2021 ASPEN ENERGY WEEK FORUM

EDGE OF TOMORROW: DECARBONIZING THE U.S. POWER SYSTEM

A Report from
2021 Aspen Energy Week Forum

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THE ASPEN INSTITUTE ENERGY & ENVIRONMENT PROGRAM

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EXECUTIVE SUMMARY

The power sector must be front and center in efforts to decarbonize the economy. In the United States, the sector has reduced emissions significantly over the last 15 years or so, due to a combination of relatively flat load growth, coal-to-gas switching, and increases in wind and solar deployment. Renewable energy is now in the "awkward adolescent" stage – big enough to know it will be a central part of the integrated grid, but not there yet. Renewables play a key role in several studies and models presenting potential paths to achieve a power system that is reliable, affordable, and fully or substantially decarbonized. However, under policies currently on the books, power sector emissions could also flatline over the next 30 years, given high load growth (as other sectors electrify), fewer uneconomic coal plants that can be retired, additional nuclear power retirements, and continued growth of low-cost natural gas. Voluntary decarbonization commitments made by utilities, if actually realized, could help lower emissions further, but there is still a big gap remaining to get to net-zero.

The power sector is the easiest sector of the economy to decarbonize, but that does not mean it is easy. The primary barriers to the rapid scale-up of clean energy are now more institutional and social/cultural than technological or economic. For example, community opposition to siting of low-carbon infrastructure (e.g., wind, solar, transmission) represents a key barrier. Deployment will require understanding community concerns and respecting communities' self-determined energy choices, but there may also be a need for federal preemption of decision-making if siting and deployment of clean energy infrastructure at the necessary scale and speed are to be achieved. Additional barriers include challenges related to interconnection, critical materials, resilience, security (including cybersecurity), and customer adoption.

Deployment will require understanding community concerns and respecting communities' self-determined energy choices, but there may also be a need for federal preemption of decision-making if siting and deployment of clean energy infrastructure at the necessary scale and speed are to be achieved.

Equity and labor issues have become more central over the last couple of years. America's energy economy is deeply inequitable, as are the impacts of climate change. The clean energy transition should improve air quality, community health, and affordability, but conscious efforts will be needed to avoid creating decarbonized-technology haves and have-nots. Frontline communities' receptivity to potential climate solutions depends on whether a given project helps solve a community's long-standing problems, as well as on honest, consistent engagement. It is only possible to move at the speed of trust, and trust has to be earned. Communities also need access to capital that can allow them to build wealth via the energy space. While the clean energy transition cannot be freighted with solving every systemic inequity, the huge sums of money spent on energy and climate could be used to make progress both on decarbonization and on other systemic challenges facing frontline communities. Communities that have been reliant on high-emitting facilities and industries require focused attention during the clean energy transition as well; leaders in those communities are clamoring for opportunities to re-use coal plant sites and retain some of the jobs. The clean energy future, supported by the right policies and standards, might create the kinds of middle class, family-sustaining jobs that the old energy industry did and still does. Unions have the capacity to train as many people as needed to enable a clean energy transition at speed and scale. Unions have not had much success in onshore wind and solar, but most of the rest of what is needed to decarbonize the power grid involves union work.

Markets can play a key role in decarbonization, providing price signals and structures that allow customers and other market actors to drive clean energy deployment. Competitive markets have thus far been delivering decarbonization, but that does not necessarily mean they will continue to do so. Markets are experimenting with and figuring out how to adapt to states with decarbonization and clean energy targets, as well as to all the distributed, dynamic, demand-side resources coming onto the system. There are many actors who would like to see markets established where they do not currently exist, such as in the U.S. West and Southeast, though there are issues to fix in organized markets related to governance, transmission build-out, and other areas. A sizable majority of corporate renewable energy offtake has been happening in organized wholesale markets, and corporate energy procurers are continuing to evolve their approaches, including some that are now looking to source 24/7 clean power on every grid they are part of. While most corporate procurement is centered around renewable energy credits, there are groups working to figure out what next-generation corporate clean energy procurement looks like.

Markets are enablers, and policies can help shape what they are enabling and how well they do it. While states have led the way on policies to decarbonize the power sector, the federal government has important roles to play. There is now a rare opportunity to enact significant climate measures in Congress, via the two major policy packages that appear likely to move – a bipartisan infrastructure package and a big budget reconciliation play. The bipartisan framework could be an avenue for important complementary policies, such as with respect to siting and permitting of transmission, that would be hard to present as budgetary policy for inclusion in a reconciliation package. The centerpiece policy in a reconciliation bill has been a Clean Electricity Payment Program, which is similar to a Clean Energy Standard but involves incentives and payments for load-serving entities that perform at a certain level. Extensions of clean energy tax incentives for project developers are likely to be part of the package too, though perhaps modified to enable more projects to get built (e.g., by adding a direct pay option). There have also been proposals in Congress for technology-inclusive tax credits to help breakthrough technologies get from demonstration to commercial deployment; other tech innovation policies could include greater investments in technology demonstrations and demand-pull procurement approaches (e.g., advanced market commitments). In addition, transmission planning and development – both in terms of building new transmission and upgrading existing transmission – need policy and financial support, as does the distribution grid. There is also a need for large-scale policy change around project development, otherwise climate solution projects will not be able to be built quickly enough.

The clean energy conversation often goes straight to supply-side solutions, but that ignores the potential of the demand side – energy efficiency, conservation, and demand response – where digital technologies have opened up new opportunities.

Greater ambition on emission reductions calls for greater tech inclusivity, and a broad suite of technologies will be needed beyond wind and solar. The clean energy conversation often goes straight to supply-side solutions, but that ignores the potential of the demand side – energy efficiency, conservation, and demand response – where digital technologies have opened up new opportunities. Digital technologies will also provide insights, monitoring, and tools to inform and execute the decisions needed to achieve net-zero, including decisions by corporate buyers seeking 24/7 clean electricity, electricity system managers, and others. Long-duration energy storage will enable variable renewables to replace thermal generation. Geothermal energy can provide dispatchable renewable power by repurposing a lot of U.S. oil and gas innovations and idled workers, while the U.S. hydro system needs to be rebuilt, better maintained, and optimized. Carbon capture, utilization, and storage could be a particularly useful option in the many regions of the United States reliant on high percentages of coal and gas generation (as well as in countries such as China and India), and there are net-zero natural gas technologies for new power plants coming to market soon that can capture almost all emissions. Nuclear power produces more than half of current non-emitting electricity, and there will be important demonstrations of advanced nuclear technologies throughout this decade that might enable them to play a role in decarbonizing the power sector by 2035. Zero-carbon fuels such as hydrogen (or perhaps ammonia) are shaping up to be essential for decarbonizing the economy, though the power sector may end up being more of an exporter of hydrogen to other sectors. While these and other individual technologies may be needed, it will also be important to start demonstrating smaller versions of an overall energy system (e.g., in clusters or hubs) that is safe, reliable, resilient, affordable, secure, and net-zero.

DECARBONIZATION CONTEXT

2021 represents the halfway point between 1992, when the United States committed in Rio to address climate change, and 2050. U.S. efforts on climate in the first half have not been nearly effective enough.

Paris in 2015 saw two major steps forward. First, there was Mission Innovation. Innovation is at the core of addressing climate change, and government investment must be accompanied by large amounts of private capital moving into the space. Second, all countries of the world acknowledged responsibility (to be carried out in differentiated ways) for being part of the solution. Nationally determined contributions (NDCs) from signatories, however, were not commensurate with Paris's climate targets. That ambition is now the job of the Glasgow meeting: NDCs for 2030 that are commensurate with an ambition to reach net-zero by 2050. The force behind net-zero commitments is large and global, but the task is to translate that into a sustained sprint to get there over the next 29 years, as well as to provide the billions of dollars that have been pledged but not delivered to developing countries.

Net-zero is only a way station on the path to a net-negative economy, and carbon dioxide removal may be needed at a very substantial scale.

To achieve net-zero, it is clear that energy efficiency and other demand-side activities across all economic sectors will be essential. Second, electricity must be the lead horse in decarbonization, but there are challenging systems-level issues that still must be addressed, particularly with increasing penetrations of variable sources of electricity and limitations of battery technologies. Third, other sectors have to be electrified as much as possible. Fourth, there is a need for a fuel or quasi-fuel (e.g., hydrogen) to have a reliable, resilient, flexible energy system across all sectors. Fifth, the "net" in "net-zero" is meaningful and indicates a need for negative-carbon technologies. Net-zero is only a way station on the path to a net-negative economy, and carbon dioxide removal may be needed at a very substantial scale.

All five steps are needed in the next 29 years to have any shot of reaching net-zero. Achieving the goal will also require building broad-based political coalitions to keep the agenda moving forward, but bold action is needed. What humanity has wrought is already affecting the most vulnerable and will impact future generations. Carbon is now a metric of morality.

MOVING TOWARD A CARBON-FREE ELECTRICITY SYSTEM

The power system is central to decarbonization. Trends and models show that progress has been made – but also that there is a long way to go.

TRENDS

There has been a dramatic shift in the U.S. power sector over the last 15 years or so, with relatively flat load growth nationally, lots of coal plant retirements, significant natural gas buildout (due to low gas prices), and big increases in wind and solar deployment (due to reductions in cost). The result has been about a 40% decrease in greenhouse gas emissions from the power sector, though there will be some amount of rebound this year as the economy recovers from the COVID-linked recession.

With dropping prices and increased deployments, renewable energy is now in the "awkward adolescent" stage – big enough to know it will be a grown-up in the energy scene, but not there yet. Renewable energy is on the verge of being a central part of the integrated grid. Power purchase agreement (PPA) prices for wind dropped below the cost of existing natural gas power around 2012, and solar PPAs did the same around 2017-18. Most cost numbers people cite for wind and solar do not include the cost of storage, but even solar-plus-storage PPA prices are under 4 cents per kilowatt-hour (kWh). Cost figures for renewables also do not necessarily incorporate costs tied to what they are replacing – such as ratepayers paying for stranded costs of assets that are retired early. Still, further cost reductions for wind and solar are expected.

Due to these cost trends and forecasts, as well as other factors such as policies and utility commitments, there is tremendous developer interest in wind and solar. There are currently more than 600 gigawatts (GW) of wind and solar seeking to interconnect to the grid in the United States, and much of it is proposed to be paired with storage.

MODELS

Over the past year or two, several studies and models from think tanks, universities, and other thought leaders have presented potential paths to achieve a fully or substantially decarbonized power system, as well as projections of how such paths might fall short.

