2018 ASPEN ENERGY WEEK

DESIGNING TRANSITIONS FOR THE NEW ENERGY ECONOMY

A REPORT FROM THE 2018 ASPEN ENERGY WEEK

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THE ASPEN INSTITUTE ENERGY & ENVIRONMENT PROGRAM

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DEDICATION

This report is dedicated to the late Jim Rogers, a long-time mentor and friend to the Aspen Institute Energy and Environment Program. We are eternally grateful for his contributions in thought, leadership, and counsel – Jim's commitment to environmental stewardship and social equity continues to inspire us every day. We hope to honor his legacy and vision for a greater future in all that we do.

FOREWORD

The inaugural Aspen Energy Week evolved from the Energy Policy Forum, which created key learnings and connections throughout its 40 consecutive years. This year, Aspen Energy Week emphasized even greater action and influence by bringing together a diverse group of entrepreneurs, policymakers, industry executives, and thought leaders to design the next energy economy. The robust discussion analyzed the critical challenges and opportunities for a successful and equitable energy transition.

Even with the urgent environmental and energy challenges we are facing today, there is a tremendous amount of power in optimism, experimentation, and innovation. We have the utmost confidence that we can effectively devise, design, and deploy a new wave of policy and regulation, technology, market reform, and innovation for a cleaner and more equitable energy economy.

Together with the Aspen Institute Energy & Environment Program, we acknowledge and thank the Aspen Energy Week sponsors for both their funding support and their participation. Their generosity and commitment to our work ensure the convening can continue to provide valuable high-level discussion.

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We would also like to extend thanks to Dave Grossman for writing this report and expertly capturing the dialogue that took place throughout the week.

The speakers, participants, and sponsors are not responsible for the contents of this report. It is an attempt to represent ideas and information presented during the convening, but not all views could be included, the views expressed were not unanimous, and participants were not asked to agree to the wording of the report.

We conclude from the discussion that it is imperative to have so many experts from across industry, finance, policy, regulation, politics, and technology involved in a productive dialogue that defines opportunities for concerted action on designing the energy transition. It is increasingly important to have an effective convening space for enlightened leadership and space for organizing deep dialogue to devise impactful actions, plans, and original policy.

Ernest Moniz & Andy Karsner
Aspen Energy Week Co-Chairs

EXECUTIVE SUMMARY

The primary driver of conversation in the electricity sector, at least over the last few years, has been the sectors' adaptation to climate change policy, regulation, and other technology changes. While federal policy has been rolled back over the last two years on this topic, cities, states, and companies have taken up much of the slack.

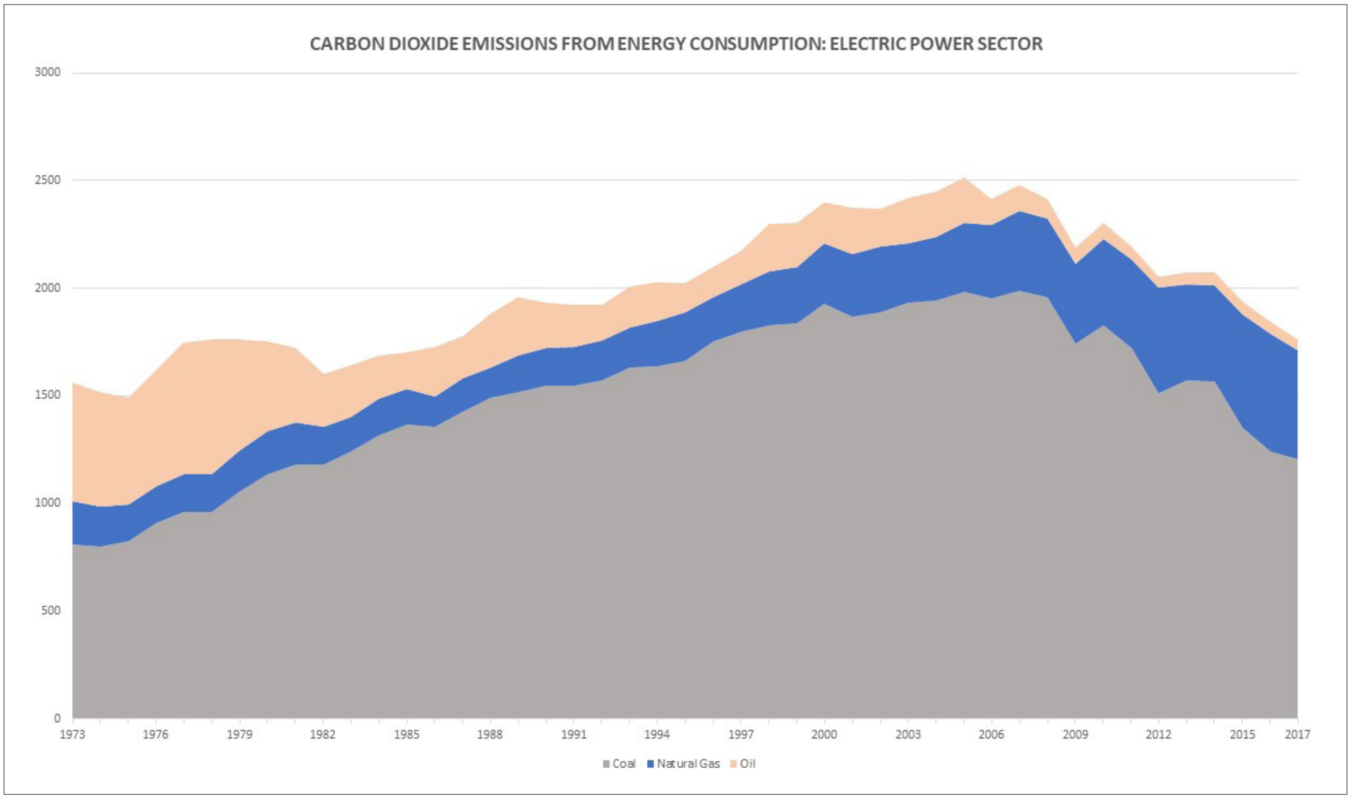
The overarching imperative that must guide discussions of policy, regulation, technology, and more is the need for deep decarbonization. As global emissions continue to grow, humanity will either commit itself to an ever-steeper emissions reduction trajectory and ever more negative emissions technologies – or to a destabilized climate. Decarbonization is needed economy-wide – not just in the electricity sector, where there is a clearer path to decarbonization, but also in transportation, industry, buildings, and other sectors. Deep decarbonization will require pursuing large-scale energy efficiency, decarbonizing electricity, electrifying other sectors, developing zero-carbon fuels for the harder-to-reach corners of the economy, and achieving significant negative emissions. Existing technologies such as renewables will be important, but so will technologies still at more nascent stages of development and deployment, such as hydrogen, advanced nuclear reactors, storage and battery technologies, ever smarter cities, and large-scale carbon management and negative emissions technologies. Financing for many of these technologies, however, is a continual challenge.

