus or industrial site. There are plenty of already-developed sites where new nuclear could go. It could be helpful to create a geospatial tool that shows the existing nuclear fleet, existing and closing coal plants, and areas of the grid that will need peak capacity. Adding in even more opportunities (e.g., solar in transportation rights-of-way) could help support regionally appropriate decarbonization strategies.

There are some challenges with coal-to-nuclear conversions, including the ownership of the coal sites and the regulatory processes needed to convert them to nuclear. The developer of the site may face challenges in moving what has traditionally been a regulated, rate-based asset to something that is a commercial opportunity. (This is less of a challenge for merchant coal plants.) The remediation of environmental issues around the conversion are also meaningful. Still, the potential for a coal-to-nuclear transition is enormous. Most jobs could be transitioned from a coal facility to a nuclear facility; the plants just boil water differently, but many systems are the same regardless of the heat source for boiling water.

The IRA (section 1706) included support for energy infrastructure reinvestment, which would be relevant for repowering a coal plant with nuclear. The energy infrastructure reinvestment program is potentially a very large program — $250 billion of potential loan authority by DOE and $5 billion of credit subsidy — to reinvest in existing sites to repower, repurpose, or replace a facility that has ceased operations or to improve an existing facility to reduce emissions. While the program is a great opportunity, it is not a panacea. For example, because of how the IRA works and how it was passed, commitments for those loans must be made by 2026, which is a fast turnaround for some of these kinds of technologies.

Siting is important with respect to distributive justice as well, in terms of expanding equitable access to the benefits of nuclear energy. Nuclear plants come with lots of tax revenue and high-salary (often unionized) jobs, but existing nuclear plants tend to be located in whiter, wealthier communities, while more polluting fossil fuel facilities are more likely to be located in low-income communities of color. The IRA included a tax credit bonus for building in an energy community, as well as a direct pay option that could help expand new nuclear to municipalities, non-profits, and others without a tax burden. New business models could also help expand access to nuclear; for example, small and municipal utilities could sign PPAs for new nuclear to help get access but mitigate the risks of cost overruns. Some communities may want to be hands off and buy the electricity, while others may want more ownership, authority, and involvement. Factory-fabricated, small, and micro reactors could facilitate community ownership, as well as industrial commercial customers, campus and university power reactors, and off-grid applications. There will be a diversity of reactors and business models to meet different needs.

Internationally, the U.S. government could offer more partnerships and investments to help build capacity in the many lower-income countries that are pursuing new nuclear. Companies could offer build-own-operate models (which Russia has been successful with) and spent fuel take-back, which could help allow earlier access to nuclear energy and aid countries in their economic growth in a low-carbon way.

Efficiency & Electrification

The United States has had great success in decoupling electricity growth from economic growth. Some of that has come from offshoring manufacturing, increasing services, and pushing out energy-intensive industries, but a fair share of it is also due to incredible conservation and efficiency gains that have helped put every electron and molecule to better use. At the same time, energy use may start growing as electrification increases. Conservation, efficiency, flexible demand, load management, and electrification will all play key roles going forward.

Opportunities & Challenges in Electrification

In the transportation sector, which is the largest source of U.S. emissions, light-duty EV sales are rapidly increasing. EVs represent about 7% of sales today; the goal is 50% of sales by 2030, but even with the IRA, the most optimistic projections suggest EV sales could make up 40%. There is also a lot of supporting infrastructure that needs to built.

In the buildings sector, sales of heat pumps overtook sales of gas furnaces for the first time in 2022, before any IRA incentives went into effect. Heat pumps may be cheaper than gas furnaces for new buildings, given the avoided costs of further extending gas infrastructure to a new building or home. For existing buildings, however, the cost situation is less clear. In many geographies, it is often lower net cost to electrify existing buildings, especially if HVAC system upgrades are already planned, since a heat pump is a single appliance that can replace two others (furnace and air conditioning). The majority of equipment replacements, however, are unplanned; they occur at the point of failure, when it is an emergency situation and people are not looking at lifecycle costs or net present value. Electrification may be particularly hard for places with lots of older homes that still have steam and water-based radiators, such as in the Midwest. Installation costs can also be high if existing equipment needs to be ripped out, and the less experienced an area is with heat pumps, the more contractors charge for the trouble of learning how to install them. These costs can be unrealistic for many families (especially low-income families) to absorb. Home electrification is a long-term project, and people need the time, the money, the right contractor(s), and so many other things lined up to even think about it.

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Building electrification is not just about homes. The commercial and industrial building envelope is also getting more complex, as electrification advances and energy needs change. Some facilities, for example, are deploying more robotics and automation, which require more energy; likewise, some facilities are charging their own EV fleets and customer vehicles. Whether commercial and industrial electrification pencils out is very dependent on geography, since electricity and gas prices vary widely. Electrification costs are still too high in many places, but the hope is that as more manufacturers and other companies begin the electrification journey, and as more maintenance staff and infrastructure are able to maintain the journey, costs will come down.

Electrified vehicles, buildings, and industries, not to mention investments in electrolytic hydrogen, can lead to dramatic load growth on a grid. Some estimates project load to be 50-150% higher, but grid equipment and infrastructure in neighborhoods is often not designed to accommodate such large load increases. Grid infrastructure has to be replaced, upgraded, expanded, and/or hardened to meet the demand. That, too, can be very costly. At the same time, utilities are having to wait almost three years to receive new transformers for their grid systems.

There is still tremendous potential to lower the costs of electrification, including creating solutions and innovations that help with delivery and financing challenges. About 15 years ago, the solar industry, DOE, and many others identified and successfully began implementing the necessary actions to bring the cost of solar down in the country, including hardware, financing, customer acquisition, permitting, and interconnection. That playbook has not yet been utilized enough to lower the costs of electrification.

Electrification, Efficiency, & Equity

Some wonder whether the focus in the building sector should now be more on electrification than efficiency — whether the point of diminishing returns has been reached on energy efficiency. While it may be that, in some milder climates, there is more bang for the buck in electrification than in more energy efficiency and building envelope improvements, there are climates where there is still much more to be gained from energy efficiency. There are also myriad reasons why efficiency is still important in all regions. For example, across models of deep decarbonization and energy transition pathways, future energy systems that deploy energy efficiency and load management are lower cost, more reliable, and more resilient. In addition, for cities, energy efficiency is still the principal tool for reaching clean energy and decarbonization goals. Cities often have no direct control over generation, but they do over usage.

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More fundamentally, skipping over efficiency and going right to electrification is unjust. There are growing numbers of consumers dealing with energy burden, energy insecurity, and energy poverty (e.g., not using air conditioning and heating when needed because they cannot afford it). The United States has fought inflation while avoiding a recession (at least so far), but energy affordability remains a key topic. There is a huge wealth gap in the United States, and energy efficiency reduces how much energy people use and pay for. Places with a lot of electrification may also have higher rents, and there is already a housing affordability issue in the United States. It is important not to solve one problem while creating another for the same group of people.

Like the digital divide, there is a growing energy divide in the United States. It covers everything from electrification, energy burden, and utility shutoffs to electrified mobility. For example, people may not want EVs if they do not see charging stations in their communities; low-income communities cannot be left out in the deployment of EV infrastructure. Likewise, if people do not have the means to upgrade their electrical panel or do not have access to sufficient WiFi or broadband, they may not get to install and benefit from a building automation system in their building or a smart thermostat in their home. Another dimension to equity and electrification is the fact that as the wealthy electrify and leave the gas system, there will be a smaller set of low-income customers who cannot afford to electrify who may be left footing the bill for that gas system, which exacerbates the energy affordability issue. Rate reforms and other measures are needed to avoid putting the burden of decarbonization and electrification disproportionately on the poor. If the people not part of the 1% (or 10%) are not explicitly included in plans for the transition, the United States will have to try to solve an energy divide problem in addition to all the other challenges it faces.

Retrofitting existing buildings and homes is necessary to meet climate goals and to achieve a just transition. The vast majority of buildings that exist now will still exist in 2050, which means massive retrofit efforts are required, but many building owners will not pay for the retrofits themselves. People who cannot pay need big subsidies, and those who can pay need incentives and mechanisms to make it easy. There is a federal tax credit (section 25C) to get people to invest in home energy efficiency, but the majority of taxpayers use the standardized deduction, not itemized deductions, which means the tax credit is mostly for the richest Americans. Other tools are needed, including ones that would enable aggregation of communities so retrofits could be done by block or neighborhood.

Consumer protections are also important. A lot of federal money is hitting the streets, and the past has clearly shown that a lack of adequate consumer protections can make potentially good programs into predatory ones.

Weatherization and energy efficiency have yet another benefit in a changing climate as well, namely with respect to health and resilience. Homes with more modern building envelope improvements can perform better during storms and other extreme weather events than homes with weatherization based on building codes from 30-50 years ago.

Education of Consumers & Contractors

Education and engagement are necessary for advancing energy efficiency, demand management, and electrification. Many of the actions needed for decarbonization ultimately have consumers at the end of the process; those consumers have to be educated about what actions are happening, why, and the range of energy-saving, cost-saving, and non-energy benefits. It is important to bring consumers to the table, including those who are hardest to reach and need support the most.

In addition, the audiences for the IRA's range of incentives are in many ways different than for other pieces of federal legislation, with key audiences including contractors, car dealerships, homebuilders, and fleet buyers. It is important not to underestimate the extent to which these middle people need to be reached out to by federal officials and clean energy advocates to get them engaged in the conversation. There is a lot of education that needs to happen. For example, some dealerships dissuade people from buying EVs because they do not service them. In the Midwest, there are still contractors telling customers that heat pumps do not work in cold weather, that solar does not work in the region, and so forth. Contractors make their money selling big gas furnaces and have little incentive to invest in learning about selling, installing, and maintaining heat pumps; it may be necessary to offer contractors incentives to take the time out of their busy days to get educated on some of these technologies so they can advise people to do the right thing instead of the easy thing. If contractors, car dealers, and others are not educated, they will continue to be a barrier to the growth of energy efficiency, electrification, and clean energy.

In order to equitably serve communities, populations that have been historically excluded from wealth generation and the benefits of investment have to be intentionally courted and invited to join as workers and business owners in growing areas of need, including energy auditors and contractors.