For example, grid simulations suggest that an 80% clean grid by 2030 (in line with some recent Clean Energy Standard proposals), coupled with aggressive vehicle electrification goals, would remain fully dependable across the United States for every hour of the year, but hundreds of gigawatts of existing natural gas capacity (which would be dispatched less than 1% of the time) would be required to maintain reliability. Demand response programs would also play a big role in reliability. A lot of new renewables and battery capacity would be needed every year, comparable to the levels China built in 2020. Load would increase about 20-25% by 2030 and about 70% by 2050, which is significant but not unprecedented. Electricity costs would be lower than today, mostly because of how rapidly wind, solar, and storage costs have fallen; this does not even take into account environmental costs. (Other models that include the industrial sector in industry-heavy locations do require inclusion of environmental costs in order for the ultimate costs to be lower.) Because costs for wind and solar have fallen so much, clean energy investment would be cost-effective across the country, even in regions that are traditionally thought of as having relatively poor resources; this would create more jobs and new investment and tax bases across states, not to mention significant health, environmental, and climate benefits.

This is one possible outcome. However, under a model reflecting policies currently on the books, power sector emissions could also flatline over the next 30 years. High load growth is expected over that period (e.g., due to electrification of end uses such as transportation), there will be fewer uneconomic coal plants that can be retired, and economic pressures could lead to additional nuclear power retirements. Renewable energy will increase substantially, but so will natural gas. If natural gas prices stay low, emissions from the power sector could flatline despite the range of federal and state policies enacted so far. Voluntary decarbonization commitments made by utilities, if actually realized, could lower emissions by about 20% more, which is meaningful but still insufficient; there is a clear future for solar power and existing nuclear in meeting this shallow level of decarbonization, but there is still a big gap remaining to get to net-zero.

If natural gas prices stay low, emissions from the power sector could flatline despite the range of federal and state policies enacted so far.

Models, of course, are not reality. Modeling involves a set of computer codes that run algorithms based on radically simplified views of the world. Models do not represent the real world and do not reflect the full complexities and realities of energy grids. For instance, regardless of model assumptions about reliability, the grid may not remain reliable and resilient without big investments in grid modernization to transform it into an integrated energy network. The parameters and inputs involved also make a huge difference. There has not been consensus in models on the blend of policies and technologies needed. Industry would benefit from more common, broadly accepted decarbonization models; there are too many models out there now. With respect to timing, it may be that models should think of 2035 as the target for decarbonization more than 2050, given the increasing urgency around the climate crisis. If 2035 is the goal, then plans and models have to focus on technologies that already exist, since technology development and deployment can take decades. (The timeframe from development to commercialization can be shortened with incentives and focused investments – as, for example, COVID vaccines made clear – but market development still takes time.) By 2035, much of the existing fossil capacity will also have reached the end of its useful economic life.

BARRIERS TO A CARBON-FREE ELECTRICITY SYSTEM

The power sector is the easiest sector of the economy to decarbonize, but that does not mean it is easy. There are significant barriers to the rapid scale-up of clean energy technologies. The primary barriers now are more institutional and social/cultural than technological or economic.

SITING

A lot of models that project robust deployments of clean energy technologies rely on those technologies' technical potential, but that is not the same as feasible, near-term deployment potential. A technology's technical potential is based partly on the notion of available land for it, but there is a big difference between available land and developable land. Many things can put land off-limits for development (e.g., easements, competing uses), make land physically unsuitable (e.g., mountainsides), or make development difficult, costly, and time-consuming (e.g., community opposition). Social acceptance and siting of low-carbon infrastructure represent a key barrier.

Decarbonization pathways that call for very high penetrations of wind and solar thus have significant amounts of completion risk associated with them; there is a strong chance less will get built than planned, given local opposition.

Models suggest a need for many gigawatts of large-scale wind and solar over the next 15 years, which means significant numbers of solar and wind projects built every year. Local siting and permitting decisions would need to enable those projects. Hundreds or thousands of communities every year would need to agree to host large-scale installations. In densely populated areas, finding the space for huge amounts of onshore wind and solar will be challenging. Even in less populated areas, opposition to siting can be a challenge.

Iowa, for example, has massive technical potential for wind power, but after only a small percentage of it had been developed, public opposition to wind development grew in the state. People were concerned about the health impacts of wind turbines, noise, and lights. They were also concerned about the impacts on views – and as wind turbines get taller and bigger, the number of people in the turbines' viewshed increases. In addition, there are people who simply do not want industry outside their doors, having moved to rural areas precisely for that reason. The growing opposition in Iowa has been manifested in the increasing number and stringency of local ordinances on wind farm setback requirements. Over the past decade or so, no counties have undone these ordinances, and when new ordinances pass, they are more severe and restrictive than first ordinances used to be. About two-thirds of Iowa is now covered by wind ordinances, including some counties with moratoria.

Decarbonization pathways that call for very high penetrations of wind and solar thus have significant amounts of completion risk associated with them; there is a strong chance less will get built than planned, given local opposition. As clean energy technologies deploy, they may do so in more of an S-curve than a hockey stick. As more of the sites that have good resources, are close to transmission, and are far from communities are utilized, the projects will increasingly involve more interaction with communities. Over time, there will be fewer amenable landowners, sites may have worse resources and be further from transmission, and active landowner opposition may grow. All of these increase costs and risks for project developers. (It is worth noting, though, that in places such as Texas, it appears that wind farm sites were selected based not on the best wind resources but rather on where local tax abatements were available, and secondarily on proximity to transmission; with different local tax policies, the next wind sites developed could end up having better wind resources.)

These challenges are not unique to wind and solar, though. While a lot of attention is paid to market and political acceptance, community support for infrastructure siting is never a foregone conclusion, no matter what the project is. Transmission projects, for example, take at least a decade to get built due to permitting hurdles and local opposition. Landowner pushback is not going away, which is one reason that co-locating transmission underground in existing transportation corridor rights-of-way (e.g., highways, railroads) may be desirable; such co-location could cut the development cycle in half for transmission.

Project siting cannot be shoved through communities; it has to be very local, personal, and collegial. Communities get upset when projects seem to come out of nowhere, and community support also depends on whether members of a community believe a project creates value for them. That could be economic value (e.g., lease payments to landowners, jobs, tax revenues), but it could also involve other forms of value (e.g., health). Deployment will require understanding community impacts and concerns, recognizing the potential drivers of community acceptance, and prioritizing what communities actually want in terms of clean energy deployment (i.e., respecting self-determined energy choices). Some developers, for instance, have overcome local moratoria based on economics and self-determination. Many farmers and landowners have owned farms for a long time, are having a hard time earning a living, and are looking for alternatives. Clean energy deployment can offer a lifeline, spurring locals to oppose moratoria. There are also options such as agrivoltaics, where both agriculture (e.g., sheep, leafy vegetables) and solar coexist on the same site. Every community is different, and the levels of community opposition vary widely based on geography, culture, technology, and the details of any given project.

While community engagement is vital, there may be a need for federal preemption of communities, counties, and states – for more central command – if siting and deployment of clean energy infrastructure at anything close to the necessary scale and speed are to be achieved.

Community members that get involved in utility proceedings often come with very strong opinions about what they do and do not want, but these opinions often are not based on the same facts that utilities, regulators, and developers are operating on. Community education is essential. The general public should not have to understand the details of the energy industry, but the public needs enough information to make well-formed decisions about the seriousness of the climate challenge and the potential solutions. A lot of information that would be needed to understand decisions related to certain types of projects, though, is not available. For example, information about where critical vulnerabilities in grid systems are is not information that should be out in the general public, for the sake of grid security. That can make it hard for the public to understand the rationales for proposed projects. It can likewise be challenging to figure out how to take the public's and communities' wishes into account in situations that involve complicated electrical engineering or critical infrastructure security; it can be hard to find members of the public that have the knowledge and skill sets to provide input.

While community engagement is vital, there may be a need for federal preemption of communities, counties, and states – for more central command – if siting and deployment of clean energy infrastructure at anything close to the necessary scale and speed are to be achieved. The United States (and the world) is very far from the scope and scale of action needed to address climate change, and the current system is not designed for speed or success. Racism, classism, and other forces have punished communities for decades, but the answer is not to make every decision a local one. American society is very focused on individual rights, but sometimes the needs of the many outweigh the needs of the few. Given the urgency to address climate change, it is not feasible to wait for years to get all the pieces and processes perfectly right. The needs and desires of local communities must be considered and balanced, but governments and utilities have a responsibility to act and to act quickly.

TRANSMISSION INTERCONNECTION

Transmission interconnection is another significant barrier. In the process of project development, multiple things have to happen to get to construction, often in parallel and with unrelated timelines and constituencies. In addition to needing land control and addressing siting, permitting, and environmental conditions, developers also have to apply for interconnection. They need to get cost figures and permission from utilities to connect to the grid, and the process and rules are different in every state. Wind and solar projects are taking longer than they used to (now up to about 3.5 years) to get through the interconnection queue and to commercial operations.

Most proposed projects are never built. Less than 20% of wind and solar projects proposed between 2000 and 2015 actually reached operation. Projects can fall out of the queue because any one (or more) of the necessary elements does not happen successfully, but interconnection is one of the hurdles. Interconnection queues are long, and interconnection costs are skyrocketing. (Utilities pin at least part of the blame for high failure rates of projects in queues on developers, for putting in speculative projects.)

CRITICAL MATERIALS

Many clean energy technologies rely on an array of specialty metals, including cadmium, cobalt, gold, and zinc. These items are mined and produced across a diverse, geographically diffuse global supply chain – including in places with notable geopolitical risk – raising significant supply chain risks. There is very limited ability to guarantee supply through the international trade system; as the rapid international restrictions on personal protective equipment (e.g., N95 masks) last year showed, international trade obligations can evaporate quickly. The United States does not have the market access needed to ensure supplies.

Furthermore, there are real environmental, health, and human rights risks associated with a global expansion of mining and extraction, and there will be competition with other users of those materials. Clean energy deployment will therefore likely confront resource constraints over the next few decades.

For some of these materials, such as zinc and manganese, the United States is completely import-dependent, but there is no political agreement on even the smallest actions on critical minerals. For economic and security reasons, the United States would benefit from having more of the clean energy value chain at home versus abroad, but that would likely mean a lot of new mines in the United States, which is anathema to the environmental community. Supply chain diversification will also be important – doubling down on alliances with friendly, stable, reliable trading partners – but there is no appetite for new trade deals.

Many of the materials do not currently have substitutes; there is a need to invest in research and development (R&D) to find substitutes or other solutions. In addition, there is a need to invest in recycling, which can mitigate some of the supply chain constraints; this will require domestic and international policies, as well as changes in product design, but these seem unlikely in the current international framework. Despite much global talk about a circular economy, there appears to be neither the appetite nor ambition to confront the technical and policy requirements to recycle complex products in the global value chain. This is a failure of governance and imagination, and it has big implications for the availability of critical materials in the clean energy sector.

RESILIENCE & SECURITY

The electric power system is a large, complicated machine that works in real time and crosses borders to keep the lights on. The grid has been under tremendous stress in the last few years, facing weather extremes, forest fires, cyberattacks, and other challenges. There has been chronic underinvestment, increased danger from state and non-state actors, and the imperative to smoothly transition to a carbon-free system. There is now a need to rebuild the airplane while flying –

transforming the grid in a relatively short period of time to decarbonize it and address other environmental and justice concerns while keeping the grid reliable and resilient. Resilience is the ability to anticipate, identify, and respond to threats; it is not just bouncing back, but rather bouncing forward based on lessons learned. Grid decarbonization needs to occur in a manner that ensures continued resilience and enhanced security, especially with more renewables, more "smart" distributed energy resources, and more players involved.