The question from a climate perspective is whether humanity can change mere additions of clean energy into a real transition.

The decarbonization imperative and technological, policy, and economic developments are affecting the energy mix in the United States and globally. In particular, natural gas (which is becoming more of a global commodity like oil) and non-hydro renewables (especially wind and solar) have seen growing market shares in the U.S. and global energy mixes over the past decade or two. The planet, however, does not care about shares but about the actual tons of carbon and other greenhouse gases. The question from a climate perspective is whether humanity can change mere additions of clean energy into a real transition.

The shifting energy mix, in turn, has led to significant churn in U.S. wholesale electricity markets, as natural gas, wind, and solar have compressed the market clearing price, to the detriment of resources such as nuclear. As the role played by renewables transitions from being marginal to meaningful, driven in part by state policies, the bulk power markets are facing new challenges. The way state policies interact with wholesale markets, however, was not discussed much until a couple of states sought both to add renewables and to protect existing nuclear. Many of the ensuing battles over these efforts have been proxies for fights about carbon, jobs, and other preferences, leading markets to become more complicated and spurring some to call for directly addressing carbon. At the same time, the current Administration has plans to prop up coal and nuclear plants in the name of national security.

Technologies with implications for deep decarbonization and the future of the energy sector go beyond energy. 3-D printing, for example, could disrupt distribution and supply chains – and the energy used in them – for all products, as there will be less need to ship components around the world if they can just be printed on site. Automation could change how vehicles work and how energy infrastructure is maintained. Voice assistants could become coordinators of smart devices in homes, bringing a new channel of value to utilities and other energy providers. Blockchain could enable



a transactive, decentralized, and secure grid. These and other technological disruptions could converge in unpredictable ways and create widespread changes in society and the economy, as well as in energy.

These changes in technologies, energy mixes, and environmental imperatives – along with energy systems that are increasingly decentralized and pressure from consumers seeking greater control and choice – are creating significant stresses on utilities and the grid as a whole. Many utilities are exploring grid upgrades, digitization, new power supply options, new customer-side services, different rate designs, electrification of other sectors, and ways to promote equitable distribution of benefits from the energy transition. Several are also exploring more fundamental changes, such as moving toward a model of being orchestrators of the centralized and decentralized assets connected to the grid, with third-party companies being the content providers on the utilities' integrated platforms. A system with more distributed, cleaner, two-way power flows requires a modernized grid, and several states are pursuing grid modernization initiatives, each in their own way, with utilities as key players. Such a modernized grid requires greater flexibility – such as from more battery storage and increased use of demand-side management – and also has to address cybersecurity concerns.

These changes in technologies, energy mixes, and environmental imperatives are creating significant stresses on utilities and the grid as a whole.

The pace of change in technologies and policy imperatives makes it challenging – and, at the same time, vital – for utility regulators to enable innovation and decarbonization while ensuring reliability, affordability, and the like. In addition to allowing utilities to recover system investments in digital infrastructure, regulators could also explore changing rate designs to spur utilities to focus on performance instead of volume of electricity sold – and to eventually become deliverers of services instead of sellers of a commodity. Regulators also need to figure out how to create business models that support third-party companies and how to create opportunities for failure in providing services and solutions, as there is no innovation without failure. At the federal level, the U.S. Department of Energy has been a key driver of fundamental research and development, as well as of related financing, making projects and technological innovations happen that have been beneficial to the energy sector. There is a need, though, to think more creatively about public-private partnerships that allow both sides to be more flexible, creative, and nimble in advancing clean energy innovation.

The low-carbon transitions needed in the energy system, in conjunction with the broader technological changes underway, could transform the nature of energy, work, and life, bringing many benefits while also creating significant social and economic disruptions. Issues of social equity have to be considered – not only because it is right and just to do so, but also because failure to do so could create political headwinds to those transformations. The energy transition is and will be extremely painful for a narrow set of people, such as those in parts of the country more reliant on the coal industry, where hopelessness and despair are leading to increased social trauma and decreased quality of life. The transition will proceed more smoothly if it is a big tent that creates an upside for everyone. It is essential for clean energy policies and investments to have clear links to economic development, such as job creation and job training.