There is also a need for a more diverse workforce and contractor base to advance energy efficiency and conservation programs. Diverse families, especially in immigrant and minority communities, are more likely to let people who look like them into their homes. With the contractor base in clean energy being mostly white and male, there are families that simply will not be reached. It is important to figure out how to reach different communities and serve them with honor. For example, there are some cultures in which women cannot allow men into their homes unless their husbands are there; having a more diverse team can help identify and address customer hurdles such as that. In addition, in order to equitably serve communities, populations that have been historically excluded from wealth generation and the benefits of investment have to be intentionally courted and invited to join as workers and business owners in growing areas of need, including energy auditors and contractors.

Enabling Demand Flexibility

Efficiency, load flexibility, and virtual power plants will not fully replace the need for new generation and grid investments, but they must become bigger parts of the toolkit. All the connected devices in homes and vehicles can be used to support load management, load shifting, and cost reduction. For example, while EVs will increase load and require more

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grid investment, they can at the same time be grid resources for load flexibility. Bidirectional charging capabilities, mechanisms to promote flexible load (e.g., time-of-use rates to incentivize off-peak charging), and other approaches can help EVs be not just a demand creator but also a flexibility resource that only improves as more EVs are deployed. With basic controls and price signals, a lot of load-shifting and demand flexibility can be achieved to better match generation output.

All the hardware and software necessary to deploy and utilize these demand-side resources at scale already exist; what is lacking are the policy, regulatory, and market rules to allow them to deliver at scale. In organized wholesale markets, there is a need for greater action to make room for these resources in the markets. In vertically integrated markets and at the retail level, there is a need to create the incentives for utilities and customers to create and exchange the value of flexible loads. This will be difficult and will require leadership, collaboration, and a willingness to innovate by state policymakers, utilities, system operators, clean energy companies, and others. The United Kingdom is leading the way globally in creating a system-wide flexibility exchange, which might be a model for others to follow.

Some markets have a range of features to incentivize large loads to drop off during peak periods, to shape the load profile, and to aggregate various distributed energy resources into virtual power plants. The challenge for many such efforts is the lack of visibility to the grid operator because there is no two-way communication. The big need to unleash these resources is a standard communications protocol. More broadly, there is a need for interoperability protocols, including things like standards for communications and control of resources, protocols and standards for reviewing interconnection requests, metering and telemetry requirements, and other elements of digital architectures that can become the backbone of systems for exchanging and transacting flexibility. Common data standards can also help make the load flexibility and efficiency opportunities cheaper for everyone; without a common data standard, the energy transition either does not happen or happens while leaving lots of people behind.

The Commercial & Industrial Sectors

Companies in the commercial and industrial sector have been pursuing energy efficiency efforts for many years, but there are still potential energy efficiency gains that could be realized in existing facilities and buildings. Facilities that were state of the art 10-15 years ago are nowhere near it now, so even facilities that have already been upgraded have to go through refresh cycles. For example, businesses that installed LED lighting as one of their first energy-saving measures years ago are finding opportunities now to replace old LEDs with new LEDs that are more efficient.

Given that industrial and datacenter loads can be several hundred megawatts, even small efficiency gains can yield significant energy savings. There are opportunities for efficiency everywhere, from the level of the plant or facility to hardware to how software and data systems operate across that hardware. While there may be less incentive to take other actions that may provide grid reliability or carbon reductions (e.g., moving load across datacenters based on the carbon-intensiveness of the grid at different times and locations), there should be inherent incentives, in the form of cost and energy savings, to take basic steps to improve energy efficiency. The customers' ability to be efficient with their loads still helps the grid, as it means the system does not have to deal with those loads. If commercial and industrial customers can get transparent and accurate price signals, they can also provide backstop demand response optionality for the grid.

A big issue, however, is competition for corporate capital. Energy efficiency projects can pencil out positively, but they often do not make the cut in annual budgeting because the corporate dollar is seen as more valuable in marketing, product development, or other places. The energy services company approach and other forms of outsourced energy services may therefore be the only way to tackle the opportunities, although some corporate executives would balk at paying someone else to do the project and reap the energy savings.

Inertia in the relationship between humans and the technologies they are used to can be another obstacle. Companies selling high-efficiency technologies have technologies available today that need no policy intervention to make them pencil economically, and yet they sit in catalogs and do not get bought. Inertia is strong. In old buildings, for example, one should not discount the challenge of getting a building manager who has always used the same HVAC system to use a new one. Likewise, people tend to have a strong inertial relationship with their backup power diesel systems with uninterruptible power supply.

Natural Gas

While electrons are very important, the other principal way to carry energy around is through molecules (though, again, systems for the two are deeply intertwined). The biggest overall American energy topic last year may well have been the role played by natural gas on the international stage, but the future of gas during the energy transition remains a matter of debate.

International Role of U.S. Gas

While the United States tries to claw out a strategic advantage in clean energy supply chains, it already has that advantage in gas. The past year has been a big one for the role of U.S. gas production in the global balance of power in the energy space, especially following the invasion of Ukraine. Since the invasion, there has been an incredible scale-up of America's global energy presence after a decade or two of leaving that to other countries. Record volumes of U.S. liquefied natural gas (LNG) were shipped, and there have been global deals involving U.S. LNG (as well as nuclear technologies). Gas provided an incredible tool in the fight against global authoritarian imperialism, and that should not be discounted.

U.S. LNG made an important contribution to stabilizing Europe. Europe had been accustomed to buying cheap pipeline gas from Russia, and when it became unavailable, Europe had to draw gas away from places (mostly in Asia) that had longer-term contracts. Europe had generally been the market of last resort for global LNG; when there was extra supply, or it was cheap, some supplies would go to Europe. An interesting shift has occurred, however, with Europe now depending on LNG supplies. Europe is now the baseload that U.S. LNG is headed to, while Asia is now the swing market. (A lot more U.S. LNG may also be heading to China, given China's caution about a second pipeline from Russia, which could factor into U.S.-China geopolitical considerations.)

Europe's newfound reliance on LNG has important implications for global price volatility, energy security, and the outlook for coal. While U.S. LNG played a big role in meeting Europe's energy needs, those gas supplies then were not available to others, and there was a big price spike. The volatility created energy crises in Pakistan, Sri Lanka, India, and elsewhere, creating the overall impression that gas is not a resource that is going to be energy secure over time. Gas companies will always sell where prices are the highest.

Europe paid for gas on the spot market, rather than accessing the lower prices possible through direct contracts with LNG producers. Most LNG is sold on long-term contracts, and new LNG plants are being built in the United States only on the back of new contracts. Many suppliers need 10- to 20-year (or longer) offtake agreements, and Europe, with its net-zero targets, cannot, for the most part, sign such long contracts (though some are now being signed). Another problem with signing long-term contracts is that new projects come online in 5-7 years, which is not useful for Europe, which is concerned about the next few years. Europe also was not sure how much demand uncertainty there would be, since Europe beat its target for reducing overall gas consumption. Spot contracts and long-term contracts are not the only choices that Europe has; there is a set of more creative ideas, including seasonal contracts and options contracts. Europe could also sign long-term contracts and then re-sell the gas supplies elsewhere in the out-years of the contract, but the valuation of those out-years has a huge error bar because it is unclear how much gas the world will need in those years.

Indeed, looking at global energy scenarios through 2050, gas consumption represents the largest uncertainty. Across the most credible scenarios, renewables and nuclear are projected to increase (though there is variation in how much), coal to decrease, and oil to stay flat or decrease. For gas, however, the scenarios range from big increases to big decreases. Across scenarios, gas consumption and production in midcentury has about 500 billion cubic meters of uncertainty;

there are scenarios where consumption globally grows by half in 2050, and there are scenarios where consumption is cut to 10% of current levels. A significant portion of gas consumption is in buildings, and any conversation on the future of gas has to consider trends in building electrification, heat pump deployment, and industrial electrification. In the United States, the past year saw significant challenges to the social license of additional use of gas, with accelerations of bans on new gas connections and some culture war battles about gas stoves. There are a lot of unknowns.

Whether global gas demand increases or decreases, the volumes needed will be huge for a long time. That means the general assumption of a coming decline in fossil fuel communities is worth examining more granularly. The picture may be different for coal, which has less of a global market, but for oil and gas, demand is likely to be robust for decades. The question is which supplies fall off the curve first — and how politicians respond to that. If, for example, U.S. production falls and jobs are lost, but Saudi and Iranian production stays steady, U.S. politicians may not accept that and may pursue efforts to prop up domestic production and jobs. Each country wants to be the one producing the last barrels of oil and cubic feet of gas.

Still, the conflict between building lots of gas infrastructure to reliably meet near-term energy needs and achieving net-zero goals is real, and Europe is a harbinger of how hard it will be to write long-term gas contracts over time. Investments are needed in some hydrocarbon assets, including gas, to meet current and potential future energy needs, but those would be inconsistent with trying to be on track for net-zero goals. A big question is whether the United States can make strategic, productive use of its gas resources over the next 30 years amidst the energy transition in a way that allows gas's best attributes to shine, allows the United States to have a strong strategic position, and does not undercut the energy transition. The United States could help the world by finding more fluid contractual agreements that allow for enough gas infrastructure investment today to meet potential global demand and that have some mechanism in place from day one that provides for accelerated timelines for retiring or repurposing the facilities. Such mechanisms could help ensure there is gas export capacity as a hedge, in the event that zero-carbon infrastructure ends up being too hard to build at scale.

Emissions from Gas

For gas to be part of the climate solution and the future energy mix, there are several key needs. Importantly, natural gas needs to displace coal, not zero-carbon energy. If it displaces renewables or nuclear, gas is unquestionably higher-emitting. The vision of gas displacing coal around the world to drive down emissions, however, is easier to picture than to do in practice, for many reasons. For example, there is tension between that objective and the fungibility of U.S. gas in a global market. The U.S. government has an obligation to approve exports only when DOE determines that they are not inconsistent with the public interest, but historically that regulatory lever has not been used to create such restrictions, and it would be highly problematic for the United States to decide who to send energy to and who not to based on criteria that the United States decides are the important ones. Besides, if the United States restricts its gas exports, there are other countries that will happily fill the vacuum. Another challenge to having gas displace coal is that there is not enough infrastructure for gas around the world. Less than half of current global coal capacity is close to a gas pipeline, and most of that is not located in developing and emerging economies. Price and energy security are also serious concerns for emerging and developing markets, and LNG can be an expensive and unreliable option, as countries learned when Europe took lots of the world's LNG supplies (leading some countries that lost out on gas supplies to burn coal instead). Finally, even if gas displaces coal, that only goes so far in the climate fight. Gas is a complement to renewables and other zero-carbon energy, but ultimately it is development of zero-carbon energy that must be driven.