The grid's foundational capabilities will have to include cybersecurity as a paramount concern, or else there will be new resilience and reliability problems. The world already has tens of billions of unhardened devices communicating with power grids, representing extreme vulnerability. With the advent of 5G, and, in the future, quantum computing, the threat landscape is unbelievable.

There is now a need to rebuild the airplane while flying – transforming the grid in a relatively short period of time to decarbonize it and address other environmental and justice concerns while keeping the grid reliable and resilient.

Cyber vulnerability suggests a need to collect different data. Security is no longer just about the Straits of Hormuz or barrels of oil; there is a need to step back and figure out what data should be collected to ensure energy security in the face of current and expected threats. There also needs to be a national requirement across sectors for cybersecurity notification. Systemic attacks build over time, and the government needs the evidence to be able to short-circuit attacks.

Maintaining resilience, reliability, and cybersecurity while decarbonizing will require collective defense and collective response. The resilience of the grid (and of national infrastructure more broadly) is a shared responsibility, especially since most of the infrastructure is owned and operated by the private sector or entities other than the federal government. Increasingly, the largest companies involved are not energy companies. Public-private partnerships are of vital importance, collaborating across levels of government and across sectors to enhance resilience. Representatives of all the different players in this complex ecosystem – all of the numerous entities involved in the operation of the grid and other key infrastructure – need to be brought to the table to understand the threats and hazards and to engineer resilience from the outset. The right entities, data, and requirements need to be figured out to ensure resilience and cybersecurity, all without slowing down deployment of solutions needed for decarbonization. Healthy paranoia is needed about threats and challenges facing the system moving forward.

It is not possible to predict the future, but it is possible to prepare for it. Utilities will need the right transmission modeling and planning, as well as real-time tools with strong cybersecurity to operate the decarbonized grid of the future. The tools that exist now are not at the level of resolution needed, and planning decades ahead is difficult. There is a need for climate models to inform utility decisionmakers and regulators about the longer-term regional impacts of climate change on electricity production, demand, water resources, and the like, so good decisions and investments can be made now to avoid uneconomic outcomes, stranded assets, erosion in reliability and resilience, and other unintended consequences. More broadly, there is a need for flexible, adaptive, and credible planning regarding transmission, grid architecture, distribution, communications, distributed "edge" technologies, and more. The speed of technological change is not aligned with how utilities have traditionally planned and operated. With the growth in distributed energy resources (DERs), for example, utilities do not know where demand will come from. If someone buys an EV, a huge load just appears on the grid. Rooftop solar installations just appear on the grid. Customers are becoming less homogenous, which is a challenge for utilities. Utilities and grid planners need better planning tools with better visibility if they are to successfully skate to where the puck will be.

Few people have the knowledge and skill sets to cut across climate change, the energy system, cybersecurity, human rights, resilience, supply chains, and the numerous other factors at play. It is not clear which entities have the capacity and the responsibility to think through all the issues, but there is a need for people who can think across the ever-more-challenging cross-cutting issues.

CUSTOMER ADOPTION

Another critical hurdle on the way to widespread deployment of technologies – though one focused less on the power sector per se – is getting customers to adopt new technologies. For example, there are numerous highly efficient technologies already out there that customers are not buying. Someone whose job is to maintain a building and make sure the heating and cooling systems and lights work will often choose the technologies they know about, trust, and have always used. When companies have products that are affordable and meet objectives (e.g., greater efficiency) but that are not seeing uptake from consumers, companies should consider ceasing production of the older products that do not meet the objectives. Auto manufacturers are just starting to move in that direction, but many other equipment manufacturers are not. There is a need to better understand customer decision behaviors and sunk costs in the value chain if the goal is to commercialize and deploy clean technologies quickly.

THE PEOPLE PIECE: EQUITY, JUST TRANSITION, & LABOR

The human components of decarbonization have become more central over the last couple of years, from human rights issues deep in supply chains to the needs of workers to the importance of ensuring all U.S. communities benefit from low-cost, carbon-free, pollution-free power. If the goal is to have decarbonization approaches and technologies be durable, there is a need to center people in the conversation, including frontline communities most impacted by pollution and climate change.

ENVIRONMENTAL JUSTICE COMMUNITIES & EQUITY

The extreme inequities in America's energy economy (and economy writ large) are evident in the convergence of COVID, climate change, the racial crisis, and the economic crisis. African-Americans have lower household incomes, higher unemployment rates, a very small percentage of energy sector jobs, and little revenue from the energy sector. Black families are more likely to live near toxic sites than white families, regardless of income. The current system is deeply inequitable, with financial and political decision-making in the hands of a wealthy few. Climate change itself will be a profoundly inequitable phenomenon, causing the most detrimental impacts on the people (and species) least responsible for causing it and least able to adapt to it.

Climate change itself will be a profoundly inequitable phenomenon, causing the most detrimental impacts on the people (and species) least responsible for causing it and least able to adapt to it.

The clean energy transition will help improve the health of some of the most vulnerable communities by reducing or eliminating combustion-based, pollution-emitting sources of energy, thereby improving air quality and community health. Affordability may also improve over the long term, due to the greater efficiency of electric technologies; for example, by around mid-century (or earlier), the average customer in California can expect total energy costs in real terms to drop by about a third.

It will require conscious efforts, however, to avoid creating decarbonized-technology haves and have-nots; it is important to protect the customers least able to get the new technologies from being stranded with high-cost, high-carbon technologies. For example, climate-tech and energy startups, like many other startups, are incentivized to go after early adopters, which often means wealthy white men. This is already evident with EVs and EV charging; the United States is barreling towards a future in which 80% of charging is done at home, but more than 40% of vehicle owners do not have a dedicated parking space. Companies and governments are building a solution that does not work for almost half of Americans. Electric vehicle infrastructure programs have to include focused investments in low-income communities and multi-family buildings.

Policies also need to provide support for disadvantaged communities to adopt low-carbon building technologies (e.g., heat pumps, energy efficiency technologies). Load is often constrained and energy burdens are high in low- to moderate-income (LMI) communities. Energy efficiency and demand response programs, in addition to storage and solar, need to be targeted to LMI communities, and there may be a government role in providing loan guarantees or loan-loss reserves, since LMI customers are often seen as too risky to serve. A challenge many cities are facing is the long history of underinvestment and the continuing impact of redlining on the built environment in some neighborhoods, which has left housing and building stock in shambles. Similarly, investments in DERs in neighborhoods will be affected by the quality of the feeder line and what utilities have invested in previously; not everyone has the same access to participate. There is also a challenge in many service territories in allowing customers without central air to participate in demand management programs. In addition, since demand-side technologies rely on digital devices that require internet connections, broadband access is now a vital part of the equitable decarbonization conversation. The combination of all these barriers means that, like with utility-scale renewables, some urban land may be technically available but not really developable for climate solutions.

Frontline communities are not necessarily interested in all potential climate solutions. The White House Environmental Justice Advisory Council, for instance, said it did not support carbon capture, utilization, and storage (CCUS). Environmental justice (EJ) communities are not monolithic, however. They are very different, very decentralized, and very focused on the local, specific, blatant problems they are facing; EJ organizations are committed to reducing pollution and disproportionate impacts, as well as to building wealth in their communities. As long as a particular project solves a given community's explicit long-standing problems, that community may be receptive. Education can be one part of solving social acceptance challenges – for instance, it is not clear that pollution-burdened communities are aware of the air quality benefits of industrial CCUS – but there must also be honest, consistent engagement. Good process often (but not always) yields good decisions, but there are lots of processes that could yield better results with more views at the table; there are options never considered because no one raised or pushed them. The benefits of projects need to be equitably distributed, public engagement must be robust, and community input must be not only solicited but acted upon.

It is only possible to move at the speed of trust, and trust has to be earned.

Industries have not really engaged communities in a good faith manner over many decades. Communities have not been brought to the table, projects have been developed without equity in mind, and projects have been unable to demonstrate benefits beyond jobs (which do not always come to fruition or benefit the communities). Across the lifecycle of energy technologies, there are also additional historical elements related to workers and communities that must be considered. Tens of thousands of coal miners have died of black lung disease, yet companies are still fighting families trying to get help; expecting some communities to have trust in companies proposing CCUS for coal may not be realistic. Likewise, with respect to nuclear, there are whole health clinics devoted to dealing with the effects on uranium mine workers.

A process buttressed by trust and a shared intention to transition to zero-pollution technologies can allow decarbonization projects to move forward, even if frontline communities are not thrilled about any particular technology choice. After generations of abuse by energy-related industries, though, expecting communities to suddenly have faith and trust in them is a tall request. Trust is in pretty short supply in society right now in general – and particularly in pollution-burdened and disadvantaged communities. It is only possible to move at the speed of trust, and trust has to be earned.

A key part of increasing trust in frontline communities involves creating opportunities for wealth-building. Wealth-building does not involve one-offs, but rather actual ownership of assets (e.g., real estate, stocks), which disadvantaged communities have not had. Most LMI communities have lots of renters, who generally would not own many of the energy technology assets that would be deployed, adding another level of complexity to addressing their energy burden and the need for wealth-building.

Communities need access to (long overdue) capital that can allow them to build wealth via the energy space. It matters who is getting the capital dollars. A key question is whether people are willing to pay more for justice and equity – whether there is support not just for growing the pie but for redistributing the pie to direct more wealth toward people who have not had it. There has been some progress in directing private, public, and consumer capital to EJ communities for the clean energy transition. In state capitals around the country, advocates have successfully pushed to get lots of dollars dedicated to BIPOC developers, along with requirements to pay prevailing wages. States are including more focus on underserved communities and use of minority- and women-owned businesses in their energy efficiency programs. The Biden Administration's Justice40 initiative aims to deliver at least 40% of the overall benefits from federal investments in climate and clean energy to disadvantaged communities. Tax policy can also drive capital investment and wealth-building. The Opportunity Zone program, for instance, can unleash trillions of dollars of private-sector financing into community-led projects; it has been focused to date on real estate, but if a second round was focused on green infrastructure, it could be a significant way of creating ownership and long-term (10-year) investment in communities.

Bold approaches are needed to achieve goals around wealth-building, clean air, and equitable access to clean energy.

More is needed, however. For example, wealth creation will come from entrepreneurs, but the current energy innovation ecosystem is set up for people who already come from family wealth. Entrepreneurs are expected to prove they want success so badly that they forego lives and pay while getting their businesses up and running. Many people, including in EJ communities, may not be in a position to go for years without a paycheck. The innovation ecosystem must be fixed – not only because it is the right thing to do, but also because there is a correlation between revenues and the diversity of management teams.