Some communities also bear more of the burden of the current energy system than others, and different communities and individuals come to the clean energy conversation with different backgrounds regarding injustices and privileges. Building social equity into energy policies ought to involve defining the burdened areas, understanding what the barriers are to reducing pollution and increasing clean energy access in those areas, explicitly prioritizing those areas in clean energy policy, and ensuring that the policies and strategies are actually executed, monitored, and modified as needed. Efforts to advance clean energy, energy efficiency, clean mobility, economic development, and more – all with community involvement and input – can advance clean energy solutions, reinvigorate communities, and promote greater equity. Indeed, addressing the significant social inequity caused by the existing energy system can be a key motivation for the clean energy transition, as it is in states such as Hawaii. Community solar can be one way of boosting access to clean energy, though improved financing models are needed to make it more available to low-income populations.

Addressing the significant social inequity caused by the existing energy system can be a key motivation for the clean energy transition.

There are proactive policy opportunities that can be pursued to advance an energy transition that is both accelerated and equitable, though some foundational elements, such as improved metrics and greater public and policymaker support, would certainly help. At the federal level, little climate progress is expected given the current Administration and Congress, though the budgets enacted by Congress have been strong in terms of clean energy R&D. There are numerous measures that conceivably could be pursued under existing legislative authority, including Clean Air Act regulations, programs to advance solutions for hard-to-decarbonize sectors, and a carbon adder for wholesale electricity markets. In addition, there are relevant issues outside of the traditional energy and environmental realms that deserve focus, including spectrum policy, automation, artificial intelligence policy, infrastructure funding, and workforce training. There is also a lot of potential for policies at the sub-national level, including local government efforts to advance smart cities, state financing efforts such as green banks, and state policies such as renewable or clean energy standards. California is the only U.S. state with a comprehensive climate policy, with a variety of different programs aimed at climate change, including an economy-wide cap-and-trade system. Such economy-wide carbon prices are one way to push progress across sectors, but other types of policies can also affect the markets for clean energy, including government procurement standards. Furthermore, there are several globally-oriented U.S. policies and international policy harmonization efforts that could be pursued. Policy discussions cannot be just domestically-focused if the aim is to actually bend the global emissions curve downward.

DECARBONIZATION

The overarching imperative guiding discussions of policy, regulation, and technology is the need for deep decarbonization. The transition to low- and zero-carbon energy must be accelerated in order to avoid the worst impacts of climate change.

THE MATH & THE PATH

The climate math is daunting, and delay in taking serious climate action has made the job ahead much harder. If serious mitigation efforts had started in 2000, the reduction curve to have a two-thirds chance of staying below 2°C of warming by 2100 would have been much less steep than it is now (though still quite steep), with an annual rate of emission reduction around 3% per year (without factoring in negative emissions). If serious mitigation efforts start now, it will require a 10% per year rate of reduction. If serious efforts do not start for another 10 years, it will require a 30% annual rate of reduction. Many global carbon budgets indicate that the world is already locked into 1.5°C of warming absent negative emissions technologies. As emissions grow, humanity is committing itself to a need for ever more negative emissions technologies – or to a destabilized climate. Delays in action are making the job ahead not only more difficult, but also costlier.

Economy-wide decarbonization is needed, encompassing transportation, industry, buildings, and other sectors that will be much more challenging to decarbonize.

In the United States, which represents more than 15% of global energy-related carbon dioxide (CO2) emissions, emissions have to decline at a rate of about 155 million tons per year for the next couple of decades. This will require reducing to zero the emissions of about 12 gigawatts (GW) of coal, 12 GW of natural gas, and 12 million vehicles – each year, every year, between now and 2040.

In discussing the low-carbon future, conversations tend to focus on the electricity sector, as how decarbonization can occur there is generally understood. Economy-wide decarbonization is needed, though, encompassing transportation (including not just personal vehicles but also trucking, aviation, and shipping), industry (e.g., industrial heat and processes), buildings, and other sectors that will be much more challenging to decarbonize – at least on a timescale in accordance with general understanding of climate requirements. Most literature on pathways to deep decarbonization have the same basic steps: pursue massive energy efficiency, decarbonize electricity, electrify other sectors, get zero carbon fuels for the harder-to-reach corners of the economy, and achieve significant negative emissions to counterbalance the emissions that prove too difficult to eradicate.

Some argue that all the technologies needed to address climate change already exist and that the key challenge is figuring out how to scale them. Billions of dollars in private investment are already flowing into climate solutions, including renewables, energy efficiency, microgrids, transportation, and carbon management technologies. That is still insufficient, however. Trillions are needed, and projects and technologies are not as pervasive as they need to be.

Others argue that, while a lot of progress can be made with technologies that already exist, technologies under development have to be made into realities (at scale), and scientific breakthroughs may be needed in the longer term. Technologies with breakthrough potential for deep decarbonization include (but are by no means limited to) hydrogen, advanced nuclear reactors, storage and battery technologies, smart cities and grids, and large-scale carbon management and negative emissions technologies. In the United States, increased support from the U.S. Department of Energy (DOE) will be necessary to advance innovation and new technologies.