For gas to be part of the climate solution, methane emissions also have to be slashed. If methane emissions offset the benefits of carbon reduction from coal displacement, then gas is not a solution. This is true in the United States as well as globally. Gas has arguably played a big role in cutting U.S. power sector emissions, but the assertion that gas has half

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the emissions of coal is about the point of combustion only. The story of U.S. emission reduction in the power sector may not be nearly as positive as has often been presented, given the lack of good monitoring and the uncertainty about leakage rates. There are debates about whether natural gas is actually less carbon intensive than coal over its full life cycle (though the local air pollution impacts of coal and coal ash are severe, and those benefits have to be kept in mind regarding gas-coal tradeoffs as well).

There has been increasing awareness of the problem of fugitive methane emissions. Emissions estimates in the value chain, however, are incredibly variable, depending on things like the assumed leak rate of methane and whether one is using a 20- or 100-year time horizon. There is credible empirical evidence of leakage rates that are a fraction of a percent, and there is credible empirical evidence of leaks that are multiple percents. Some assessments put the break-even point between gas and coal at a leakage rate around 2.5 - 2.75%, and other studies that take into account the global cooling benefits of coal combustion (due to aerosols) have put the point of parity at a leakage rate as low as 0.2%. The results vary significantly based on the assumptions. The huge error bars on any estimates or comparisons highlights how critical it is to get to an understanding about the actual intensity of the natural gas value chain. (It is also important to recognize that while methane emissions from gas systems are a problem, far more methane emissions around the world come from agriculture and landfills; there are also projections that methane released from a melting Arctic could consume a meaningful amount of the remaining carbon budget.)

Because of aerial and satellite capabilities that are emerging, it may well be that unintended and intentional methane emissions go from unknowns to knowns fairly quickly. There are many advanced monitoring and modeling frameworks coming online now or within the next year that will be incredibly useful for improving the ability to understand and reduce methane emissions. There is a growing international system of systems for methane monitoring, including systematic aerial surveys with advanced imaging, a new generation of satellites, observations from aircraft and the International Space Station, and more. Methane data is being released publicly, with images, geolocation, emission rates (with uncertainties), and sectoral attribution. The data is increasing, with action from many governments, non-profits, companies, and philanthropies. It is imperative to coordinate and pool resources across actors to scale up monitoring and to provide trusted and transparent accounting of the true greenhouse gas footprint of natural gas supply chains.

Methane emissions are not just a climate story; they are also a wasted supply story. Combined, all the methane flared, leaked, or vented would constitute the third-largest gas producer. A growing body of empirical evidence has accumulated over the last decade underscoring the scale of methane emissions from oil and gas operations. Analysis of data from multiple observing systems on land, in the air, and in space indicates a relatively small number of high-emission point sources ("super-emitters"). The role of super-emitters varies dramatically by region and sector, including sectors beyond oil and gas, but the trend generally holds worldwide. High-emission events can be divided into leaks (unexpected) and process emissions (e.g., venting, flaring) that are mostly expected and mostly wasteful. In addition to the challenge of super-emitters, it is also important to take action on the widely distributed population of smaller emitters in most oil and gas operations.

The methane issue has long been seen as a solvable problem, but it is long past time to actually solve it if there is to be a role for gas in the energy mix of the United States or anywhere else moving forward. Methane data is being communicated to regulators and industry operators in various countries, including the United States. When sufficiently motivated and armed with actionable (i.e., complete, reliable, and timely) data, operators can take steps to diagnose and repair leaks and wasteful venting. Some operators have found that nearly half of the super-emitters detected with flights were previously unknown, and leaks have often been quickly repaired (as sometimes verified by subsequent flights). Some utilities have pledged to achieve net-zero emissions from methane in the natural gas value chain and have utilized satellite monitoring to find leaks at the hyper-local level, done work to replace pipes with materials that are less prone to leaking, and taken other steps to achieve the goal of eliminating methane leaks. Many of the solutions to methane emissions can be implemented now and are very positive for workers, but there is a need for new contractors, workers, and apprenticeships to build that workforce.

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Energy Secretary Granholm has asked the National Petroleum Council, a federal advisory committee to the Secretary, to conduct a study on how to reduce the greenhouse gas footprint of the natural gas industry. The Secretary wants the study to review: (1) the technological investments, market mechanisms, and policy and regulatory measures that can be used to reduce greenhouse gas emissions from the industry; (2) how to ensure people and civic groups are meaningfully engaged and societal concerns about natural gas use and greenhouse gas reductions are addressed; and (3) how to simultaneously address affordability, energy security, and decarbonization. The study is looking at emissions associated with the entire value chain, up to but not including end uses— in other words, natural gas production and delivery. Methane is a core part of the study, as is carbon dioxide. The study will include a deep dive on various detection and measurement technologies. The aim is to publish the study in April 2024.

The goal should be for supply to come from the most GHG-efficient plays and delivery systems, and there should be competition within the industry to provide supply on those metrics. A differentiated natural gas market is emerging as a potentially important international tool to reduce greenhouse gas emissions across global natural gas supply chains. Such competition could be a way to prod action by national oil companies (NOCs), which might be well positioned to drive down methane emissions because they are not responsive to shareholders; the current presidency of the UNFCCC COP may be uniquely situated to move NOCs. If the market values more GHG-efficient production plays, and if U.S. producers are winners in that world, that could also open new doors for political support for major U.S. climate action; natural gas could be a political bridge to bring more Republican support to major U.S. climate policy. Building trust in something like a differentiated market, however, will require a transparent framework for reporting of independently verifiable and actionable emissions data — especially for methane.

Even if gas displaces coal and methane emissions are addressed, most greenhouse gas emissions from the natural gas value chain are from end-use combustion rather than from emissions upstream or midstream. That makes CCUS for natural gas combustion particularly important. The prospects for natural gas with CCUS are strong, and there are proposed federal regulations that could help accelerate CCUS plants.

Ensuring coal displacement, addressing methane emissions, and deploying CCUS for end-use gas combustion will not just happen. Conscious decisions have to be made in the United States, Europe, and the rest of the world to make those things happen.

Decarbonizing Aviation

Aviation is the third-largest contributor to U.S. transportation GHG emissions, factoring in fuel used for both domestic flights and international departures from the United States.

The U.S. transportation sector — the least energy-diverse and highest-emitting sector in the country — currently depends heavily on petroleum fuels. Aviation is the third-largest contributor to U.S. transportation GHG emissions, factoring in fuel used for both domestic flights and international departures from the United States. Predictions are that aircraft emissions globally will increase substantially over the next 20 years. Decarbonization requires solving for the mobility landscape, including mobility in the skies.

Innovative Technologies

The aviation sector has been improving its energy efficiency, but not as quickly as the sector has been growing, which means net emissions have been on the rise. The key challenge is to decouple emissions growth from the growth of the sector. There is still more to do to advance thermal efficiency, but the traditional architecture is reaching the limits of efficiency. This must be a decade of investment, to mature and scale technologies and architectures for the next generation of products.

In 2021, the U.S. Department of Transportation (USDOT) released an Aviation Climate Action Plan that lays out a whole-of-government approach and policy framework for decarbonizing the sector. The United States will implement a suite of policy measures to foster innovation and drive change across the ecosystem, including airlines, manufacturers, suppliers, airports, energy companies, airline customers, and various levels of government. The vision is that emissions will be decreased through many measures, including: introduction and development of new, more efficient aircraft; improvement in aircraft operations; production of sustainable aviation fuels (SAF); electrification and perhaps hydrogen for short-haul flights; advancements in airport operations; international initiatives, such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA); and domestic policies and measures to help meet emission targets and to support research on climate science related to aviation impacts. The federal government has also established an interagency climate innovation working group and has introduced a Sustainable Flight National Partnership at the Federal Aviation Administration (FAA) to demonstrate aircraft technologies that achieve improvements in fuel efficiency.

While liquid fuels and SAF will be key to the sector's decarbonization, so too will other innovations in aviation technologies. Some of those innovations could involve the design of the aircraft itself. For example, one U.S. Air Force project is looking at blended wing body (BWB) technology. Recent advances in design and manufacturing have allowed for the challenges presented by a non-cylindrical pressure vessel to be overcome. Since the whole aircraft produces lift, not just the wings, the aircraft is much more efficient, reducing the amount the DOD has to pay for aviation fuel. BWB aircraft would allow the military to provide more mission capability, because they have more internal cargo volume and require less refueling for longer distances. Less refueling could mean a better, more secure, less targetable fuel logistics supply chain, particularly for missions in regions (e.g., the Pacific) that could involve trips thousands of miles long. The first flight could be in the late 2020s, with craft out in the field by the mid-2030s. The first aircraft will use existing propulsion systems, but if hydrogen or other propulsion systems become available, they could be integrated into the second generation of blended wing body aircraft.

There are innovations being pursued in propulsion systems as well. Some are working on open fan propulsive systems. Advances in materials technology (for the fan blades) and supercomputing capacity (to gauge the fluid dynamics) have unlocked the potential for open fan, which provides turbofan aircraft speeds at turboprop efficiencies.

Others are working on zero-emission engine designs. The climate impact of aviation is about not just CO2 from fuel combustion, but also high-altitude emissions of combustion artifacts such as nitrogen oxides (which are inherent in high-temperature combustion), particulate matter (from unburned fuel), and high-temperature water vapor. To solve that problem, there is a need to move away from combustion at high altitudes, such as by electrifying the systems. One way to do that is with on-board hydrogen and a fuel cell to produce electricity to drive electric motors; such fuel cell systems can be far more efficient than thermal engines. The technology will likely start with small commercial aircraft, but it could be applied to all sizes of aircraft over time. Over several decades, as the current fleets of aircraft that burn hydrocarbons phase out (hopefully after using SAF as transition fuel), hydrogen may become a primary moving force for aviation. For smaller aircraft, $5-6 per kilo of hydrogen could be the break-even point, given the efficiency difference between relatively small combustion engines and fuel cells. Some green hydrogen projects already reach that price point, and within the next few years (which is when the aviation technologies could be entering the market), the cost structure could be even better.