Bold approaches are needed to achieve goals around wealth-building, clean air, and equitable access to clean energy. Neither the climate nor communities have time for incrementalism. Systemic inequities – touching on race, housing, health, education, hiring, income, and much more – are serving as barriers to the energy transition, but there is a question as to how much these systemic issues and crises can be put on the back of the energy transition to solve. For example, committee jurisdiction in Congress and agencies with targeted missions keep energy issues relatively siloed from other issues. While tackling climate change cannot be freighted with every other issue, there will be huge sums of money spent on energy and climate. If spent well and with the other issues considered in everything, from the beginning, progress could be made both on decarbonization and on other systemic challenges. If every leader in the energy space thought of justice and equity as being just as central to their jobs as reliability and resilience, they could make an incredible difference.

The people dealing with the energy transition may not be equipped to meaningfully address inequities in income, education, health, housing, toxic exposure, and more. Those in the energy sector need to engage more with groups tackling other systemic issues. There is a need to engage in multi-solving approaches, with input and engagement from the multiple constituencies and sectors affected by the myriad interconnections among issues. Only in multi-solving can broad support and political will be gained. Opportunities could involve air regulations, energy efficiency and renewable energy standards, fleet electrification, building codes, R&D investments, hiring policies, campaign finance reform, and more. There are models at the local and state levels of community-focused, community-oriented, equitable, worker- and labor-driven multi-solving efforts that can be replicated and scaled. Even at the federal level, things like the Biden Administration's executive orders on environmental justice planning suggest a dawning recognition and some degree of progress on multi-solving and more comprehensive policy planning.

JUST TRANSITION

Communities reliant on high-emitting facilities and industries require focused attention during the clean energy transition as well. In Canada, for instance, Alberta's 2015 climate plan included a fund to compensate power providers for stranded assets in the coal sector; from that also came a multi-stakeholder coal transition coalition. The coalition developed a multi-pronged plan that included targeted funds for retirement transition, relocation for laid-off workers, vouchers for training and education, two big province-wide funds (for municipalities and First Nations) to bring forth economic development projects to help the transition, and an economic support fund to focus on province-wide economic diversification. There are some good models for just transition efforts.

In coal-heavy U.S. states, communities (and utilities, local county economic development offices, local school boards, and others) are anxious about coal plants closing and are clamoring for opportunities to re-use those sites and retain some of the jobs. One option could be to repower coal plants with advanced nuclear, using the existing transmission and balance-of-plant infrastructure (as well as many of the plant workers). These could be built faster than traditional nuclear plants, could be built to be flexible, and could be very cost-competitive. A strategy that complements renewables, keeps communities whole, retains jobs, reduces health impacts from air pollution, and enables high-capacity-factor clean generators using existing transmission could de-risk the overall transition of the grid, as well as get support from Republican politicians whose states or districts are home to many coal plants. Datacenters are another option for redevelopment of coal plant sites and re-use of existing interconnection infrastructure; they can employ some (but not all) of the workers from the closed coal plant and deliver resources for the tax base to support local schools. Coal plants are difficult sites to redevelop, but the benefits are substantial for communities, workers, and developers. More work should be done to find replacement uses for the sites.

LABOR

Decarbonizing the entire economy through clean energy and electrification will require a strong, resilient grid, which in turn will require a skilled and diverse group of employees and contractors helping a variety of communities. As much creativity as is going into technologies needs to be applied to workforce challenges.

With regard to equity and diversity, the renewable energy and utility industries are more diverse in terms of race and gender than coal mining and oil and gas extraction. Resource extraction tends to be very place-specific, while renewables are more about manufacturing of products, which should open up opportunities for a more diverse workforce as the energy transition progresses. That said, the clean energy industry is still incredibly non-diverse compared to the national population and the national workforce. More BIPOC skills training is needed, but multi-week training programs are not accessible for some low-income people, who cannot leave a paying job that supports their families. Diversifying the workforce has to involve paying the workforce.

Unions can provide opportunities for all, providing people of color, veterans, women, and others with skill sets that will last a lifetime.

Unions can provide opportunities for all, providing people of color, veterans, women, and others with skill sets that will last a lifetime. The renewable energy industry has been less interested in working with labor unions than other parts of the industry. Unions are pretty demanding when it comes to what is required economically to deploy workers; union members decide what they are worth and engage in collective bargaining. They have not had much success in onshore wind and solar, but if the vision of clean energy can expand beyond those, most of the rest of what is needed to decarbonize the power grid involves union work. Building small modular reactors and other advanced nuclear technologies, for example, will involve union labor, as will offshore wind. Unions have the capacity and expertise to expand apprenticeship programs to train as many people as needed to enable a clean energy transition at speed and scale, as long as there are clear policy commitments, including for jobs at collectively bargained wages.

The clean energy future might create the kinds of middle class, family-sustaining jobs that the old energy industry did and still does, but it will require getting the policies right. Labor standards should require that investments of tax dollars result in wages that give people the opportunity to maintain or attain a place in the middle class. If federal or state funds supporting the transition include such standards, the result could be the creation of millions of careers and jobs (both direct and indirect).

ORGANIZED MARKETS & CORPORATE ENERGY BUYERS

Markets can play a key role in decarbonization, providing price signals and structures that allow customers and other market actors to drive clean energy deployment.

DECARBONIZATION & THE FUNCTIONS OF MARKETS

Markets are networks for social learning. Through the process of price discovery, it is possible to learn people's preferences and values. Electricity markets enable at least three critical functions: coordination (e.g., supply and demand), innovation (e.g., through price signals and low barriers to entry), and flexibility (e.g., in how resources are absorbed and dispatched). In general, markets help people coordinate on things that are scarce. Historically, the scarcity in energy markets has been framed as physical capacity to deliver energy, but it may well be in the future that some other capability (e.g., ramping) is at the margin.

Existing markets have done well what they were designed to do, which is not to achieve decarbonization. Right now, under the statutes and constructs established in states, energy system planners and managers are focused on ensuring reliability, affordability, statutory environmental compliance, and perhaps resilience to big threats. They are managing around those criteria, with everything else secondary or emerging. Deregulated, competitive markets have thus far been delivering decarbonization – through a happy accident of low-cost gas and renewables and the turnover of older, uneconomic assets – but that does not necessarily mean they will continue to do so. Energy system planners and managers are starting to be asked to account for carbon (among other very challenging factors), and markets are experimenting with and figuring out how to respond to states with decarbonization and clean energy targets. How regional transmission organizations (RTOs) and wholesale markets manage the intervention of state policies will have a profound impact on the ability of markets to sustain themselves.

Markets are enablers, and policies can help shape what they are enabling and how well they do it.

Markets do not function perfectly, and they do not operate in isolation. Markets are enablers, and policies can help shape what they are enabling and how well they do it. State policies can be very consequential, but so can market structures. Some states have policies that are very friendly to renewables and are very carbon-centric, but they can be really hard places to fit projects into the market. Other states have far fewer carbon-friendly policies but are much easier places to build renewables projects. In Texas, for example, the price-driven competitive market has led to huge amounts of wind and solar; indeed, the vast majority of the queue in Texas is renewables and storage, based solely on the economics. The way the market is structured has a huge effect on what projects do and do not get built.

Markets are also working to adapt how they operate with respect to all the distributed, dynamic, demand-side resources coming onto the system. The electricity system can be thought of like a sponge – if the system is trying to absorb more heterogenous and distributed resources, the system has to be flexible. Markets, discovery processes, and price-based dispatch enable the sponge to grow and absorb more distributed energy resources, and Federal Energy Regulatory Commission (FERC) Order 2222 may amplify this by enabling aggregation of smaller DERs for market participation. Markets also give more value to and thus can boost deployment of resources such as community solar. Ultimately, markets have the potential to enable transactive energy systems, which would allow people and entities to participate in local energy markets, with digital devices automatically executing bids reflecting willingness to pay and offers reflecting willingness to be paid for energy from DERs. There is a chance now to design markets for distributed resources in a way that does not exist yet; that design needs to be able to control DERs in real time and to count on them showing up. It will also involve a very different set of market participants.

Also on the demand side, price signals and rate design can play important roles in driving energy efficiency and demand response. Giving commercial and industrial customers more sophisticated, day-ahead, real-time price signals allows them to optimize cooling loads, process work, and other loads. There is similar potential on the residential side, with smart thermostat programs and time-of-use price signals. Deploying these market tools enables demand-shifting. The way regulatory constructs value energy efficiency programs, however, will affect equity; constructs that value total energy saved versus total number of households adopting a technology or practice may yield very different programs. In this case and many others, constant attention to market rules and design is essential for markets to deliver on any particular goal or set of goals.

Price signals and rate design can play important roles in driving energy efficiency and demand response.

Price signals are just one example of the power that data can have in a market. Data lets multiple actors in a market make choices for their own reasons. In the near term, increased transparency of data could help bring more clean energy online. Locational marginal prices are already known, and in some places there is a system map of where constraints exist on the grid, but improved data transparency to better understand locational marginal emissions could help developers understand and make informed choices about where to place renewables. That data will eventually be needed anyway.

CORPORATE BUYERS

Investors and shareholders have played a critical role in driving utilities and corporations to adjust their investments, behaviors, engagements, and targets in the climate and energy space. A couple of years ago, the huge wave of voluntary utility decarbonization commitments was just beginning, but 70% of all the electrons transacted in the United States are now by a company with a deep decarbonization commitment on the generation side. (Those commitments, often targeting somewhere around the 2050 timeframe, also often include 2030 and 2040 commitments.) The largest U.S. renewables deployments have come through utility PPAs, in states with both more and less market structure. There have also been increasing numbers of notable corporate clean energy commitments, and corporate buyers have been additional huge drivers of renewables deployment, mostly in organized markets.

Corporate energy procurers are continuing to evolve their approaches. Some corporate buyers are now looking to source 24/7 clean power on every grid they are part of. That makes companies think more about not just price and carbon content, but also when and how power is provided, hourly resource adequacy, and how to create a market with transparency on carbon so market participants can choose decarbonized resources. It is a more holistic approach that gives companies more of a stake in the grids where they operate. Only a small handful of corporate buyers have the capacity to participate in markets in such a mature, sophisticated, meaningful way, but if the sizable skills and knowledge gap in other companies can be addressed, the number of corporate buyers that want to participate meaningfully in markets is huge.

Currently, most corporate procurement – as well as regulatory compliance – is centered around renewable energy credits (RECs). RECs (and the PPAs for them) do not represent carbon or climate value, misallocate resources, and can lead to non-optimal climate outcomes – particularly as non-renewable zero-carbon assets that do not have RECs try to scale. In addition, while new wind and solar are eligible for RECs, procuring additional existing hydro would not be. The ultimate metric for different options and pathways has to be about carbon impact; carbon is not the only metric, but it is indispensable and must be front and center. It is not economically, equitably, or environmentally preferable to build all the wind and solar possible and then figure out other technologies to fill in the rest. Other technologies are not just gap-fillers; they are vital technologies that need to scale. There are groups working to address the limits of RECs and to figure out what next-generation, more tech-inclusive corporate clean energy procurement looks like.