Deep decarbonization pathways are not centered in the developed world, however. The United States is important, particularly as an incubator of ideas, but what China and India do will be far more impactful. It is essential to influence the countries that are adding most of the emissions going forward. For instance, the expected build-out of electric power globally over the next several decades envisions the developing and emerging world adding the equivalent of two EUs and one United States. (In 2016, for the first time, global investment in electricity exceeded investment in oil and gas.) The efforts in advanced economies have to be translated to others, both in terms of policy structures and technological innovations. The flow is not just one way anymore though; Chinese industrial policy, for instance, arguably spurred the solar revolution.

ENERGY EFFICIENCY, RENEWABLES, & BATTERIES

Energy efficiency is the least carbon-intensive and one of the most cost-effective options to decarbonize. California, for instance, has pursued energy efficiency aggressively and has seen per capita energy demand remain basically flat for the past 40 years as a result – at the same time the rest of the country's per capita demand rose substantially. While California's energy rates are among the highest in the country, its energy bills are among the lowest.

Energy efficiency has to be a decarbonization priority, requiring technology, design, policy, new business models, and much more. Greater ambition on efficiency is also needed; if society and governments have low expectations for what can be achieved with energy efficiency, they will inadequately invest in mining what is in reality a very large resource. The notion that there is a limited amount of "low-hanging fruit" is generally inaccurate, as efficiency opportunities "grow back" faster than they can be harvested. There is, for instance, empirical evidence that integrated design opens up efficiency reserves that are several-fold bigger and cheaper by using fewer and simpler widgets in ways that are more artfully timed and sequenced. Likewise, creating digital twins of facilities' energy systems can help them pursue deep energy efficiency (and demand response) opportunities.

Energy efficiency is the least carbon-intensive and one of the most cost-effective options to decarbonize.

Renewables, too, are a key part of the decarbonization pathway. The economics are very attractive – and radically different from even a few years ago. Solar PV prices, for instance, have been plummeting. Long-term solar contracts in Nevada have come in under 2.5 cents per kilowatt-hour (kWh) including federal subsidy. Over the next decade, if financing conditions remain stable (which is a big variable), 2 cents per kWh will be achievable without any subsidy.

As renewables deployment increases, though, challenges arise. The risks of congestion and curtailment, for instance, are already stopping some building of renewable energy, and that risk will become more prominent as renewables scale up. In addition, the marginal cost of carbon abatement goes up, and pushing to 100% renewables gets really expensive.

As more renewables get built, including sometimes where and when there is no demand (having been driven by policies rather than markets), there are options for what to do with that excess electricity. Storage is one key option. As with solar, lithium-ion battery prices have been plummeting over the past few years. Because of the economics, some utilities are starting to envision meeting the need for flexible, load-following, fast-ramping resources with battery storage instead of gas peaker plants (or hydro) within several years. Batteries are unlikely to take over for peakers entirely within the next couple of years, though, as there is nowhere near enough worldwide battery production to meet the need. The duration of battery storage also is not yet long enough for some utility needs, such as during cold snaps or major storms. In addition, the price of batteries does not really reflect the fact that lithium is mined in only five countries, and cobalt in just one (the Democratic Republic of the Congo). There are many different potential battery chemistries out there, though, and there is potential for massive disruption from material science breakthroughs involving earth-abundant materials. Different materials and chemistries could yield better, lower-cost, longer-lasting batteries, but more budgetary support is needed for advanced materials research and applied research.

Transmission needs to be one of the tools available, as it can help integrate vast amounts of renewables while lowering power prices.

Transmission lines across the country could also get increased electricity from renewables to where it is needed. (After all, 3pm in California is 6pm in New York, right when additional power is needed.) Transmission needs to be one of the tools available, as it can help integrate vast amounts of renewables while lowering power prices. An extensive national network of high-voltage transmission lines, however, seems highly unlikely, at least on timescales needed to solve the climate and energy transition challenges, given obstacles such as money, rights-of-way, and NIMBY opposition. Even multi-state transmission projects – ones that pass through non-customer states – are overly complicated. Transmission projects that go directly from producing states to consuming states, however, are important. The fact that railroads are starting to get into transmission, granting rights-of-way along rail lines for high-voltage lines, is also a potential game-changer.

There are other possible solutions as well. For instance, demand response could shift loads to the middle of the day, when solar power is at its peak. Renewables could be built closer to loads, in the form of distributed generation. In addition, as described below, excess renewables could also be turned into hydrogen, fuels, or products, leveraging the electrons to synthesize other aspects of a broader decarbonization effort.

HYDROGEN

The hydrogen-plus-electricity economy is one of the visions for addressing hard-to-decarbonize sectors. Hydrogen, like electricity, can sit in the middle between primary energy sources and energy end-uses, acting as a major energy carrier. For example, there is a pilot project in the North Sea to build offshore wind and bring the power to the southern part of Germany, which is expensive from a transmission perspective. Instead, the power could be used to create hydrogen at sea and pump it into pipelines for use by industry, large vehicles, and perhaps households.

Hydrogen could be used for industrial processes and could potentially help in the transportation sector as well, though use of hydrogen for transport faces some hurdles. For instance, hydrogen (a kilo of which has roughly the same energy content as a gallon of gasoline) requires a totally different car and a totally different fueling infrastructure, and it has to compete with battery electric vehicles, which can just plug in. Still, some vehicle manufacturers are actively promoting hydrogen for transport.

Hydrogen also has real promise for utilities. Hydrogen could be used as long-term energy storage, creating the potential for moving peak from season to season (especially if hydrogen can be made cheaply). In addition, if hydrogen is cheap enough, every existing combined cycle plant could be retrofitted to use hydrogen.