While hydrogen may be promising, there are many unknowns in the upstream energy ecosystem, including what clean energy storage vectors will look like, what infrastructure will allow, and what clean energy sources will be available to aviation. For instance, it is not a given that clean hydrogen will be available to the sector. Aviation is one of the most expensive sectors to decarbonize globally, and any clean energy allocated toward aviation has an opportunity cost that comes from not deploying it somewhere else that may be an easier or more efficient decarbonization opportunity. The sector should not be settling now on a single energy vector. Options should be kept open, and technology should be matured across market segments to enable different parts of the industry to access whatever energy carriers are actually available.

The timing for the next generation of aircraft may be in the mid-to-late 2030s. Since it can take several years to certify an airplane, that only leaves a few years to get some of the technologies up the technology-readiness curve and ready to launch. That is challenging. Some of the major current players in the aviation space are engaged in the challenge of advancing innovative technologies. The airlines, for instance, are involved in various ways, including participating in discussions (e.g., on BWB initiatives), engaging in hydrogen hub conversations in different regions, and investing in companies. For carriers, any fuel or technological approach has to be supported across the country and at all of their airport hubs. The large airplane manufacturers are also somewhat engaged, including working with various engine innovators. The large manufacturers, however, have years of orders on current models, and their parts suppliers have backlogs of parts for those planes. They are trying to keep their businesses afloat and are not really incentivized to switch models. Accordingly, many innovative approaches are being driven more by startup-type companies, which have many people who used to work at the big manufacturers and who want to help the newer technologies proceed, mature, and take the next leap.

These startups are often the private part of many public-private partnerships that are helping to accelerate the next generation of aviation technologies. Considering the financial and human capital required to develop innovative technologies and get them certified, public-private partnerships are essential to scaling the investment and getting the different families of technologies to maturation in order to enable the next generation of aircraft.

Another key challenge in decarbonizing aviation is the billions of new consumers in emerging economies that will be flying around on low-cost carriers. Most of the aircraft being purchased in emerging economies are existing narrow-body models, and thousands more of the current generation of airplanes will be delivered. Technologies developed and demonstrated in developed economies need to quickly spread to rapidly developing markets, otherwise there will be even more of the current generation of aircraft that have to be retrofitted or replaced.

While commercial aircraft represent the bulk of emission reduction potential in aviation, there will be a need for other technologies that can replace some aviation-miles-traveled. For instance, further innovation and expansion of higher-speed rail could replace a lot of short-range air travel. Part of the answer for sustainability in the aviation sector is moving people faster and better on the ground.

Another part of the answer could be electric unmanned aerial systems (UAS) and drones. There are many practical use cases for UAS that can provide flexibility, remote operations, and autonomous operations; examples could include military missions, reconnaissance, search and rescue, and first response to the scene of traffic accidents. In the transportation sector, UAS have mostly been leveraged for asset monitoring and management (e.g., bridge inspections).

Regulatory & Public Hurdles

The innovations are real and exciting, but they will run up against an ossified regulatory approach. That approach has led to aviation being an almost perfectly safe mode of transportation, which is amazing, but it is not very accepting of new models of propulsion and transport for manned aviation. Unmanned aviation, such as commercial drones, represent a cautionary tale. There has been very little regulatory progress on drones in over a decade, despite the fact that they do not weigh very much and have little chance of killing anyone. There has been little progress because regulators are attempting to force an emerging technology into an old regulatory framework that is not particularly accepting of it. The regulatory apparatus is not agile, nimble, or adaptive. Regulators have created a very safe and stable environment with respect to one set of legacy technologies, and it can be tough to ask established regulators to be innovative. (Innovative aviation companies may want to learn from advanced nuclear reactor companies who are currently dealing with the challenges of getting innovative technologies certified through an ossified regulatory apparatus.)

That said, regulators interacting with innovative aviation companies have shown huge interest in seeing the technologies applied commercially. There is interest not just at the top, but also from subject matter experts at the middle and lower levels, who see the challenge and want to participate in making aviation cleaner. Agencies are putting in significant funds and devoting meaningful attention to the new approaches, which could translate to faster certification once technologies have been proven. It is challenging to push a new paradigm through an existing regulatory framework, but regulators have generally been receptive.

At the various aviation regulatory agencies around the world, there will need to be harmonized, standardized approaches to new technologies; that is the only way the commercial air industry can work. Compartmentalizing the challenges can help. Retrofitting existing aircraft and keeping existing control surfaces and flight characteristics as they are (i.e., just replacing the engine) reduces the scope of change and may allow for quicker regulatory approval. Testing and proving out technologies and design changes one at a time in a more traditional environment allows each to be assessed on its own; future generations of products can then incorporate many of the already-assessed technologies.

Even if the sector can solve the innovation challenges and obtain regulator buy-in, there is still a consumer at the end of the value chain whose entire lived experience of aviation is piling into a tube. Any significant changes could be challenging. Humans have behavioral quirks, willingly facing vast amounts of risk every day but accepting almost none when they fly. Consumer tolerance for change is a key factor in decarbonizing aviation (and, really, every other sector). As different solutions are tested and developed, it is worth thinking about how to minimize the changes to the lived experience of consumers. DOD could play a role in proving out technologies in ways that get the public comfortable with changes.

International Aviation

Globally, most aviation emissions happen outside of domestic borders and are not subject to countries' Nationally Determined Contributions under the Paris Agreement. A separate framework was needed. The United Nations and the International Civil Aviation Organization launched CORSIA, which applies carbon pricing to international aviation.

As it currently stands, CORSIA is not that strong. CORSIA forces airlines to buy carbon credits on the voluntary carbon markets (which have their own issues). CORSIA has created a regulatory wrapper around those credits and restricts the types of credits available, but the price is not that different from what is available on the open voluntary market, which suggests the stricture is not that significant.

That said, it is notable that all UN nations agreed to the CORSIA framework, and CORSIA could help create the right economic environment to drive some of the new technologies. CORSIA is voluntary for the next few years but then will become a compliance market; it is unique in having a compliance market built on the voluntary market. Most carbon pricing systems (e.g., cap and trade) that are compliance markets allow offset crediting as a compliance mechanism, often with some limit, but what is different with CORSIA is the expectation that most airlines will comply by taking advantage of the voluntary carbon market option, given how few other options currently are available. The work now is to strengthen CORSIA, whether by expanding its scope, bringing more high-quality carbon credits to the marketplace, or better restricting some lower-quality offsets.

Airports

The entire aviation ecosystem has to be considered as the sector decarbonizes — not just the planes. While airports are a relatively small portion of the sector's emissions, they might be easier emission reductions to achieve. Airports are essentially small cities. They have hospitals, restaurants, all kinds of buildings, parking lots, and millions of people. There is a lot about decarbonizing cities that can also be applied to decarbonizing airports, and vice versa.

Some of the decarbonization involves technological change, such as switching away from diesel generators. There is also a lot of gain still to be had from energy efficiency and better practices in airports. For example, an airline asked its pilots at one airport to plug in at the gates instead of keeping the planes running and saved millions of dollars in jet fuel just through that conservation effort. Likewise, in the military, there are planes that run engines at all hours because support equipment was not sufficient or reliable enough to run power to the plane properly. Improvements to equipment, procedures, and behaviors can lead to lots of energy and dollars saved.

It is important both to decarbonize the airports and to enable the airports to provide low-carbon energy to the new generations of aircraft. The latter is the bigger lift and needs to be addressed. The potential needs of airports that are electrifying could be game-changing for the serving utilities. Re-charging of electrified aircraft, as well as the array of supporting trucks and vehicles, could mean an airport load that is many times larger than what is currently the norm. There are some FAA grant programs to electrify ground service equipment, and there are ways to put solar and other assets on airport facilities. Utilities, however, generally have not been part of public-private partnerships and dialogues around innovation and the need to support infrastructure growth at airports to support decarbonization. Utilities will likely need to confront these types of electrification challenges much sooner in the medium- and heavy-duty freight sector and in the electrification of manufacturing and industrial facilities, but they should expand their focus to include airports as well. There is a need to bring in utilities, the FAA, and others to figure out the authorities and abilities airports have to look at their electricity supply in different ways, as well as the roles, training, and certification standards needed for runway staff.

The U.S.–China Relationship

China is the largest current global emitter of greenhouse gases. There is no solution to the problem without China. The relationship between the United States and China, however, has become fraught with tensions.

China's Supply Chain Dominance

U.S.–China tensions create strong headwinds for the clean energy transition, most obviously by affecting costs and supply chains. Cheap and available Chinese products, including solar, batteries, and magnets, have accelerated the transition in the United States and globally for many years. Recent tensions have played big roles in the imposition of solar tariffs, export restriction on elements such as germanium and gallium, and other supply chain challenges.

In 2000, the U.S. Congress voted for permanent normalization of trade relations with China, thinking it would support Chinese reformers, create reciprocity of market access, and improve China's approach on human rights. It did not work very well. The pendulum is now swinging the other direction, but China was not a passive actor during the intervening years. Export-led growth has driven a lot of economic growth in China over the past few decades, and the Chinese government has invested billions in building the ecosystem around strategic industries' supply chains to achieve that, including in the clean energy sector (e.g., EVs, solar). With respect to solar, for instance, China dominates supply chains for polysilicon, ingots, cells, and modules. Most of the largest wind manufacturers are also in China (though about half of the U.S. supply chain in wind is domestic), and China dominates critical minerals processing as well. China pushed to develop these industries to build expertise in new industries and to shift the balance of power between China and the United States (and the West more broadly). It has been a self-sufficiency game, to hedge against Western efforts to contain it. China has moved from being dependent on the West for many things to being interdependent and then to being less reliant on others than on itself.

The risks of dependence on China are real but may also be exaggerated in some cases.

In discussions of Chinese supply chain dominance, there is an assumption that it is a problem if the vast majority of something is imported from China. That is true in some areas, but it may be less true in others; the risks of dependence on China are real but may also be exaggerated in some cases. For example, the United States is heavily dependent on Chinese supply chains for smartphones, but there is less consternation about that. It is worth thinking about what, if anything, is different about energy. Some things are sensitive national security concerns, but many other things may not really be problems. It is important to be clear about what the issues of concern actually are, and why. For instance, concern about China winning the clean tech race is not about addressing climate change but about industrial competitiveness. Given the need for speed and scale in clean energy deployment, the risk of significant cost inflation in global supply chains if there is meaningful separation from China, and how hard it will be to change supply chains, it is important to be clear on where the problem areas are.