Beyond procurement per se, there is a need for every company that cares about greening the power supply to be actively advocating for policy on grid transformation.

Beyond procurement per se, there is a need for every company that cares about greening the power supply to be actively advocating for policy on grid transformation. There has been general advocacy (e.g., signing on to broad statements), and specific, brand-forward advocacy calling for very specific clean energy policies is starting to happen here and there. Companies do not get rewarded for policy advocacy, but investors are starting to penalize those who are not advocating.

EXPANDING ORGANIZED WHOLESALE MARKETS

About 80% of corporate renewable energy offtake has been happening in organized wholesale markets – not because that is where the load is, but because they provide great economic and decarbonization value. Large corporate buyers of clean electricity have found that they can move much faster in RTO markets – signing power deals with retailers or developers in a matter of months, compared to conversations and approvals that can take years in more vertically integrated markets. Buyers can also move at much greater scale (i.e., obtaining far more megawatts), can procure resources more cheaply, and have more flexibility to structure deals that serve their supply needs in organized RTO markets.

In addition, organized markets create billions in cost savings for customers (across all consumer classes); there have been some misleading articles and debates about whether markets have saved money, but the evidence is that they have. Organized markets that cover larger regions are also beneficial for managing variable resources, and they have thus far helped contribute to huge carbon dioxide emission reductions.

There are many who would like to see markets established where they do not currently exist, such as in the U.S. West and Southeast, where they would be expected to create significant savings and emission reductions. Some state legislators in those regions are looking at moving toward regional competitive markets. A market in the West is starting to develop organically, but a market in the Southeast is not politically developing yet.

The West could benefit from a market to connect non-California renewables with loads across the region. Aside from carbon, markets in the West would also help with improving transmission planning (given the deficiencies of FERC Order 1000), optimizing renewables, and optimizing load and resources across a broader footprint. However, from a practical standpoint, a Western market may face challenges with resource adequacy and governance. California's wheeling order, for example, means that if another state needs firm resources that go through California, they are not really firm; if California runs short in an energy emergency, it can pro rata curtail firm generation coming through the California system, which leaves the original procurer short. Those kinds of practical market design and governance challenges have to get resolved.

CHALLENGES WITH ORGANIZED MARKETS

While expansion of RTOs may be desirable, they are not perfect. There are many issues to fix related to governance, better facilitating transmission build-out, deployment of advanced generation technologies, and other areas.

There has been lots of talk about RTO governance and stakeholder processes, such as the need to give consumers more of a voice. Things can be improved, but the processes are not designed for speed or change; they are designed for inclusiveness and to establish guardrails. If stakeholder and governance processes are made more elaborate or complicated, things might get even slower than they are now.

Changes to current RTO rules will also be needed to allow for privately financed transmission that can aggregate and deliver geographically diverse clean generation. Merchant transmission is studied now as a generator, not as transmission, but it should be studied as transmission (just as utility projects are). Merchant transmission also needs to be compensated for the range of benefits that modern high-voltage direct-current (HVDC) lines bring in making the grid more reliable and resilient; for example, it should be compensated for the capacity and ancillary services it can deliver.

The compensation challenge is not unique to merchant transmission. Various energy technologies provide different types of value to the system, including carbon-free, reliability, resilience, and safety, but there often is not compensation for those attributes of power. That is something markets will have to evolve to account for, though there is a question as to how much should be incorporated into the RTO process as opposed to simply operating in parallel. Performance-based rates are one way to provide incentives for utilities to change behavior – not just on carbon, but also on reliability, safety, and other areas.

Changes to current RTO rules will also be needed to allow for privately financed transmission that can aggregate and deliver geographically diverse clean generation.

More broadly, the markets, in the view of some, are completely broken because they are lumping together different technologies with different values and attributes to compete against each other.

While organized markets have delivered some decarbonization thus far, some are skeptical about the suitability of markets to drive a carbon-free grid. For example, markets may not drive sufficient innovation, since innovation is economically irrational. Achieving net-zero will not happen through deployment and markets alone; there is a need to do stupid, irrational things and hope they work. In addition, wholesale energy market auctions are based on the marginal costs of suppliers to produce energy; that is a great way to use assets efficiently, but a carbon-free grid (especially by 2035) will be dominated by technologies that generally do not have marginal costs. Energy markets alone would not be sufficient to decarbonize unless it happens to be the case that zero-carbon energy is the lowest-cost energy for all desired attributes. Other complementary mechanisms would be needed, such as a Clean Electricity Standard. The interactions between energy markets and policies that price carbon or incentivize emission reductions can get complicated. There are market-friendly ways such policies can be designed, but other designs could make all of the current debates about market reforms moot.

FEDERAL POLICY

States have led the way on policy to decarbonize the power sector, with state renewable energy, clean energy, and energy efficiency measures, but there is an important role for the federal government to play in spurring emission reductions in line with scientific understandings of what is necessary.

INFRASTRUCTURE & CLEAN ENERGY STANDARDS

The DC policy scene is getting back into the game of big clean energy and climate policy. Bipartisan activity over the past two Congresses has included expansions of incentives and new investments in innovation, most notably via the Energy Act of 2020 enacted in December. Now, Democratic ambition on climate change in Congress could not be much higher, and there is at least movement afoot in the Republican Party to talk about climate policy. Plenty of disagreement remains, but there is potential for progress.

There is now a once-in-a-decade (or more) opportunity to enact significant climate measures in Congress. There is not one climate policy that solves all problems. Progress to this point has come from state renewable energy policies, state investments in energy efficiency, technology innovation, federal air quality regulations, federal tax credits, and many other things. There are lots of drivers, and there will continue to be. The current policy conversation seems more cognizant of that reality than prior ones, talking about a range of different policies and programs. The two major policy packages that appear likely to move – a bipartisan infrastructure package and a big budget reconciliation play – will contain many climate elements.

There is not one climate policy that solves all problems.

While carbon pricing is not completely off the table, the centerpiece policy in a reconciliation bill has been a Clean Energy Standard (CES), but not a CES as traditionally understood. The Clean Electricity Payment Program (CEPP) is like a CES but is structured differently to abide by budget reconciliation rules, with incentives and payments for load-serving entities that perform at a certain level. There is some skepticism about developing a CES-like policy that is reconcilable and effective, but it is possible.

In terms of the economics, some of the credit prices being discussed are large and could have significant effects on utility customers. Some sort of alternative compliance payment option as a cost offramp will be important. The ability to average across states could also bring down credit prices. It will be important to structure a CEPP to avoid ratepayers double-paying. At least some load-serving entities that can build and own generation will get an incentive payment, which ought to be used to offset costs to customers; the CEPP has a stated intention that payments flow through to customer bills, but there really is not a mechanism to actually do that. Even for utilities that do not own generation, real people will pay these bills, and the credits are costly. It is important to figure out how to offset those costs, or there will be no political buy-in or pathway forward.

There will be battles about other critical details of CEPP design as well. For example, whether CCUS should count in a CES has been battled out in similar state policies, and there is skepticism that current or future technologies will get to 100% emissions capture (as opposed to 80% or 90%). There is also skepticism about offsets, particularly at a time when wildfires are burning down forests that had been set aside for carbon credits. In addition, there will be battles around reliability – i.e., what happens when a utility does not meet the standard because the lights had to be kept on. There will also have to be resolution reached on whether a national CES-like policy preempts or preserves the ability of states to set more aggressive policies.

Unless there is a significant emissions fee element to the CEPP, it will have a hard time getting close to 80% clean by 2030. The incentives will probably not be enough to move the needle that far; it is not clear that a policy diet based solely on carrots is sufficient. Achieving such levels will require not only continued positive incentives, but also some disincentives (whether fees or regulations) for existing and new emitting power.

There is an imperative now for legislators to get together and act on climate.

A CEPP could be very impactful, but what passes via reconciliation can be relatively easily undone when partisan control of Congress switches. It may not be durable, investible policy. In addition, whatever is passed now needs to not sabotage the potential for additional policies that will be needed in years to come; the next policy action cannot once again be a decade away.

The bipartisan framework could be an avenue for important complementary policies, such as with respect to siting and permitting of transmission, that would be hard to present as budgetary policy for inclusion in a reconciliation package. For that to happen, 60 senators have to feel like they benefit. Big national programs and mandates have happened on a bipartisan basis before, such as on cutting sulfur dioxide from power plants, passing drinking water standards, and achieving rural electrification. There is an imperative now for legislators to get together and act on climate.

The packages in this Congress probably will not go far enough or spend enough to satisfy some climate advocates, and these votes alone will not solve climate change. These packages, though, represent the best opportunity to pass climate-course-correcting legislation since 2009. It is important to make the most of this opportunity, even if the results are imperfect.

CLEAN ENERGY TAX POLICY

While the CEPP will be a key tool to incentivize load-serving entities to put more clean resources on the system this decade, tax credits will be needed to incentivize project developers. This could include both long-term extension of clean energy tax incentives and tax policy that incentivizes all zero-emitting resources. A technology-inclusive tax credit can avoid leaving out potentially important technologies, as geothermal was left out of earlier tax credit extensions.

Tax credits may need to be modified, though. Tax equity markets like to be safe, and they are complicated, challenging, and inefficient. Tax equity investors represent the most conservative capital in the whole stack, yet policies such as the investment tax credit (ITC) and production tax credit (PTC) put them in the driver's seat for project financing. The requirements of those investors regarding PPAs and revenue lines for renewable energy projects really narrow the number of projects that move forward. The efficacy of tax credits also depends on the supply of tax investor money, which depends on the profitability of companies. When profitability drops, as it did in 2020 due to the pandemic, the supply of tax investor money diminishes. Creating a direct pay option in the tax credits would be hugely helpful for actually getting projects built, though there seems to be some Republican pushback to the idea of direct pay. Expanding the transferability of credits might also increase the pool of potential investors.

In addition, tax credits need to have timeframes that are long enough to align with project development timeframes. Tax credits that expire and have to be extended every year are uncertain, making it harder for projects that take years just to get permits to secure financing. More certainty is needed.

Tax credits also need to be large enough to incentivize the behavior they are targeting. The 25C tax credit for residential energy efficiency, for instance, provides such a small credit for changing windows that it is far from enough to drive the desired behavior.

Beyond deployment of existing technologies, tax policy can accelerate the closure of coal units too. The next set of coal plants in the United States are not old and still have significant book value. Tax policy or incentives could enable those plants to be retired without putting the burden on the backs of the same communities that are losing their economic base; it would add insult to injury to ask them to pay for a plant to be retired early at the same time the industry that is supporting their economy is being shut down.

Beyond deployment of existing technologies, tax policy can accelerate the closure of coal units too.