Hydrogen can be cheap. With new technologies and the newly expanded Section 45Q tax credit, it is conceivable to get hydrogen at 63 cents per kilo. If natural gas is cheap, hydrogen could be below a quarter. With Allam-cycle natural gas plants, there is line of sight for production of super-cheap hydrogen. (Hydrogen could, of course, be produced from other sources besides natural gas.) Transitioning from conventional natural gas to hydrogen could be further facilitated by powering the conversion process with excess renewable energy at zero marginal cost.

Countries with cold winters and few renewable sources are places where hydrogen (or bio-gas) could be especially useful. Existing natural gas infrastructure could be re purposed for hydrogen, which avoids stranding those assets in a low-carbon world. Britain, for example, is starting to inject hydrogen into the existing natural gas system. There is a pilot underway to replace all natural gas heat with hydrogen heat (made with steam reformation with carbon capture and storage (CCS)); if the pilot works, all of Scotland will be next. Hydrogen is a way to get low-carbon heat into the system. While existing infrastructure in most places cannot be instantly converted for hydrogen use, inner tubes can be run through existing gas pipelines to enable them to carry 100% hydrogen. Europe is far ahead of the United States in thinking about these kinds of changes, given the greater focus and investment there around deep decarbonization.

NUCLEAR

To achieve deep decarbonization, existing nuclear plants need to be kept online, as well as a pathway created for advanced nuclear. There are a handful of companies with real line of sight to advanced nuclear. NuScale Power, for example, is close to a deal on its small modular reactors and could be online by 2024. Its technology is on track, but it needs some certainty to get off the ground, such as a loan guarantee, a deal to site a reactor on a military base, or to close the deal it is working on. Oklo is pursuing mini reactors that could fit in a shipping container, which could be ready as soon as 2022, but they do not have the initial fuels they need. Likewise, TerraPower needs a test reactor in the United States; it is testing in Russia at the moment.

To achieve deep decarbonization, existing nuclear plants need to be kept online, as well as a pathway created for advanced nuclear.

While there has been tremendous innovation in advanced nuclear (both fission and fusion), with lots of startups, there is a need to massively scale up support and investment. In the meantime, policymakers have struggled to figure out how to support existing plants. At the federal level, nuclear has been lumped in with coal in search of a solution, while at the state level it has been lumped in with renewables.

TRANSPORTATION

Transportation represents a significant source of greenhouse gas emissions in the country – and an even bigger relative source in states that are decarbonizing their electric grids. In California, for instance, transportation accounts for more than 40% of greenhouse gas emissions.

Investment in the electrification of transportation will be essential. Electric vehicles (EVs) are starting to see growing penetration throughout the United States, especially in California. Advancements in technology have been a key factor in the evolution of clean transportation, such as in helping to overcome concerns about cost and range anxiety. Consumer demand is another driver, and EVs are now more accessible to consumers than ever.

Some utilities, where permitted, are working with their customers to advance EV penetration (e.g., through charging infrastructure). Utilities in some states can raise a lot of capital and get to scale quickly. All California utilities, for instance, are making significant investments in this space, and the state is running an interesting experiment in giving the three major investor-owned utilities there different models for providing services in the EV area. While some utilities are leading in pursuing EV charging opportunities, many others appear to be acting as if they refuse to see EVs as an opportunity. A decarbonized grid with electrified transportation represents a more complicated picture for these utilities, which are unsure what services they can and will be asked to provide.

There are challenges presented by a large number of EVs on the grid. For instance, the system is not currently designed to handle large, unexpected, variable loads such as EV charging, which is why some utilities are pushing for time-of-use rates to shift those loads. In addition, the model of EV deployment one anticipates affects the infrastructure needed. Many utilities, for instance, are thinking about individual family owned EVs, but with the advent of autonomous vehicles – which are likely to be electric, centrally managed, and fueled as fleets – different strategies may be required.

It is important to recognize that the challenge of reducing transportation emissions cannot be confined to electrifying personal vehicles. For instance, there is a need to advance electrification within large, ready-to-adopt industries, such as goods movement, transit, and niche providers within transit. Electrification of goods movement could also provide real benefits to communities, such as improved air quality around ports.

There is also a need to pursue strategies to reduce emissions from heavy-duty trucking, ships, and airplanes. Natural gas vehicles, for example, could play a role, particularly in heavy-duty vehicles and in the marine sector. There could also be further investments in hydrogen fueling stations in the future. In addition, consumer procurement power could be used to accelerate markets for cleaner options. For instance, a large customer consortium could come together and put out golden carrots, laying out specs for ambitious efficiency goals for, say, planes and trucks, promising that the consortium will buy a certain amount if the specs are met.

SMART CITIES

Clean energy and transportation are coming together in smart cities, which are integrating technologies to advance environmental sustainability, citizens' well-being, and economic development. Beyond electricity and transportation, this also includes water, buildings, and lots of technologies and infrastructure. The intersection between smart city platforms and new energy networks will be transformative, including intelligent buildings, connected homes, and a range of services that can unlock new value and new roles for those in the energy sector.

Clean energy and transportation are coming together in smart cities, which are integrating technologies to advance environmental sustainability, citizens' well-being, and economic development.

There are many smart city initiatives underway globally, with numerous companies and stakeholders involved. Not all stakeholders, though, have the level of sophistication and inclusion that might be desirable in order to engage with constituents, vendors, and others to prepare the needed infrastructure for a smart city. It can be a challenge to unify the political infrastructure and get the various agencies to work together towards a master plan. The water people do not talk to the gas people, who do not talk to the police or the mayor, and very few smart cities have energy companies and regulators in the discussions at the front end. In addition, the various stakeholders do not look at value and investments in the same way; the way a utility versus a government versus a technology provider views investments, for instance, can be totally different.