There are a few sensitive things to be addressed in the U.S.–China relationship, but for cost purposes, there should be lots of trade in everything else. If the goal is to achieve speed and scale globally via cheap and relatively good quality EVs, solar panels, wind turbines, and the like, China offers that. There should be a small yard with a high fence. If solar panels, batteries, and many other clean energy components are within that high fence, the restrictions on global trade could have huge implications for cost inflation for the transition.

On the other hand, the costs from China have been low for reasons — labor arbitrage, environmental arbitrage, and intellectual property theft (and other supports) — that the United States cannot compete with. China has dominated due to strong state incentives and support, low input costs, tolerance of energy- and emissions-intensive industries, and "encouragements" for foreign firms to transfer technologies into China and then scale them up. The labor arbitrage issues go beyond Chinese borders; China has been buying up critical mineral resources throughout developing countries and exporting its own labor practices. The purpose of clean tech efforts is to benefit people and the environment, so it is hard to justify buying products that are made in ways contrary to that (e.g., with forced labor), even if that means costs are higher. That was the rationale behind the Uyghur Forced Labor Prevention Act (UFLPA). The UFLPA requires companies to prove to Customs that no part of the supply chain touched Xinjiang province, but companies are still trying to figure out how to do that. In the meantime, there are warehouses filled with solar panels that are just sitting and waiting. Some argue that tariffs of any sort do not help anyone and have cost billions of dollars, radically slowed deployment of renewables, and put climate goals at risk.

If Chinese clean energy supply chains get cut off or disrupted, the nature of the disruptions will be very different than when Russia cut off some gas supplies to Europe. Economies would not come to a halt immediately. There is a big difference between disruptions to the daily flow of energy and to an input in a finished good. Disruptions to, say, solar panels or critical minerals might lead to cost increases and delays, but not to catastrophe. That said, even inputs to finished goods could be weaponized. The problem with really high levels of market dominance is that it provides too much market power and creates limited resilience and diversity in the system. For instance, countries have not really weaponized their oil supplies, though they have with gas supplies, in part because there is no supplier of oil that produces more than about 10% of supply. Cutting off oil exports would therefore mostly cause pain to the exporter and would not really target whoever the country is seeking to hurt. Critical minerals are more like gas than oil; there is relatively little cost to China from cutting off supplies, and doing so can cause significant, targeted pain.

The risk of concentration in the supply chain is not just that the dominance might be weaponized, but also that there is heavy reliance on a potentially unstable partner.

The risk of concentration in the supply chain is not just that the dominance might be weaponized, but also that there is heavy reliance on a potentially unstable partner. A lot of the conversation about dependence on China is framed around the presupposition of China's economic strength and geopolitical rise, but those are not givens. China does have great strength in clean energy manufacturing, critical minerals, and other important areas, but the macro picture is quite complex. Economic growth has been down in China recently, youth unemployment has been high, and there will be millions of retirements in coming years. There have been ongoing issues around China's failure to build a true engine of innovation. If China is soon or already operating in a position of macroeconomic weakness and demographic decline, there is a non-trivial risk that China could be quite unstable over the next couple of decades.

Either way, the fragility of U.S. supply chains in a world that is fracturing is a significant political and substantive risk to the clean energy transition. The U.S. government recognizes the dependence on China, but the concern is less about particular areas where there is dominance and more about the fact that the United States is dependent across a multitude of technologies in the upstream and midstream. That is a real risk to U.S. climate, energy, and economic goals.

The aim is not to phase out China's production, which is not possible anyway; China is the largest demand center, which means it will have a large supply, which will bring production costs down. Scrubbing technologies such as solar and batteries of Chinese presence is also virtually impossible, at least in the short term. Even if the United States resurrects solar panel manufacturing, the module manufacturing is concentrated in China — and even if the modules do not come from China, the wafers, silicon, or polysilicon probably do. To counter Western policy measures, some Chinese companies have also moved into other provinces or other countries to be able to sell into Western markets; buying components from Mexico, Vietnam, or other countries does not mean China is absent from those supply chains.

If the United States wants to be a leader in the future of clean technology, there must be some revival of U.S. manufacturing. The domestic content requirements and adder in the IRA, for example, are already spurring plans to ramp up solar module manufacturing in the United States. Increased domestic mining (e.g., for critical minerals) will also likely be needed. Domestication of clean energy manufacturing can help with quality control and with delivering projects on time and on budget. In addition, when systems in the United States go offline because of increasing natural disasters, having components domesticated makes it easier to get back online faster. There are some concerns that bringing lots of U.S. manufacturing back could lead to significant cost increases, which in turn could have negative impacts on deployment and on jobs associated with deployment, but it is not a given that onshoring of manufacturing and mining will be a large driver of increased costs. If things are not competitive to do in the United States, they will not happen regardless of any change in policy. Besides, of all the many potential causes of price shocks and increases, onshoring of jobs is the only one that solves or at least counterbalances a political problem.

Still, given the need for massive deployment of clean technologies within a decade or so, there are questions about whether there is sufficient time to scale up domestic manufacturing for clean energy components. In addition, a lot of the manufacturing that politicians are looking to re-shore is energy-intensive and messy, including mining and processing. The United States is very well endowed with metals and minerals, but permitting reform and litigation reform are needed to access them. Realistically, a lot of manufacturing will not be re-shored. It could be friend-shored or near-shored, but it will not all be coming back to the United States.

The world is much bigger than just the United States and China. If the concern is about the resilience and security of supply chains, then the response should include diversification of supply chains and more trade with more countries. Protectionism for U.S. jobs and manufacturing is not necessarily the same thing (and can create headaches for companies, who do not know where the policy risk will land and may face the costs of duplicating supply chains). There are many countries concerned about the lack of diversity in supply chains. American relationships with countries across Asia are deepening quickly, as other countries are also concerned about China. One of America's key goals should be growing the diverse global supply chain needed for global decarbonization (even if that means slowing elements of America's decarbonization).

Even with those efforts, the United States will continue to have a large dependence on China for quite some time. For example, there are many ways to reduce dependence on China for critical minerals, but there is no scenario in which China is not a dominant presence in global critical mineral supply chains. There is not enough thinking about other policy steps that can be taken to increase security and resilience. Beyond diversification, steps such as preparing strategic stockpiles can help reduce supply chain risks.

In addition, while the focus of conversations has been how the United States can gain more control over supply chains for specific clean energy technologies, it is important to recognize that technologies are always evolving. New technologies could render the discussions moot.

Anti-China Politics & Chinese Investment in the United States

Anti-China protectionism is really popular politically. For instance, legislation almost passed in Congress this year that would have retroactively imposed sanctions on companies that had already made investments. The popularity is there even for things that would have negative strategic ramifications. It seems like a decision has been made, perhaps not expressly, that the United States is prepared to sacrifice speed and scale in tackling climate change, as well as other objectives and interests, in order to confront China on a range of issues. For example, hindering Chinese imports and bringing significant manufacturing of goods back to U.S. shores might lead to increases in cost, and tariffs on clean energy can cripple the ability of large companies with aggressive decarbonization goals to meet them. Cheap solar from China also accelerates utility-scale solar deployment, which contributes to the U.S. economy in many ways, including finance, wealth creation, and jobs. The installation part of solar is the most U.S.-based, the U.S. manufacturing base for trackers is expanding, and operations and maintenance provide more good jobs. There seems to be bipartisan support in Congress at the moment for an anti-China approach, however, so elected officials seem to have decided that such an approach is a politically good move despite the potential ramifications.

There is a lot of nuance and complexity in the situation with China, but it is hard to have nuance in the public, oversight, and political spaces when it comes to China. For example, foreign direct investment is usually seen as good, but there have been some high-profile incidents that highlight the tensions around China's involvement in the United States. A company that was selected to receive funds under a DOE program had significant operations in China (a subsidiary had party members), and DOE retracted the offer under intense pressure from the Senate (though the specific basis for the retraction has not been publicized). Another company partnered with a major U.S. auto manufacturer to build a U.S. battery manufacturing facility, and despite the creation of thousands of jobs, the project faced state rejections before finally finding a home. These are dramatic signs of the current U.S.-China tensions. The acceptable levels of cooperation with Chinese enterprises are not at all clear at the moment.

The appropriate relationship with Chinese entities when spending lots of U.S. taxpayer dollars advancing new technologies through DOE grant programs (i.e., where there is risk of tech transfer) may be very different from a situation involving broadly deployed tax credits to increase deployment of clean energy or clean energy manufacturing in the United States. Likewise, there are reasons to have concerns related to the production of certain key components needed for critical infrastructure (e.g., grid interconnection). It is rational to have very different approaches to risk for different kinds of programs, sectors, technologies, and situations.

Some suggest that the United States should let Chinese manufacturers sell as much as they want in the United States, and have tariffs waived for a few years, on the condition that they invest a large amount in manufacturing in the United States. That would allow the United States to learn more about the complicated clean energy manufacturing that China has come to dominate. There are a variety of technologies that China is better at manufacturing than the United States, including lithium iron phosphate (LFP) batteries. Allowing Chinese companies to invest in the United States means they will need to transfer technologies to the United States; there is an opportunity to capitalize on those technology transfers and to create the ecosystems needed to diversify manufacturing and supply chains over time.

This is something of a role reversal, and the idea of technology transfer and taking intellectual property from China can lead to some uncomfortable conversations in the United States — particularly given the competitive struggles U.S. manufacturers have had, the degree of access China already has in the U.S. market, and how closed and opaque China's market is. However, if the United States will be buying Chinese products for a while anyway, it might as well recognize that and figure out how to get more from it by building manufacturing domestically, learning how to do it better, and gaining jobs. (Having Chinese manufacturers invested in the United States could also reduce the risks of disruptions in China-based supply chains.) There could be an analogy to the situation with Japanese automakers a few decades ago, when there was great hostility as their imports started challenging American automakers; that hostility is largely gone in the United States today because those companies invested extremely heavily in the Midwest. The relationship with China is more complicated, but that could be a model.

China would like the opportunity to sell and invest in the United States. Chinese experts are thinking about proposing a list of goods that both governments would approve for trade and investment in the clean energy area, to facilitate Chinese sale and investment in the United States.