Tax policy can be directed toward innovation as well. There are proposals in Congress, such as the bipartisan and bicameral Energy Sector Innovation Credit (ESIC), for technology-inclusive tax credits that aim to help breakthrough technologies get from demonstration to commercial deployment. ESIC is a flexible ITC or PTC for nascent, low-market-penetration (under about 3% market share) technologies, with the credits phasing out based not on time but on market penetration. ESIC also includes a hydrogen PTC, with climate/emissions thresholds to meet and higher incentives for zero-carbon and net-negative hydrogen (based on tailored lifecycle analyses that do not take into account upstream or downstream emissions). In addition, it includes an ITC for energy storage technologies – pumped hydro, lithium ion, short duration, and long duration. Even in being tech-inclusive, it is virtually impossible to be tech-neutral, as each technology has unique needs.

For innovation tax credits too, making tax credits direct pay could be important. Projects with new technologies are not getting the investment they need. Tax credit investors take no risk and generally want months of operational data, but innovative projects may not have even reached the point of having operational data. The reason solar and wind can access finance using tax credits is because they are very bankable, known projects that are simple and low-risk. Technologies coming to the fore may have challenges taking advantage of tax credits if they do not fit in that category. While some developers of clean energy technologies have been surprised to find the financial community to be more adventurous and non-extortionate than it used to be (because it sees the prize as being bigger), other developers have had to turn to venture capital, which is expensive.

OTHER TECH INNOVATION POLICY

There is a need for continued investment in the technologies that will move the power sector not just to 80% zero-carbon but all the way to 100%, including 24/7 technologies such as hydrogen, CCUS, advanced storage, advanced nuclear, and advanced renewables. There also needs to be a renewed focus on policy solutions that accelerate demand-side tech. Not all of the bets in newer technologies will pay off, and markets alone will not drive those bets. There is a huge role for policy support for basic and applied research, reinforced and expanded across all emitting sectors. There need to be demonstrations of technologies at full commercial scale, so de-risked that buyers will invest heavily.

The U.S. government has not been terribly good at putting public dollars into technology demonstration in meaningful or scaled ways, but there has been progress in that regard. The Energy Act of 2020 included an Advanced Reactor Demonstration Program (ARDP) to target money going into nuclear at the Department of Energy (DOE) in a more effective, meaningful way in order to attract private capital off the sidelines and deliver demonstrations on a tight timeframe. The ARDP is a good model of a policy that can drive private dollars with great impact. There have also been a series of other DOE announcements regarding technology demonstrations. In addition, there is funding appropriated in the bipartisan infrastructure package for technology demonstrations authorized in the Energy Act of 2020. Across the board, additional federal investments in RD&D for the advanced energy technologies in the bipartisan infrastructure package have significant positive return on investment, resulting in lower-cost clean energy, lives saved, public health benefits, air quality improvements, and more. There is substantial room for additional investments with good payoffs.

While there has been increased funding to support demonstration projects, there has not been enough intentional focus on mechanisms to broadly share the lessons learned from the projects. (To be fair, sharing of best practices is not done enough anywhere in any industry.) Sharing of best practices can also avoid having to figure out contracting arrangements and other "internal permitting" details (e.g., involving internal risk teams and lawyers) anew every time an innovation is deployed by a utility or other company. Any time intellectual property is involved, people will have varying levels of risk tolerance, and there are often risk-paranoid people willing to let projects die on the contracting vine. For any demonstration, a balance has to be struck of what to share nationally, share with partners, and keep internal.

While there has been increased funding to support demonstration projects, there has not been enough intentional focus on mechanisms to broadly share the lessons learned from the projects.

There are lots of barriers to getting more companies involved in DOE demonstrations, and DOE needs to do more to programmatically engage innovators of color. More broadly, DOE is trying to expand the commercial and public impact of its research investments, including with a new office focused on stewarding tech transfer and commercialization across the national labs and other activities. Incentives, funding, incubators, and accelerators in regional innovation hubs (anchored by national labs) can all play roles in filling gaps along the RDD&D continuum that can hinder progress toward commercialization. The revitalized Loan Programs Office at DOE could also make a difference in getting new technologies to commercial deployment.

There needs to be more thinking that involves starting with deployment and working backwards; RD&D needs to begin with the end in mind. Most efforts start with R&D and try to push uphill toward deployment, but thinking about deployment from the beginning can help inform demonstration, development, and research and can help ensure priming of the market and the broader ecosystem to support deployment. Neither public nor private sector entities do this well. The ability to run techno-economic models is a skill not ingrained into engineers as they are educated; engineers should be trained to deploy their technological skills and knowledge with an eye toward commercialization.

Beyond demonstrations and investments, demand-pull (or market-pull) innovation policy can be very effective. Demand-pull policy can include measures such as advanced market commitments (as was done with COVID vaccines), technology inducement prizes, and public or private procurement approaches that lay out desirable performance characteristics. Different instruments may be needed for different technologies and contexts.

SUPPORT FOR TRANSMISSION, DISTRIBUTION, & PROJECT DEVELOPMENT

Transmission is an area in particular need of policy support. It is often on the periphery of climate discussions and gets less advocacy attention, which puts it at higher risk of dropping out as legislative packages are negotiated this year. It would be a huge loss if it did.

The U.S. transmission system is a 20th century system that has huge constraints, and mechanisms to expand it are inefficient. There is a need to build more transmission to connect areas with abundant renewables to demand centers, as well as to accommodate greater demand as transportation and buildings get electrified. Interregional transmission is not easy or fast to build; obstacles must be removed. Planning currently involves decisions at federal, regional, state, and local levels; it is not set up for speed, and projects end up getting canceled. There are also lots of state and local actors that can block the permitting processes for longer interregional lines. FERC recognizes these transmission planning inefficiencies and has plans to overhaul the process. FERC also has some backstop authority on siting and could step in, but that power has been diminished by court decisions.

Transmission needs financial support as well. The transmission ITC being considered for the budget reconciliation package would help, particularly as ITCs tend not be repealed. An ITC with a 10-year runway (the timeframe for reconciliation) is politically resilient transmission policy that can help rapidly deploy and build transmission, though it will not be enough on its own. There is some money for transmission in the bipartisan infrastructure framework too (plus clarification of FERC backstop authority). New FERC rules to make payment structures work better are also needed.

Equally important to new transmission is existing transmission. There are opportunities to replace, upgrade, and optimize existing transmission, and in a high-electricity future, there is a need to zero in on those, which can help avoid some increases in generation. Advanced transformers, software, and other technologies can help increase the temporal granularity of matching demand to generation and can help avoid electricity losses between generation, transmission, and distribution. The federal government has a role in incentivizing those solutions.

American democracy does not do speed well, but there have to be ways to make project development faster without giving up on public input and democracy.

The distribution grid also requires attention. The distribution system often gets forgotten, but DER capacity is growing and is expected to continue to do so. There is a real opportunity to increase decentralized and digitized resources in smaller-scale, more diverse, residential and non-residential applications. Modeling work suggests that greater penetration of DERs in the distribution grid helps facilitate more renewables penetration at utility scale and makes the overall grid work better and cost less. If the aim is to integrate DERs, EV charging stations, and other technologies, there is a need to upgrade and modernize the distribution system. There is a role for the federal government there too, in partnership with states, to put more funds into existing programs at a range of agencies.

Whether transmission, distribution, generation, or something else, there is a need for large-scale policy change around project development, otherwise climate solution projects will not be able to be built quickly enough. American democracy does not do speed well, but there have to be ways to make project development faster without giving up on public input and democracy. For example, policy could tie future incentives to states enacting faster approvals for projects. The federal government could also do more pre-assessments and approvals of federal lands for clean energy development. Additional economic development grants could be given to communities proactively looking for large-scale clean energy deployment.

Project development would also be furthered if policy could provide some long-term certainty on the market environment. There is infinite capacity in the world to invest in long-duration, low-risk cash flows. Since trillions of dollars are needed to decarbonize, policy makers should set a clear policy that is framed to allow for long-duration, low-risk cash flows, which will bring in capital at a lower cost. The more complexity and risk there is – the more feeling that policy will change – the higher the required return on capital. Policy's aim should be to make things simpler and lower risk, and investors will bring all the money needed. Durability, predictability, and long-term certainty matter.

TECHNOLOGIES BEYOND WIND & SOLAR

While tech neutrality is often a stated goal for policy, there are times conversations need to be more tech-specific. A broad suite of technologies will be needed beyond wind, solar, and lithium-ion batteries, and there has been remarkable success on clean technologies over the past couple of years. There are starting to be more viable 24/7 renewable energy technologies (e.g., in geothermal), exciting developments in long-duration energy storage, progress on siting advanced nuclear reactors, agreements to build natural gas power plants with no emissions and no water consumption, and more. Technology has been progressing well, though obviously not fast enough for climate purposes.

THE DEMAND SIDE

The clean energy conversation often goes straight to supply-side solutions, but that ignores the potential of the demand side. Energy efficiency, conservation, and demand response are vital to decarbonization. Demand in the United States has been flat for years while the economy has grown, and that is a huge accomplishment of energy efficiency, including strong policies and standards. Customers are playing a critical role in resource planning, such as by responding to time-differentiated pricing at peak times. Energy efficiency and conservation are so widely supported and are seen as such no-brainers that they are not getting the attention they need. The demand side needs to be in every aspect of the energy and decarbonization discussion, including R&D, regulation, standards, tax credits, incentives, and market changes.

Energy efficiency, conservation, and demand response are vital to decarbonization.

Traditional energy efficiency, from a capital markets view, is generally very easy to finance because it has a short payback time from energy savings. Digitalization has opened new opportunities for energy efficiency, with smart devices, enhanced grid integration, and other measures making energy efficiency more dynamic. "Active efficiency" is about making sure all of these technologies work together to optimize the demand side, lower overall energy use, ensure demand aligns with clean energy availability, and avoid the need for peaker plants. While the Energy Act of 2020 missed some opportunities on traditional energy efficiency, it took some good steps to move active efficiency into the market, including with programs on smart buildings and building-grid integration. Holistic integrated design can yield even greater efficiency gains than standalone measures.

In addition, it should be remembered that DOE was originally established to focus on conservation – which is different from efficiency. The economy uses lots of electricity for things that can be done mechanically, and there are potential energy savings there that require attention.

DIGITAL TECHNOLOGIES

Part of taking a systems view is having available, transparent, immediate data, to enable decisions to be made. Digital technologies will be enablers of net-zero, providing insights, monitoring, and tools to inform and execute the decisions needed. For instance, corporate buyers seeking clean electricity at all times are dependent on the realities and constraints of the grids where they operate, and both temporal matching and spatial matching require advanced monitoring and insights on locational marginal emissions. Digital technologies also support grid integration through improved electricity management at all levels – transmission, distribution, and demand – through tools such as battery management systems, microgrid controllers, models and simulations of technology combinations, and other digital tools. In addition, digital technologies enable the measurement, data, tracking, and traceability tools that allow for differentiation of zero-carbon commodities.

Software is also an area where the United States has a competitive advantage. Tech inclusivity aside, the United States needs to place bets on which technologies it can be a global leader on. Digital technologies could be a good bet.