There are also legal and regulatory challenges and structures that have to be sorted out in order to apply the technologies successfully. For instance, where smart cities are moving ahead quickly, there are questions about whether there is adequate protection against warrantless searches of data or provision for the enforceability of smart contracts. These kinds of regulatory and legal frameworks have been evolving much more slowly than the technologies.

CARBON MANAGEMENT

As noted earlier, the grim reality of deep decarbonization math argues for pursuit of carbon management on a very large scale, going to negative carbon where achievable. Carbon management almost certainly has a critical role to play in deep decarbonization, particularly given industrial emissions and big coal-fired power plant fleets around the world (e.g., India, China) that will not be shut down any time soon.

Lots of carbon management technologies already exist. For instance, NET Power's demonstration power plant uses the Allam cycle to combust natural gas in a way that enables capture of all carbon dioxide emissions. There are also facilities that pull CO2 directly out of the air that are starting to be implemented, and costs and efficiency are improving. Direct air capture tends to be the most expensive way to reduce CO2, which means its costs represent the outer bounds of costs for tackling emissions. It is the backstop technology. Today it costs around $600/ton, but there are some subsidies out there (e.g., for EVs in California) that are already higher than that. Captured CO2 can be used for a variety of purposes, including being turned into stone, fuel, or ethylene. It can also be used to produce materials through 3-D printing.

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Technologies make policies possible, and policies (e.g., procurement standards, zero-emission portfolio standards) make markets and finance possible. For example, cement and concrete can be produced to capture CO2, but procurement standards do not include such products, limiting their growth. In contrast, one policy that does exist is the Section 45Q tax credit that Congress recently expanded for carbon capture, utilization, and storage, including capture of carbon directly from the air. Getting the 45Q credit expanded was a huge win that was years in the making, with lots of political work occurring in the background, including building bridges between environmentalists and fossil fuel interests. 45Q is already spurring investment, and the reductions that result (likely more from industrial facilities than power plants) will be substantial. There is more to do, though. There is a need to work with the Internal Revenue Service to institute reasonable guidelines for 45Q, as well as to support legislation to expedite permitting for CO2 pipelines. (The technology exists to capture pure streams of carbon from industrial facilities – and, with the NET Power demonstration plant, power plants – but there is a shortage of pipelines.)

Financing is key, but carbon capture and management receive a vanishingly small percentage of clean energy investment. There is a need to dramatically expand innovation and finance efforts. Private activity bonds are one way to lower costs. It is also important to maintain the advanced fossil lending capacity in the DOE loan program office, as well as support for basic and applied research. Technology gets better, cheaper, and faster because of innovations and financing.

FINANCING CHALLENGES

Some technologies that could contribute to deep decarbonization are tougher to develop than others, facing large capital intensity but an absence of money in the marketplace. For example, some bigger technologies (e.g., energy storage, advanced nuclear) are hard for venture capital (VC) to support for many reasons, including greater VC interest in fast-growing software companies and lean startups than in technologies that require years of effort and thousands of hours of testing. These tougher technologies tend to require buying steel and concrete, but VCs do not want or know how to be in project finance. VCs tried to apply the tech model of lean innovation to clean tech, but it does not work. Likewise, big, expensive, hard technologies are difficult for institutional capital. In addition, new hardware technologies generally require the companies that invented them to own the risk that they work, but those companies tend to be thinly capitalized, which makes them hard to project finance. Some sort of public-private partnership may be needed to resolve the barriers to accelerating innovation.

There are financing challenges at the other end of the spectrum as well. For instance, there are questions about how to efficiently finance distributed energy resources (DERs), given their small, dispersed nature. (Similar challenges will apply to the shift to local manufacturing through 3-D printing, discussed later.) Tax equity is great for padding the pockets of Wall Street bankers, but not for disseminating DERs more broadly. A warehouse facility is needed, but banks do not have any data to understand the performance of these credit products. All the money sitting out there looking for returns has to figure out how to shift away from larger projects and go small.

In addition, decarbonization efforts outside of the electricity sector are hard for the financial markets as well. Electricity is a lot easier to finance, as people understand power purchase agreements (PPAs), long-duration contracts, and the like. Other process technologies, fuels, chemicals, and so forth are more complicated.

THE ENERGY MIX & WHOLESALE MARKET REFORMS

The decarbonization imperative, technological improvements, and policy and economic developments are leading to shifts in the energy mix in the United States and globally, with impacts on global energy markets and U.S. wholesale electricity markets.

TRANSITIONS IN THE ENERGY MIX

Both in the United States and globally, a review of the shares of fuels in the energy mix over time reveals a system in constant transition. In the early 1800s, wood and biomass dominated the supply of primary energy. Coal then came in, then oil, natural gas, and hydro, followed by nuclear and non-hydro renewables. Coal has peaked as a share of U.S. energy and is on the decline, while oil grew and then leveled off. Natural gas and non-hydro renewables have generally been on the rise. Still, 80% of the energy mix in the United States is from fossil fuels. The story is broadly similar at the global level.