Security & Intellectual Property

National security will always be paramount relative to other political or economic goals. In the United States, national security and energy transition risks both tie to domestic manufacturing and supply chains. These security risks have at least two aspects, involving critical infrastructure and the loss of intellectual property.

With respect to infrastructure, most technologies the United States gets from China probably have risks that can be mitigated. There will be a few cases, however, that are highly consequential, and the United States does not want to be in a position where it later recognizes big risks that cannot safely be mitigated, wasting massive amounts of work and requiring infrastructure to be ripped out and replaced. There are concerns now in telecom about the 5G rollout, and the risk should be avoided in, say, the rollout of widespread grid-scale battery storage. If disrupting critical infrastructure is a potential goal of the country providing the equipment, it is rational to be cautious. On the other hand, if the concern is principally about cybersecurity, it may matter less where the equipment comes from than whether devices are connected to the internet; any connected device creates cyber-vulnerability.

There are also many examples of China "acquiring" technology and intellectual property from U.S. universities and national labs, using a range of approaches. The framework for technology developed under federal government funding at universities or national labs is that the entity takes title, not the government. There have been cases where startups that received federal funding went bankrupt, and Chinese companies came in and grabbed the intellectual property. There were not due diligence controls in place downstream, but there will be additional controls put in place to avoid this outcome. For example, President Biden issued an executive order in 2023 to lock down some domestic manufacturing of products that come out of the national labs and other federal investments. There are lots of efforts on research security, with unclassified technologies being controlled in very different ways given the threat that China (and a few other countries) present. New conflict-of-interest processes are being introduced at labs and universities funded by the federal government, and DOE is standing up an energy security process to evaluate potential grant awardees. The new programs and controls that have been introduced or are being contemplated within the federal government will make cooperation with China that much more complicated, slow grant processes, and somewhat limit access to labs, but the sense is that the efforts are worthwhile to keep more of what is invented in the United States.

It is not clear what China's reaction will be to U.S. efforts to cut off intellectual property theft and to reduce environmental and labor arbitrage. One could argue those are at the core of China's business models. Looking back at history, it is worth remembering that when the United States put an embargo on Japan on oil decades ago, Japan viewed it as an act of war.

Cooperation & Competition

In 1979, when relations normalized between the United States and China, the first agreement signed was a non-binding one on science and technology cooperation. That agreement has been renewed every five years since, and it has played a role in various endeavors, including in cutting the production of ozone-depleting substances. There appear to be differing opinions within the Biden Administration on whether to renew it again, and some Republican members of Congress have urged that it not be renewed. Regardless of whether it is ultimately renewed or not, the fact that there is a serious question about whether a non-binding agreement to cooperate on science and technology will be renewed underscores the rapid and remarkable deterioration of U.S.–China relations in recent years.

It is vital that the United States and China be part of the global science and technology cooperative ecosystem.

It is vital that the United States and China be part of the global science and technology cooperative ecosystem. Under the Obama Administration, several successful clean energy research centers were established. There has also been longstanding nuclear R&D cooperation in the civil space. In addition, for most of the past few decades, there has been a significant diaspora of Chinese scientists that have contributed to technical progress in the United States, and for the past couple of decades, U.S. businesses have contributed to clean energy deployment in China. A lot of these have slowed quite a bit recently given current dynamics between the countries, and the knowledge exchanges are very much at risk in the years ahead. Experts and students in both China and the United States have very valid worries about traveling to the other, and tensions between the countries will likely get worse before they get better, particularly given two elections happening in 2024: the Taiwanese presidential election and the U.S. elections (in which candidates will likely be vying to be the most anti-China).

The tensions also create headwinds in terms of political dynamics with other countries around the world. Countries look to the United States and China to show leadership on climate and clean energy, as they did a year before the Paris Agreement. Other countries would likely do more if the United States and China joined hands. The big, strategic, geopolitical cooperative efforts like what produced the Paris Agreement, however, may not be seen much going forward. China and the United States have both changed during the intervening years. In the United States, for instance, the IRA is very much industrial policy enacted with China in mind and would not have passed without the domestic content requirements and other elements designed to reduce reliance on China. (Other countries are adopting similar measures, including Canada in its budget and the European Union with the emerging details of its Green Deal industrial plan.) China, meanwhile, is not very interested at the leader level in cooperating with the United States or in the UN Framework Convention on Climate Change process.

The IRA is very much industrial policy enacted with China in mind and would not have passed without the domestic content requirements and other elements designed to reduce reliance on China.

It is not clear that a cooperative partnership is possible, but that does not mean that the United States and China should not work together. Even during the height of the Cold War, the United States and the Soviet Union worked on global issues, including public health. The United States and China should likewise work on common global challenges. The Biden Administration has expressed the need to work with China on health, security, and climate, including offering to work on methane and power sector market design; it is up to China whether to accept such offers. Greening China's Belt and Road Initiative could have significant beneficial impacts around the world and could hypothetically be another area of focus. Smaller forms of cooperation, like the science and technology agreement, could also still move forward.

These efforts, however, are not necessarily the same as a cooperative partnership. There is more likely to be a competitive framework; this is not a win-win situation for both sides. The United States has an opportunity to focus on future clean technologies (which recent legislation has invested in) and to lead with its strengths, including science and innovation. There is a lot of value in some sort of stable competition on climate with China, and at this point, the competition angle may be more fruitful for producing climate outcomes, as long as a floor to the competition can be instituted to avoid things going too far. Even within the competitive framework, the countries can still work together effectively enough to help the world benefit and to address important challenges.

One aspect of the competitive relationship involves expertise. China is emulating the U.S. science and innovation ecosystem, including the national lab system, and Chinese universities are quite good and getting better. China has active talent recruitment programs to recruit Chinese scientists from the United States back to China. It is worth considering whether the United States should have its own talent recruitment program to persuade some of those Chinese scientists to stay. More broadly, the need to hire a huge workforce and to retain the people educated in the United States might suggest a need for sensible U.S. immigration policy reform.

Global Trade

Trade is imperative to American national security, economic security, energy security, and climate security. Reforming the global trading system is an opportunity for policy and other approaches to create significant leverage to move toward a sustainable future and deep decarbonization.

Revised Trading System for the Transition

The global trade world that was launched in the 1940s was probably more inclusive, more transparent, and better at lifting up developing countries than the one that emerged in the 1990s and early 2000s. The answer to the challenges in the trading system is not to walk away from it but to remake, rebuild, and reinvigorate it with a new underlying economic foundation that is more inclusive, more engaging of people, more attentive to labor concerns, and more attuned to sustainability as one of the core considerations.

The answer to the challenges in the trading system is not to walk away from it but to remake, rebuild, and reinvigorate it with a new underlying economic foundation that is more inclusive, more engaging of people, more attentive to labor concerns, and more attuned to sustainability as one of the core considerations.

The theory partly underlying global trade was that countries with a common sense of economic destiny, shared prosperity, and international cooperation would be less likely to go to war and more likely to stick together during tough times. Russia has dented that longstanding theory, but cooperative frameworks are still better and are vital for getting the world to come together around a deep decarbonization agenda. If the world breaks up into trade blocs and abandons the global trading system structure, the world will be in a worse place on climate globally. The trading system is fundamental to the success of achieving deep decarbonization across the world at speed and scale.

The World Trade Organization (WTO) may or may not be the place for a revised trading system. Some feel that regional agreements and preferential trade agreements whose origin place is U.S. domestic policy tend to be better, more effective, and faster because their sanctions regimes are built in and swifter than the WTO.

In addition, carbon reduction and the amount of subsidization that should be expected from governments to achieve net-zero at speed and scale probably are not compatible with WTO rules that were crafted for a different kind of economy. There had been an oversimplified view of energy and economic policy — with developing countries evolving industry and developed countries relying on services — but developed countries are increasingly realizing that their resilience, reliability, and security are tied to supply chains and levels of dependency. Domestic content requirements and initiatives to spur investment in countries are accelerating ambition around the world, as everyone rushes to be the exporters of technologies such as green hydrogen. A hybrid approach is needed, allowing countries to make investments that violate current trade norms, but in targeted and time-limited ways as the system moves toward one that does lifecycle accounting at the border.

As trading and energy systems shift during the transition, lots of things will need new rules, including hydrogen, ammonia, minerals, and various clean technologies. Caution and a sense of balance are needed in the near term to avoid locking in higher costs over the long term in the name of protectionism. Pending negotiations over tariff elimination on environmental goods and services are critical to enabling the trading system to support the transition. The United States, for example, cannot currently export many technologies and services because it is priced out of a lot of developing markets, but exporting U.S. technologies and services to the rest of the world could help other countries reduce their emissions.

A key political conversation must also be had on fairness and equity; the developing world needs to be brought into the bigger discussion if any trading structure is to be seen as legitimate. It is imperative to engage countries rather than push them away from collaborative worldwide efforts to reduce emissions. However, the climate concept of common but differentiated responsibilities and the WTO concept of special and differentiated treatment for developing countries have both too often led to a pass for developing countries. A new approach to equity that focuses on capacity building, finance, and innovation may be preferable. The existing International Trade Center could be repurposed as a sustainable trade center, and that mission would go a long way toward developing countries feeling they are being encouraged to get up to the standards needed to be competitive in a world where sustainability matters.

Americans' Perceptions of Trade

Trade is a vital part of the clean energy transition, but the old trade order may not have been beneficial to that transition. Indeed, it may have made it fragile. The energy transition is a decades-long proposition, throughout which it will endure shocks and opposition, which are already evident and will get stronger. Any type of trade system enabling the transition has to be durable. The old trade order did not deliver that. It delivered efficiencies, but it resulted in overstretched supply lines and overdependence on foreign sources such as China. Much of the unhappiness with U.S. trade agreements comes from the fact that the United States lowered its barriers while not getting commensurate reciprocal trade access from large and growing trade partners. The trading system also came at the cost of precarity in people's employment. Factories were shutting down, and people were losing good-paying jobs, secure retirements, and the certainty of where they would be working in 10-15 yrs. Trade was not the only cause of that, but it was a significant part of the mix.

People's recognition of these shortcomings has affected the politics of trade in the United States. There is growing backlash against the globalized system, with increased de-globalization and on-shoring efforts. The sentiment has very quickly become part of the mainstream, and that has to be reckoned with going forward.