ENERGY STORAGE

The big prize in energy storage is long-duration, multi-day storage that enables variable renewables to fully replace thermal generation. It is a multi-trillion-dollar opportunity and an area of huge climate impact. Lithium-ion batteries are fantastic, but they do not enable replacement of thermal generation.

A battery that is basically equivalent to a natural gas system – terrible cycle life, efficiency, and density, but really cheap, reliable, and dispatchable – could replace that natural gas system. There are new efforts that have recently been publicized to do this via iron-air batteries (which basically involve rusting and un-rusting iron); iron is abundant and cheap. Such storage would be a vital, complementary asset in the system.

DISPATCHABLE RENEWABLES: GEOTHERMAL & HYDRO

If there is deep penetration of variable renewables, storage will be vital, but so too will more dispatchable renewables such as geothermal and hydropower.

Geothermal energy may be the most forgotten and misunderstood of the renewables. Geothermal drilling has mostly been stuck in the 1970s, even though there have been huge innovations in drilling in the oil and gas sector. Most of the drilling innovations from shale can translate to geothermal projects. Using horizontal drilling, advanced data analytics, fiberoptic sensing, and other innovations, geothermal could play a big role in a clean energy system. Geothermal is a 24/7 dispatchable resource with a small land footprint, no emissions, and a mostly domestic supply chain. It can also produce lithium as a byproduct, which is in high demand for other clean technologies. In addition, it can repurpose a lot of U.S. oil and gas innovation and idled workers to continue drilling wells, but for a clean energy resource. Geothermal is a hard engineering problem that, when solved, solves energy, and there is more enthusiasm for it now than ever.

Geothermal energy may be the most forgotten and misunderstood of the renewables.

Policies are starting to provide some support for geothermal. DOE has more money for it than it ever has. Geothermal got back into the PTC in 2020. There has been federal action on permit reform. At the state level, California issued a call for many megawatts of a generation resource with no storage, no weather dependency, and greater than 80% capacity factor, which geothermal could be poised to fill. Thanks to the PTC, there have been several new PPAs for geothermal over the past year, and geothermal growth is also happening in countries such as Kenya and Indonesia. Permitting is still a nightmare, though; it is far easier in 2021 to permit a new oil well than a geothermal well. Geothermal is also left out of most energy and climate analyses, and when it is included, the assumptions are often wrong. In addition, the finance community has been wary of geothermal, having lost money on it a decade ago.

Hydropower is the other main firm renewable – though hydro is more variable now in some regions (e.g., due to drought). In fact, the U.S. Energy Information Administration (EIA) has started categorizing hydro as being a non-dispatchable resource in its national numbers. Clearly, though, there is regionality to hydro, and the options in New York are not the same as in California. In some regions, it is dispatchable. Many balancing authorities turn to hydro when times are tough, and it is also often the black start source.

There is a need to rebuild, maintain, and optimize the U.S. hydro system in the next decades – and climate models need to provide guidance on the conditions the hydro system needs to be prepared for. There are opportunities to upgrade hydro, with better turbine designs, increased capacity, and increased operating ranges to better follow load. There are also significant opportunities to add power to nonpowered dams. While small-scale (or micro) hydro projects have some appeal, it is hard to make them pencil out at this point; more R&D is needed. In addition, the right regulatory construct and markets are needed to stop increased wind and solar from displacing and curtailing hydro.

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Geothermal and hydro are not the only dispatchable renewables. Concentrated solar power (CSP) is going up many places around the world. It is much rarer in the United States, although there are national lab efforts to build a next-generation CSP plant that has huge storage capacity, has more dispatchability, and addresses many of the historic issues with the technology.

CCUS

Greater ambition on emission reductions – going deeper, faster, in more sectors, in more places – calls for greater tech inclusivity, yet many advocates for greater ambition also tend to be pushing for more tech exclusivity (e.g., only renewables). A suite of non-renewable, carbon-free technologies will be needed, including CCUS. The need for additional technologies such as CCUS is illuminated by the example of the power sector in California. Analysis of California wind generation data reveals dozens of days a year with little to no wind, including sometimes multiple days in a row. Particularly given the current state of battery technology, there is a need for a fuel in the system, and modeling suggests that CCUS could be key for achieving California's power and industry decarbonization goals. CCUS helps make the entire system more efficient, resulting in less need for many generation types and battery storage; it also helps deliver emission reductions.

CCUS could be of particular use and appeal in the many regions of the United States with very high percentages of coal and gas in their generation mixes. CCUS may be even more important around the world, particularly in countries such as China and India that have enormous amounts of relatively new coal generation plants. Policy, such as tax credits for CCUS equipment in addition to sequestration of carbon, can improve the investment picture for CCUS, as could potential co-generation of other products such as hydrogen.

CCUS begins with carbon capture. Most capture technologies today are likely to be post-combustion on an existing fossil-fired asset. There are several limitations to post-combustion capture, however, such as an inability to be very flexible in operation and to ramp up and down. The tech should run at some optimal load level to scrub the flue gas, both for operational reasons and to get an adequate return on capital.

There are also net-zero natural gas technologies for new power plants (not retrofits) that are coming to market at commercial scale within the next few years. In addition to capturing around 97-99% of CO2, these plants produce no air pollutants, use no water, occupy less land, and can ramp to be flexible alongside renewables. (The lack of air pollution is a big selling point with local communities.) If they also capture leaking methane or utilize renewable natural gas, it may be possible for the plants to actually be net-negative, and they have potential to co-produce hydrogen. With 45Q tax credits, they should be able to bid in at near-zero marginal cost, so power prices should not rise. When these hit the market, they could redefine what counts as best practice under the Clean Air Act, potentially raising the bar for all others with respect to new natural gas generation.

Once captured, something has to be done with the carbon dioxide. One option is to utilize it (the sometimes forgotten U in CCUS), and there is a lot of innovation happening to convert captured CO2 into other useful products. The other option is for the CO2 to be transported and geologically sequestered. The United States already has 5,000 miles of CO2 pipelines, which – regardless of one's views on enhanced oil recovery – is a huge advantage, but a challenge going forward is how fast more CO2 infrastructure can be set up. Sites that are not far from CO2 pipelines and/or have on-site sequestration will be where CCUS technology gets built out. If more Class VI wells get permitted and built, then there will be more sites for deploying projects; like the interconnection queue, speeding up Class VI well permitting will be key to deployment. More geologic storage enables not only CCUS, but also direct air capture (DAC), bioenergy with CCS (BECCS), hydrogen storage, compressed air storage, and more. However, developers of technologies that rely on storage of waste – whether captured CO2, spent nuclear fuel, or others – need to be sure to consider the potential barriers to deployment that might be raised by local opposition to such storage.

NUCLEAR

More than half of current non-emitting electricity comes from nuclear power. Nuclear plants provide mostly centralized, baseload power. (They can technically also provide flexibility, responding to grid demands or times of significant renewables generation, but it is not always the best economic option.) Many studies show that including firm power like nuclear can dramatically reduce the cost of getting to net-zero emissions while maintaining reliability and resilience. It is important to keep the current fleet operating; if renewables end up pushing nuclear out of the market in the United States and globally, that makes climate goals harder to reach. Nuclear power's environmental benefits also go beyond the absence of greenhouse gases; nuclear has no air pollution and has the smallest land use relative to energy produced of any clean energy source.

It is important to keep the current fleet operating; if renewables end up pushing nuclear out of the market in the United States and globally, that makes climate goals harder to reach.

Looking ahead, nuclear will start supporting more distributed generation, through technologies such as microreactors and small modular reactors that are more efficient and have more capabilities. Many advanced nuclear technologies involve innovations not only in size, but also in operations (e.g., passive cooling and safety features), temperatures, efficiencies, and fuels. New designs can reduce the amount of used nuclear fuel, and some are looking to extract more energy from it. Unlike current generations of nuclear plants, which involve huge engineering projects that have encountered numerous delays, smaller advanced systems allow for factory manufacturing, assembly, and shipping to the site. This means higher quantities, faster deployments, fewer delays, and less site preparation.

Advanced nuclear technologies might be able to play a role in decarbonizing the power sector by 2035. There are many private developers working on new advanced reactors, and ARDP awards involve demonstration of technologies by 2028. Microreactors are moving even faster, and some companies are planning demonstrations in the mid-2020s. Indeed, there will be demonstrations of advanced reactors throughout this decade. There is reason to be wary of celebrating individual projects and demonstrations, when what is needed is a huge national and global buildout of technologies in a very short period of time, but this is a fast-moving space with a lot of promise. The Department of Defense can also be leveraged to accelerate demonstration and deployment timelines; deploying advanced reactors on U.S. military bases – where nuclear material is already handled – could accelerate deployment and enhance community acceptance.

The concern may be less about the technologies than about regulatory hurdles such as permitting and siting. The Nuclear Regulatory Commission is trying to reform its licensing process for advanced reactors, but it is not going well; it has to be faster and better. As for community interaction and siting, some communities would be very opposed to siting new nuclear, while others are clamoring to host advanced nuclear demonstrations. One of the benefits of so many advanced nuclear designs being explored is that innovations are being explored in business models and community engagement too. For example, some developers will not start working with utilities or building any reactors until they have already done deep community engagement.

Nuclear energy can support broad decarbonization across all sectors, not just the power sector. Focusing on decarbonizing the grid before other sectors makes sense in many respects, but it means opportunities to successfully decarbonize more holistically through integrated energy solutions might be missed. The main output from nuclear plants is heat; that is generally converted to electricity, but if it is not needed on the grid, the electricity and/or heat could be used to support applications in other sectors, such as thermal and chemical storage, production of clean water, production of hydrogen, and provision of heat for industrial plants. There are efforts underway to demonstrate nuclear hydrogen production, which should be possible at higher efficiencies and lower cost than with renewables. Within the next year, there will be projects with low-temperature electrolysis on-site at nuclear plants, to be followed by demonstrations of high-temperature electrolysis.

HYDROGEN

It will be hard to decarbonize the economy without a zero-carbon fuel in the system, and hydrogen is shaping up to be essential. Indeed, there will be major geopolitical shifts around hydrogen. Hydrogen can be a source of electricity, storage, and heat (or can serve as a feedstock) across sectors. In decarbonization discussions, hydrogen production is usually either blue hydrogen (produced from natural gas with CCUS) or green hydrogen (produced via electrolysis using zero-carbon electricity). In the power sector, using renewables to power electrolyzers and using the resulting hydrogen to generate electricity would reduce far less carbon dioxide than using those renewables directly on the grid, but if the renewable electricity represented excess capacity or power that would otherwise be curtailed, hydrogen would act more as energy storage.

It will be hard to decarbonize the economy without a zero-carbon fuel in the system, and hydrogen is shaping up to be essential.

While blending hydrogen into the U.S. power sector may or may not make sense, the power sector may end up being an exporter of hydrogen to other sectors. In some places, hundreds of megawatts of electrolytic hydrogen production to support industrial or transportation needs have already been proposed. The only way to support that much production that quickly if the electrolyzers run during peak times would be to build new natural gas peakers, but if production can be shifted to off-peak times when clean energy is abundant, then the hydrogen can actually be produced cleanly. (Either route could be referred to as green hydrogen, if RECs are purchased, but only one route would actually be produced by clean energy.) Technologically, there is no reason that electrolyzers need to run at constant high capacity; they can be load-following.