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The story is also similar when focusing just on electricity in the United States (except as relates to oil). In the U.S. electric power sector, where demand has flattened due to energy efficiency gains, there are clear signs of transition. Coal's share of the electricity mix has declined as generators switch from coal to renewables and natural gas; coal is now at its lowest share ever. Nuclear power's share grew strongly from the 1970s to the 1990s and then leveled off. Over the last decade, there has been a big expansion in non-hydro renewables, especially wind and solar. Natural gas has seen its share rise significantly over the last couple of decades, following a large buildout of natural gas plants in the early 2000s. Ever since, new capacity additions have basically been shared between natural gas, solar, and wind, as coal plants and what remains of the oil-fired power plants increasingly retire.

These changes were driven in part by policy and in part by increasing competitiveness. Wind and solar, for instance, have experienced massive cost declines – which was surprising for wind, as many felt it was already a mature technology. New wind and solar are now competitive with new natural gas in many locations. When it comes to building anything new, other sources are much more expensive now. This trend of gas and renewables additions and coal retirements is expected to continue in the United States, given current policy and cost considerations.

However, it is important to recognize that the foregoing discussion is about shares of the energy mix and incremental capacity additions. If the goal is solving for climate, only tons of greenhouse gases emitted matter. Although the overall U.S. energy mix shows signs of transition and slowing consumption growth, humanity has never reduced use of any source of energy at the global level. The absolute levels of energy from biomass, for instance, have never gone down. Coal was just added on top of it, then oil on top of that, and so on. Growth in energy demand swamps the incremental changes in the mix; even as shares of energy change, the denominator is growing as well.

Conversations that are focused on the United States therefore may be overly optimistic about the pace of technological change and the clean energy transition that is underway. Looking globally, that transition is far less clear. Last year, carbon emissions went up (after being flat for the three years prior), coal had a great year, oil demand grew, and the fastest growing form of energy was natural gas (not renewables). The world is still using hydrocarbons in growing amounts – and certainly not in rapidly declining amounts as envisioned in scenarios that consider climate targets. While the pace of innovation and technological progress in clean energy has been very robust, the same very much applies to the hydrocarbon sector, which is finding ways to more economically extract resources. The question from a climate perspective is whether humanity can change mere additions of clean energy into a real transition – into subtractions of emissions.

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NATURAL GAS

As just noted, the fastest growing form of energy globally last year was natural gas. For instance, just looking at liquefied natural gas (LNG) in June 2018, demand for LNG on the water was about 45 bcf/day. (U.S. total production in the lower 48 states is around 90 bcf/day.) That 45 bcf/day demand is growing about 2.5 bcf/day year on year – equivalent to one Sabine Pass. Most of that 45 goes to Asia.

Gas is becoming more like oil in terms of being commoditized. LNG on the water means gas is readily available to everyone. It is a flexible fuel. There is always cargo available; it is just a matter of price. (Not all LNG moves by water either; China, for instance, moves about 3 bcf/day of LNG by truck every day to locations outside of the cities.) Accordingly, long-term contracts are going away as the market becomes more liquid, moving instead to more flexible short-term activity driven by commercial incentives.

Natural gas is essentially free in the United States, as developments around associated gas are bringing the variable costs of gas to zero. Producers do not need the gas to make money. For example, oil producers in the Permian have about 40% of their production as gas, but they do not need a value for the gas itself to produce it, given the value of the oil and the value of the ethane, pentane, and the like that can be made from wet gas. Other industries involved with gas have, accordingly, been booming. For instance, the United States will be building a huge amount of ethylene production over the next few years, and the petrochemical industry will be producing and exporting ethylene, ethane, propylene mix, and more at substantial levels.

WHOLESALE MARKET REFORMS

The shifting resource mix and environmental imperatives have led to significant churn in U.S. wholesale electricity markets. The point of wholesale markets was to shift risk from customers onto the market, but the markets were developed for the fossil age. With natural gas, wind, and solar booming, the market clearing price, which used to be pretty high, has gotten compressed, hurting resources such as nuclear.

States already have a range of ways to provide generating resources with the money they need. Texas has an energy-only market – no capacity market – so when there is scarcity, prices go high, which gives load-serving entities incentive to get the power they need. California has a resource adequacy requirement. Eastern markets have capacity markets, which can provide 20-30% of the revenues for generators. In addition, there have been big federal and state tax credits for all kinds of technologies, state renewable energy credits, innovations at the Federal Energy Regulatory Commission (FERC) to allow favorable pricing for demand response and connections for wind, and more. All of these were recognized in wholesale market rules, which allowed for market prices to clear at negative values to allow resources to get production tax credits.

As the role played by renewables transitions from being marginal to meaningful, the bulk power markets are facing new challenges. In California, for example, solar power has boomed, leading to dramatic changes in price-setting and in the load curve. The day-ahead price signal is negative from about 9:00 in the morning to 3:00 in the afternoon. (It starts so early in the morning because a lot of the contracted solar is located well east of the load center.) In the afternoon, there is a significant ramp-up required, and gas units are happy to pay to stay online so they can profit later in the afternoons. There are institutional levers, though, that can be utilized to help improve the efficiency of power markets in supporting higher levels of renewables penetration. The Western energy imbalance market, for instance, is an interesting example of how thoughtful reform in market design can yield value, as it aids the optimization of real time dispatch, reduces renewables curtailment in California, reduces CO2 emissions, and saves millions of dollars for customers. This has been accomplished not with new technologies but rather by looking at institutions.