There have been concrete results from this political change. The United States-Mexico-Canada Agreement (USMCA), for example, is the first large-scale trade agreement that big unions were able to endorse aggressively, as it contained strong labor protections with enforceability mechanisms. There have been binding and sanctionable environmental and labor chapters in U.S. free trade agreements starting with the U.S.-Jordan agreement (2001), and after a break of a few years, every agreement has had such chapters since 2007. These inclusions have raised standards in other countries, sometimes literally forcing countries to develop environmental ministries where they have not had them. The USMCA, however, is a gold standard agreement and the most far-reaching on trade, labor, and the environment. There have been other concrete results from the political change as well, including the inclusion of strong domestic procurement incentives in the IRA to help build up domestic supply chains while also allowing flexibility to preserve EV supply chains across the Canadian border.

Agreements on Metals & Minerals

Demand for minerals and metals will increase several-fold over the next couple of decades to meet the needs of the energy transition. More investment is needed in the metals and minerals sector, including in upstream materials (e.g., cobalt, lithium, tin, aluminum) and downstream efforts to improve efficiency of use and recycling. The mines are not sitting there waiting to be built, and the energy transition does not occur without them. The energy transition will occur globally, and given global demand, supplies, and the timeline of mining, the United States clearly will require not just domestic industrial policy but also international partnerships. The United States needs market access for critical minerals, which involves friend-shoring, the right agreements, and the right commercial partners.

There are metals and minerals on which the United States is fully or almost fully dependent on imports, and there are countries with large reserves of those metals and minerals that are not currently U.S. suppliers. (Countries that have net-zero commitments are both potential partners and potential competitors for those supplies.) China has stakes and offtake agreements in many minerals, but it does not control them. Additional U.S. efforts to develop resources and sign offtake agreements could start to create more fungible traded markets, which will be more resilient to disruptions. There are numerous forums and countries with which negotiations on the trade of metals and minerals should be easier. Whether the G7, G20, OECD, quadrilateral security dialogue, or others, there are potential forums for U.S. dialogue with key suppliers of imported metals and minerals. Many potential suppliers, however, are not part of any of those forums.

The United States may need to enhance bilateral relationships with supplier countries. Negotiating realities make that difficult, however. Since there is no trade promotion authority, discussions will produce only soft results, which means non-binding, non-sanctionable, and with no market access. Trade promotion authority is in the purview of Congress, and many members of Congress got bloodied in past trade promotion authority exercises and are not interested in losing their seats for it now, particularly since trade has become even more of a toxic issue. In addition, while it sounds appealing to negotiate with Brazil, India, South Africa, and others on critical metals and minerals, those countries all dislike regional and bilateral agreements; they are not interested in them and have published papers inside the WTO challenging the very legality of plurilateral sectoral agreements. Even if the United States could get mineral agreements from countries, the big issue is not necessarily where the minerals are from but where they are processed, and the vast majority of processing still happens in China.

Border Carbon Adjustments

At the intersection of trade and climate, there are opportunities for creative tools to leverage market access and incentivize decarbonization across key sectors. The powerful lever of trade policy has to be used to create market incentives in the global economy to reduce carbon intensity.

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One such tool is a border carbon adjustment, which puts a fee on imports based on the carbon involved in making them. Nearly a quarter of global CO2 emissions are embodied in goods traded internationally. China is the biggest exporter of emissions in the form of goods. If domestic emissions were thought of based on consumption (instead of production) activities, emissions levels in the United States and other Western countries would be markedly higher. In the developed world, declining domestic emissions are being replaced with more carbon-intensive imported emissions.

On balance, what the United States imports is more carbon-intensive than if the same goods were produced domestically. The U.S. economy is less carbon-intensive than the world average, and China and Russia are both multiple times more carbon-intensive than the United States. If U.S. imports of goods matched the carbon intensity of U.S. production of those goods, it would lower U.S. annual domestic consumption emissions by hundreds of millions of tons per year. If the matching occurred throughout G7 countries, consumption emissions could be reduced by billions of tons.

There are several key design elements and questions to sort out in a border carbon adjustment, including which imported products are subject to it, how big the fee is, how the fee is set (and who sets it), how the fees are applied to products, what the definition is of embodied carbon, what information and data sources are used, what the baseline is against which carbon intensity is measured, what domestic emission reduction strategy is coupled with the border adjustment mechanism, and how other countries are treated.

A border carbon adjustment should have a structure that produces the desired environmental results, is administratively easy to use, is WTO-compatible, and brings people in politically. Some argue a border carbon adjustment is fully compliant with the WTO. The world already does something similar with ozone-depleting substances (ODS), and it has worked well for 30 years; there are excise taxes on imports of goods that contain ODS and products made using ODS, based on countries' own data. There are debates, however, about whether Europe's Carbon Border Adjustment Mechanism (CBAM) is WTO-compatible. The EU's CBAM requires other countries to think like it does and only credits climate strategies that align with the EU's focus on explicit GHG pricing (not implicit or effective pricing), which some think likely violates the WTO principle of focusing on equivalent substance, not form. The EU also uses its own carbon price for CBAM, rather than seeking to negotiate a common price or some kind of global social cost of carbon, and it uses its own methodologies for measuring embedded GHGs in traded goods, which is seen by many as unilateral and not WTO-consistent.

The EU CBAM is very different from all the U.S. proposals that are emerging. The EU CBAM is fundamentally price-based, asking other countries and importers how much they are charging for emissions, whereas the U.S. proposals that are emerging are performance-based, asking about the carbon intensity of goods. The most powerful leverage the United States has on climate and trade policy may be the large U.S. consumer market, and a global economy that values carbon efficiency in markets will create more demand for U.S. products and manufacturing and will add more jobs in the U.S. economy. China, in contrast, would lose out in such an economy.

Republicans in the U.S. Senate are meaningfully engaging on the concept, though not on any accompanying domestic carbon tax. (Having a border adjustment in the United States, however, would make the justification for all future domestic emission reduction activities stronger, politically and otherwise.) Discussion on both sides of the political aisle in the Senate is focused on driving international cooperation, including via concepts such as a carbon club, where the United States and its allies form a common border adjustment to create an even more powerful lever to incentivize lower emissions throughout the global economy. The opportunities, from the U.S. perspective, are not just about emission reductions but also about economics and geopolitics, which are what create the political opportunity. Polls suggest that a carbon tax that raises costs garners less support from the public, whereas a border adjustment that raises costs does not.

Rather than thinking of it as a border carbon adjustment, Republicans in the U.S. Senate think of it more as a foreign pollution fee. Politically, "pollution fee on Russia and China" is more palatable in the United States; if the focus is on a U.S. version of CBAM, Republicans and industrial Democrats will not be in the conversation. The challenge is that multinational companies with deep climate commitments will be essential allies, and there will be lots of anxiety in corporate boardrooms using "pollution fee on China" language. When talking to companies, there is a need to call it what it is, which is a market-driven carbon intensity performance standard and import fee. The messaging to politicians should be different.

Since OECD countries that have real carbon commitments mostly have similar carbon intensities, a carbon border adjustment mostly puts OECD countries in opposition with the big, carbon-intensive middle countries (e.g., Brazil, Russia, Indonesia, China).

Ideally, a border carbon adjustment would include all countries, but accommodations need to be made for the least-developed countries. That said, the least-developed countries do not have very high carbon intensities. Since OECD countries that have real carbon commitments mostly have similar carbon intensities, a carbon border adjustment mostly puts OECD countries in opposition with the big, carbon-intensive middle countries (e.g., Brazil, Russia, Indonesia, China). There will be delicate balances to strike, however. If Western countries are packaging environmentalism as protectionism, people in India and Brazil will just see protectionism.

Under a border carbon adjustment system, greenhouse gas accounting will matter a lot. There will be parallel accounting, with Scope 1 and probably Scope 2 emissions accounted for by the exporter (where the manufacturing happened), while Scope 3 emissions would be accounted for by the importer. It is possible that border carbon adjustments could have the (politically unwelcome) effect of increasing emissions in importing countries even as global emissions probably decline, posing problems for domestic reduction targets. CBAM, for instance, could end up increasing emissions in Europe if it spurs more European production of emissions-intensive goods such as cement, iron, steel, aluminum, and fertilizer. The same is probably true in the United States and its efforts to re-shore manufacturing. This suggests that there may be too much focus on domestic emission reductions and not enough on global reductions. Whether for countries or companies, if everyone keeps building their own inventories and focusing on their own targets, they will continue outsourcing emissions elsewhere and blaming them even while continuing to import those emissions.

A border adjustment has the potential to be a powerful mechanism to lower global GHG emissions. It is not a given, however, that a border carbon adjustment system will lead to a decline in global emissions. The error bars on the projected impact of such a system on global emissions are large, and it is unclear if the impacts will be positive or negative. The key question is whether such a system spurs countries to put up barriers against each other, thereby hindering the flow of clean technologies around the world. In reaction to the EU's CBAM, for instance, India has floated the idea of having a border carbon adjustment against Europe based on historical emissions. Similarly, though not a border carbon adjustment, the IRA's incentives and investments can drive emission reductions domestically and abroad, but the IRA also discourages free and open trade and encourages other countries to adopt similar policies that might end up fragmenting the global trading system. The IRA is creating bad habits in some markets, with countries looking out for their own interests. There is a risk, therefore, that policies intended to push things forward may also create barriers that could hinder progress.