Hydrogen production is not limited to reformation or electrolysis, and those techniques may not dominate in a few decades compared to biologic, catalytic, pyrolytic, or other pathways. The industry is putting money into research for zero-carbon hydrogen that will not be blue or green.

There is a debate about whether hydrogen is the desired product or a building block of it. Hydrogen is a great, carbon-free fuel that is extremely flexible in its potential uses, but it is very hard to make, move, and store. Hydrogen could be used instead as a building block for ammonia. There is already experience to build on and a global supply chain for ammonia, and ammonia is much easier to move and store, but it is more restrictive in its uses.

Hydrogen and hydrogen carriers such as ammonia open up the potential to reuse existing gas infrastructure, which can avoid wasting the capital already invested in it. More broadly, there is a need to embrace the infrastructure that already exists and to drag it toward the infrastructure that is needed. The story being told now is that all investment in fossil infrastructure is stranded investment, but there is a story to tell about the value of existing infrastructure and how it can be the predicate for a clean future. Existing infrastructure and existing rights-of-way can be hugely important; scrapping existing infrastructure and starting from scratch is not a recipe for success.

TECHNOLOGIES, SYSTEMS, & HUBS

There will be a need for breakthrough technologies – including some not yet thought of – to achieve climate goals. Young engineers are thinking about totally different kinds of solar (e.g., paintable photovoltaics, perovskites), low-cost and low-capacity-factor conversion devices (e.g., for hydrogen electrolyzers), batteries designed to fit particular system problems, grid-forming inverters that can provide inertia to the power system, carbon utilization to make all kinds of products (including through molecular foundries), and more.

In addition to individual technologies, there is a need to think about systems. There will be a need for both electrons and molecules – both electricity and fuels – in a mid-century zero-carbon energy system, and a lot of infrastructure will need to be built on top of existing infrastructure. Beyond infrastructure, there is a need to think about systems from the regulatory and governmental structure perspective as well. The Department of Energy is still organized around fuels, which is very 1970s. There is not really an organization charged with systems innovation, and DOE is not well set up to do systems-level demonstrations. Various Secretaries have tried to have cross-cutting initiatives, but all of them fell apart in the Appropriations Committee, because Congress is not organized the right way either. Big organizations are very siloed, and the federal government is too. There are continual efforts to bring people together, make connections, and build relationships, but the only lasting solution is to change the way government is structured.

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It will be important to start demonstrating smaller versions of the overall energy system that are safe, reliable, resilient, affordable, secure, and net-zero. This could involve clusters (or hubs) of sectors and technologies. Los Angeles could be a good site for such system demonstration; it has abundant solar, policies aiming for net-zero, a huge amount of manufacturing, an important port, good geology for carbon sequestration, and lots of environmental justice considerations. Hubs are also starting to form in other places around the country where industrial emitters and geologic carbon storage are located. CCUS and hydrogen hubs in places such as the Ohio River Valley could each yield hundreds of thousands of jobs and billions of dollars in economic output, though the right regulatory structures are needed (e.g., hydrogen is currently regulated as a specialty chemical, not as an energy commodity). Having a strong regional governance organization that does broad economic development and that has buy-in from local communities and agencies is the ideal place to locate hubs, but many places do not have one. Still, there is money in the bipartisan framework to support regional hydrogen hubs to help demonstrate the technology, and the World Economic Forum is demonstrating industrial clusters around the world.

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Jan Vrins, Segment Leader Energy, Sustainability and Infrastructure, Guidehouse

John Wagner, Laboratory Director, Idaho National Laboratory

Marianne Walck, Deputy Laboratory Director, Chief Research Officer, Idaho National Laboratory

Trey Ward, CEO, Direct Connect Development Company

Michael Webber, Chief Science & Technology Officer, ENGIE

Jeff Weiss, Executive Chairman, Distributed Sun

Lisa Wood, Vice President, Customer Solutions, Edison Electric Institute; Executive Director, Institute for Electric Innovation

APPENDIX B: AGENDA

MONDAY, JULY 26

THE CHALLENGE: DECARBONIZING THE ELECTRICITY SYSTEM

Day one focuses on laying the groundwork to identify and discuss the problems that will underpin the week, with a focus on the U.S. electricity system. What policy levers, technological deployments, and economic forces will define the energy transition in the decade ahead? What countervailing inertia stands in the way? How should decision makers evaluate which pathways to pursue, and when?

Welcome: Greg Gershuny, The Aspen Institute

Introduction:
Miranda Ballentine, Renewable Energy Buyers Alliance
Rich Powell, ClearPath

SESSION ONE: Briefing Room: Pathways to a Carbon-Free Electricity System
Many pathways to a decarbonized grid have been modeled and described, and many state governments, electric utilities, and now the federal government have articulated goals to achieve this. What are the realistic, economically-viable pathways to decarbonize the U.S. power grid and can the U.S. get onto a track that seeks to achieve these in the timelines set out by governments and companies? And, even if everyone is aligned on the goal, how fast can we actually get to net zero emissions?

Moderators: Rich Powell and **Miranda Ballentine**

Discussants:
Spencer Nelson, ClearPath
Nikit Abhyankar, Lawrence Berkeley National Laboratory
Melanie Kenderdine, Energy Futures Initiative
Joe Rand, Lawrence Berkeley National Laboratory

SESSION 2: Barriers and Risks to Achieving a Decarbonized Electricity Sector
As the costs of renewable electricity continue to decrease, what barriers and risks remain for decarbonizing the electricity system. Can and must utilities build and maintain firm and dispatchable generation resources? As the severity of weather-related power outages increases, what generation mix is needed to increase the resilience and reliability of the grid? How might increased electrification of other sectors, like heating, transportation, and industrial processes, create new risks or make them more vulnerable to power system disruptions?

Moderator: Rich Powell

Discussants:
Jud Virden, Pacific Northwest National Laboratory
Caitlin Durkovich, National Security Council
Maureen Hinman, Silverado

SESSION 3: Beyond Clean Air: Equity in Access, Wealth-Building, and Jobs
Policymakers and the general public have a renewed focus on the imperative for carbon-free energy to benefit all people. What should be done to ensure historically marginalized communities—not just the privileged—can access low-cost, carbon-free energy for their homes, schools, and communities? Who is building wealth from the clean energy revolution and how can society expand this wealth creation? What will it take to ensure clean energy jobs are desirable for workers? Are clean energy jobs uniquely vulnerable to outsourcing?

Moderator: Miranda Ballentine

Discussants:
Pedro Pizarro, Edison International
Jacqui Patterson, The Chisholm Legacy Project
Sean McGarvey, North America's Building Trades Unions

TUESDAY, JULY 27
CATALYSTS AND COMPLEMENTS — THE ROLE OF MARKETS AND POLICY

Days 2 and 3 will dive into the catalytic and complementary solutions required to decarbonize the U.S. electricity system and prepare it for rapid increase in demand as we electrify the economy. What market, policy, behavior, and technological solutions are required?

SESSION 4: Decarbonizing from the Bottom-Up: Designing Markets for Decarbonization
Are organized wholesale markets or vertically integrated markets better equipped to rapidly decarbonize the power system in the most affordable, reliable, resilient way? What lessons can one draw from today's RTOs and ISOs? Do these lessons indicate the need for changes to existing markets, and how should these lessons influence the hypothetical initial design of a western and/or southeastern organized market? Could wholesale markets be designed in ways that also allow risk taking on innovative technology demonstration, or should this instead be left entirely to the regulated markets?

Moderator: Miranda Ballentine

Discussants:
Robert Powelson, National Association of Water Companies
Caroline Golin, Google
Lynne Kiesling, Colorado University, Denver

SESSION 5: Decarbonizing from the Top-Down: Policies and Regulations for Decarbonization
Despite decarbonization goals and pledges by governments and companies, it appears likely that, in order to achieve deep decarbonization on the scale and speed necessary to reach those goals, public policies will need to be in place. What policies (including perhaps a clean electricity standard, a price on carbon, cap-and-trade, or other mechanisms) are necessary to achieve these goals? What are the carrots and the sticks needed? How can "common good" investments such as resilience be incentivized during this process? How can regulators permit clean energy construction fast enough to combat the climate crisis, especially for particularly tricky interstate transmission projects?

Moderator: Rich Powell

Discussants:
Paul Tonko, US Congressman (D-NY-20)
Kathleen Barrón, Exelon Corporation
Emily Fisher, Edison Electric Institute
Aliya Haq, Breakthrough Energy

WEDNESDAY, JULY 28

CATALYSTS AND COMPLEMENTS — THE ROLE OF TECHNOLOGY AND POLICY

Day 3 continues the dialogue on solutions.

SESSION 6: Complementary Generation Technologies
If marginal-cost-free wind and solar energy are a huge slice of the decarbonization pie, what carbon-free technologies will be necessary to complement intermittent renewables to achieve (net?) carbon-free? What role should nuclear power play? How about fossil-plus-CCUS generation? And specifically, what is the near and long-term role for unabated gas (and its attendant infrastructure) in a carbon-free future?

Moderator: Miranda Ballentine

Discussants:
Shannon Angielski, Van Ness Feldman LLP
Adam Goff, NET Power/8 Rivers
Shannon Bragg-Sitton, Idaho National Laboratory

SESSION 7: Catalyzing and Enabling Technologies
Renewable technologies are likely to be an ever-larger part of the grid, and might be positioned to grow even further with the help of a number of key catalyzing technologies. Are well understood (yet difficult to build) dispatchable renewable technologies, including hydropower and geothermal, nearing regulatory and technology breakthroughs? What is the role of hydrogen in the energy transition? Will there soon be economical long-term storage options to solve not only the multi-hour challenge of solar and wind, but multi-day and week challenges as well?

Moderator: Clint Vince

Discussants:
Sharon Tomkins, Sempra
Brandon Middaugh, Microsoft
Mateo Jaramillo, Form Energy
Tim Latimer, Fervo Energy

SESSION 8: Technology-Supporting Policy Frameworks
New technology will be difficult to bring into the market without supportive policy, ranging from basic and applied energy research to smart deployment incentives. This has been an area of significant bipartisan policy movement, particularly through the Energy Act of 2020 passed in December. Building on the Energy Act, what policies that now exist could benefit from improvements, expanded implementation, or other increased attention focused on implementation? What is the next generation of policy that can help clean technology thrive?

Moderator: Rich Powell

Discussants:
Kristen Siegele, Office of Senator Crapo
Paula Glover, Alliance to Save Energy
Vanessa Chan, US DOE

THURSDAY, JULY 29

WRAP UP - PUTTING IT ALL TOGETHER

WRAP UP - Putting it all together

Moderators: Rich Powell and Miranda Ballentine

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