Appendices: Participant List

Jack Akinlosotu, Director of Sustainability, City of Detroit

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

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Ross Bhappu, Partner, Resource Capital Funds

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Gilbert Campbell, Founder & Chief Executive Officer, Volt Energy Utility

Thomas Ciarlone, Vice President, Real Estate and Enterprise Energy, Comcast Corporation

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***Dan Esty**, Director, Yale Center for Environmental Law and Policy, and Yale Center for Business and Environment

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Susan Gray, Head of Energy Transition and Sustainability, Argo Infrastructure Partners

Misti Groves, Vice President, Market & Policy Innovation, Clean Energy Buyers Association

Jason Grumet, Chief Executive Officer, American Clean Power Association

Leia Guccione, Managing Director, US Program, Rocky Mountain Institute

Roberto Guerrero, Deputy Assistant Secretary of the Air Force for Operational Energy, Office of the Assistant Secretary of the Air Force for Energy, Installations, and Environment

Devin Hampton, Chief Executive Officer, UtilityAPI

***Emma Hand**, Partner, Dentons US LLP

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***Nicole Iseppi**, Director of Global Energy Innovation, Bezos Earth Fund

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Allie Kelly, Executive Director, The Ray

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Mariah Kennedy, Director, Datacenter Energy Strategy (Global), Microsoft

Kalee Kreider, President, Ridgely Walsh

Harry Krejsa, Assistant National Cyber Director for Strategy & Research, Office of the National Cyber Director, The White House

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James Murchie, Co-Founder, Co-Portfolio Manager and Chief Executive Officer, Energy Income Partners, LLC

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***Jeffery Shaknaitis**, Customer Sustainability Leader, General Electric Aerospace

David Sholl, Director of the Transformational Decarbonization Initiative, The Oak Ridge National Laboratory

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Margaret Tallmadge, Senior Development Manager, Navajo Power, PBC

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***Michael Webber**, Josey Centennial Professor in Energy Resources, Mechanical Engineering, The University of Texas at Austin

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Avi Zevin, Deputy General Counsel, United States Department of Energy

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

Appendices: Agenda

SATURDAY, AUGUST 5, 2023

Arrivals and Check-In

Opening Reception

Opening Dinner

SUNDAY, AUGUST 6, 2023

Breakfast
Welcome: Greg Gershuny, The Aspen Institute

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

SESSION 1: Briefing Room: Enormous Year in Energy

Moderated by Rich Powell and **Miranda Ballentine**
This has been a big year for energy, globally and domestically, geopolitically and legislatively: a war-exacerbated global energy crisis, towering new U.S. public policy, the return of reliability issues at scale across the country. What emergent megatrends define the current energy era?

Discussants:
Elizabeth Mettetal, Energy and Environmental Economics, Inc.
***Jim Robb**, North American Electric Reliability Corporation
Josh Sawislak, Deloitte Consulting LLP
Anna Shpitsberg, United States Department of State

SESSION 2: Incentives, Mandates, and the Future: Decarbonizing Energy Broadly

Moderated by Rich Powell
Following the dramatic failure of the Waxman-Markey bill (the American Clean Energy and Security Act) in 2009, the United States entered something of a decade-long political wilderness on climate change action, with the Obama administration attempting a regulatory playbook of executive actions ultimately ruled out of bounds by the judiciary. And then suddenly, starting in 2018, Congresses of all three complexions have enacted a stunning array of climate change and energy transition legislation, marking the largest ever investments in climate action anywhere. While the Waxman-Markey bill was defined by a set of mandates, recent successful legislation mostly instead relies on incentives as a key driver of change.

Have we now entered a new era where incentives are king? What incentives will characterize the next round of legislative climate action, and when?

Discussants:
Gilbert Campbell, Volt Energy Utility
Jane Flegal, Stripe
***Michael Webber,** The University of Texas at Austin
Avi Zevin, United States Department of Energy

* *Participating Virtually*

SESSION 3: The United States and China

Moderated by Miranda Ballentine

Tensions between the United States and the People's Republic of China are at an all-time high. Whether it is over solar tariffs, security concerns, or accusations of espionage (industrial and otherwise), there is reason to worry about how relations between the world's two biggest superpowers will affect the energy transition.

Will recent rounds of tariffs lead to onshoring of solar manufacturing, and is this even feasible? What is the future of joint ventures between the two countries – and (presuming that they are a realistic possibility), what are the risks? Moving forward, how will the U.S. strategically handle critical minerals and other vulnerable supply chains that are crucial to the energy transition? And if China were to invade Taiwan – how will this impact domestic energy security and climate change outcomes?

Discussants:

Jason Grumet, American Clean Power
***Michal Meidan**, Oxford Institute for Energy Studies
Mark Peters, Batelle
***David Sandalow**, Center on Global Energy Policy, Columbia University

Forum Reception and Dinner | ***Presented by: Google***

MONDAY, AUGUST 7, 2023

Breakfast

SESSION 4: Decarbonizing Aviation: Next Generation Propulsion Technologies

Moderated by Andrew Wishnia

As a matter of physics, liquid fuel may forever have a role in the aviation system, especially for long-haul applications. Yet, it's either expensive, or not zero-carbon to make liquid fuels. Therefore, thinking beyond fuel for the short and medium-haul markets, what technologies hold the most promise to decarbonize the aviation sector? Aviation is very highly regulated and safety-oriented. Can propulsion innovations be brought to market in a safety-compliant manner while ensuring that they are available for use in a climate-relevant timeline? What policies and market conditions will be needed to bring these technologies into use?

Discussants:

Roberto Guerrero, Air Force for Energy, Installations, and Environment
Allie Kelly, The Ray
***Val Miftakhov**, ZeroAvia
***Jeffery Shaknaitis**, General Electric Aerospace

SESSION 5: Monumental Time for Natural Gas

Moderated by Rich Powell

The invasion of Ukraine and the resulting disruption in global energy markets has brought a renewed focus to the natural gas industry. Domestic prices were up and volatile for the first time in nearly a decade, taking national electricity and heating prices up with them. U.S. LNG exports, strong but stable for nearly a decade, suddenly began to rapidly expand again, rebalancing global energy flows and geopolitical power. What is the future of natural gas in the United States in the short, medium, and long terms? How will methane control considerations be addressed? What's the future for LNG exports and the US role as the leading global exporter? What policy playbooks should be brought to bear?

Discussants:

***John Dabbar**, ConocoPhillips
***Riley Duren**, Carbon Mapper
Joseph Majkut, Center for Strategic and International Studies
Carla Tully, Earthrise Energy

Lunch & Optional Hiking Trip

TUESDAY, AUGUST 8, 2023

SESSION 6: Fission: A Nuclear Reversal of Fortunes

Moderated by Miranda Ballentine

There seems to be renewed interest in nuclear power as an important source of energy for electricity generation. Indeed, nuclear power generators have enjoyed a sudden interest from policymakers in maintaining the existing nuclear fleet in the United States. Yet despite its potential benefits, nuclear fission must still deal with significant questions about safety, security, and waste disposal.

Focusing on fission, what next generation nuclear tech will be deployed in the coming decade (and beyond) - and how? What are the new potential applications of nuclear energy? How will recent legislation assist in the development and deployment of new technologies? Can the NRC create a more nimble permitting process that will nurture and empower the nuclear industry while still upholding critical public safety imperatives? And ultimately, should we be focusing on small, incremental steps or Starship-enterprise level leaps?

Discussants:
***Kyle Danish**, Van Ness Feldman, LLP
Mason Emnett, Constellation
***Jessica Lovering**, Good Energy Collective
Doug True, Nuclear Energy Institute

SESSION 7: Expansion of Markets: Western, ERCOT, SEEM, etc.

Moderated by Miranda Ballentine

Over 80% of all wind, solar, and storage have been deployed in regions of the U.S. with regional wholesale markets, and voluntary procurement (primarily in wholesale market regions) of wind, solar, and storage has deployed the equivalent of 42% of all CFE capacity built in the U.S. since 2014. How important are markets to realizing the full potential of IRA, IIJA, and CHIPS? And in what ways do market designs help or hinder grid decarbonization while promoting resilience and ensuring affordability for all citizens?

Three regions are in the midst of significant transformation–what will it mean for rapid grid decarbonization? ERCOT–the largest and most important CFE market in the U.S.-- is under intense scrutiny on the role of CFE for grid reliability; the West is deep in the process of exploring a region-wide RTO; and the Southeast has chosen a different path through the Southeast Energy Exchange Market (SEEM). What are the similarities and differences, and how will these transformations impact other U.S. markets and markets around the world?

Discussants:
Bill Flores, Electric Reliability Council of Texas
Brian George, Google
Misti Groves, Clean Energy Buyers Association
***Nelson Peeler**, Duke Energy

Lunch

SESSION 8: Transmission, Interconnection, and Physical Limitations

Moderated by Miranda Ballentine

The physical capacity to move electrons through the grid has emerged as a major choke point in the energy transition. In particular, interconnection queues have in some instances reached crisis levels of delay and are beset by a set of incentives that promote unproductive gamesmanship. Meanwhile, construction of new electricity transmission faces a daunting array of obstacles that, in the absence of policy interventions, are poised to position inertia to prevail. In what ways can policymakers confront these challenges? What lessons can be drawn from historic infrastructure successes? What role can other system actors (project developers, RTOs and ISOs, utilities) play in ushering forward solutions?

Discussants:
Charlie Anderson, Arnold Ventures
***Jeff Bladen**, Meta
Jeannette Mills, Tennessee Valley Authority
Spencer Nelson, ClearPath

SESSION 9: Conservation, Electrification, Load Management, and Demand Response

Moderated by Rich Powell and Miranda Ballentine

As the effects of climate change manifest in increasingly unmistakable ways, system operators more often face grid stability crises for which a more diverse toolset might prove valuable. And, after a decade of incredibly cheap U.S. power and gas, fresh instability has renewed the economic case for many efficiency and conservation investments. Framed in the context of an ever expanding set of "connected" devices (thermostats, consumer electronics, appliances, electric vehicles), what are the emerging futures of load management? How will load management be impacted by continued electrification? What consumer demand signals might prove particularly effective? What role does traditional conservation play?

Discussants:
***Zachary Freeze**, Walmart
Paula Glover, Alliance To Save Energy
Leia Guccione, Rocky Mountain Institute
Carla Walker-Miller, Walker-Miller Energy Services

Forum Reception

Forum Dinner | ***Presented by: Wells Fargo***

WEDNESDAY, AUGUST 9, 2023

Breakfast

SESSION 10: Trade Transformed: Risks and Opportunities in deglobalization, multilateral cooperation, and the post WTO era

Moderated by Rich Powell

The United States' trade agenda is undergoing a period of historic upheaval. Globalization seems to now be disfavored relative to new "America First" strategies (exemplified in particular by the array of recently passed historic subsidies for domestic clean energy investment). Abroad, the relevance of the World Trade Organization continues to decline and European allies have announced a "border carbon adjustment mechanism." All the while, multilateral, bilateral, and regional trading regimes are emerging as the new trade world order. In what ways is the United States well positioned to leverage trade opportunities to reinforce energy security and climate change imperatives?

Discussants:
Greg Bertelsen, Climate Leadership Council
***Dan Esty**, Yale University
Melanie Kenderdine, Energy Futures Initiatives
Ross Templeton, International Association of Iron Workers

Forum Adjourns

Lunch

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