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While renewables growth has caused challenges, the way state policies interact with markets was not discussed much until a couple of years ago, when New York and Illinois sought not only to add clean generation in the form of renewables but also to protect existing zero-carbon generation in the form of nuclear, as several nuclear plants were at risk of going offline. This led to lots of litigation and complaints at FERC that these nuclear support programs were messing up wholesale markets – despite large parts of those markets already getting out-of-market supports, including supports for wind, offshore wind, and solar that are often higher than the supports for nuclear.

PJM proposed two different reform approaches to address this issue of out-of-market support for resources, which essentially said that resources in capacity markets have to reset their prices to what they would be without subsidies. FERC issued an order, on a party-line vote, that agreed that the state programs were interfering with the market but rejected the PJM approaches. Instead, FERC said that generators (or states) could decide there are resources they like and want to keep in the market and so could carve them and the associated load out and pay them directly. This would lead to significant devaluation of capacity markets.

Many of these battles are proxies for preferences about products, performance, or jobs. For instance, some argue that if prices are too low to support nuclear plants' operation, then they should be retired, while others argue that the emissions implications should be taken into account in the market. As today's markets seek to accommodate the various proxies for preferences, they are getting more complicated and less useful. Until the focus shifts to carbon specifically, the range of discussions and complexities will continue. Markets can be tools for innovation, but not innovation on carbon; for that, some kind of government impetus is needed. Some argue that there is a need to just pick a number on carbon costs and get on with it; the rest will sort itself out.

A carbon adder would be one possible route. Recent Supreme Court decisions (e.g., on demand response) have given FERC significant authority over wholesale power markets. If FERC is looking to eliminate undue discrimination in the marketplace, its powers are at a zenith. A carbon adder in the markets would level the playing field for a lot of resources and would be a market mechanism that is historically consistent with FERC's philosophy. Indeed, the New York Independent System Operator (ISO) is contemplating factoring in a carbon intensity adder for each resource, then clearing the market accordingly. (This is easier to do in a single-state organization than in a regional one, in which states would have to agree with each other to do it, which requires both consensus and political courage.) If New York files this proposal at FERC (possibly in 2019), it will be something of a free-for-all. It appears to be within FERC's authority, and fossil generators would get to do things in a more market-based way, but some FERC commissioners are opposed. That said, it is not clear if New York will actually go forward with the proposal and sacrifice control; the state controls its renewable energy and zero-emission credit programs, but a carbon adder would fall under FERC control.

A carbon adder also is not a simple matter from a technical perspective. Assets are becoming more dynamic in their dispatch, which means carbon intensity can vary in real-time dispatch, with swings of 15-20% within an hour or two. In addition, methane emissions ought to be addressed, which means the adder should not be just for carbon but also for CO2-equivalents – but the equivalents concept is imperfect, and it will be tough to figure out the appropriate charges for methane. There will be lots of details to work out. Instead of a carbon adder, it is also conceivable that ISOs and Regional Transmission Organizations (RTOs) could just create a clean capacity market, defining the service of clean generation.

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To some, the debates about wholesale market reforms seem like playing around the edges, making tweaks for a sinking ship based on the idea of continuing to use energy markets both as the central compensation mechanism and as the central dispatch function for the system, even as more zero-marginal-cost resources come online. Some argue for thinking about bigger market redesigns, with no room for energy markets to play a central dispatch function. Such redesigns would have to account for the interplay between gas, coal, nuclear, and renewables (and more), as well as for the role capacity markets play in putting people on the hook to have hardware or demand response ready when demand crunches arise. Many experts (but not at FERC) are looking at redesigned market structures.

At the end of the day, with excess capacity and more (often clean) resources coming online, some plants simply will not run. The Trump Administration is seeking to bolster its preferred resources, trying to protect coal and nuclear plants. The Administration's national security arguments received a shot in the arm from the Supreme Court's ruling regarding the travel ban and the discretion the Administration has in these matters. There is a national security argument to be made with respect to sustaining the U.S. nuclear industry. For example, if the United States steps away from commercial nuclear power, it has geopolitical implications, as China and Russia are providing nuclear plants to countries around the world. It also affects U.S. credibility in its significant role in nonproliferation efforts.

DISRUPTIVE, NON-ENERGY-SPECIFIC TECHNOLOGIES

The technologies that will have implications for deep decarbonization and for the future of the energy sector go beyond energy. There are a lot of advances happening in IT integration, big data, artificial intelligence, digitization, automation, human-machine interaction, quantum computing, additive manufacturing (i.e., 3-D printing), blockchain, gene editing, and more – all with the potential to create widespread changes in society and the economy. While people tend to overestimate the effect of technology in the short run, they tend to underestimate it in the long run.

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3-D PRINTING

Additive manufacturing involves creating new components or objects out of many possible materials using 3-D printers, lasers, or other binding technologies. It allows for building through addition (from the ground up) instead of subtraction (taking raw materials and using parts of them to make something). The process itself is far more energy efficient and has far lower materials costs. In addition, the technologies and products being designed are often themselves more efficient, designed with computers and printed as single components. The disruption from 3-D printing will be monumental. It will affect everything from the ability to make a solid-state battery cell to how cars and engines are manufactured.

It will also disrupt supply and distribution chains (and the energy used in them) for all products. There will be less need to ship components around the world, as one can just print them on site where they are needed or sold. That will have huge implications for the use of diesel-powered trains, shipping, trucking, and air travel.

The efficiency of 3-D printing processes compared to conventional manufacturing means the amount of material needed may be lower, which could lead to reductions in the amount of resources needed and waste generated. On the other hand, it is also possible that by dramatically lowering the cost of making things, additive manufacturing could lead to making far more things and having an even more consumerist society that has more impacts on waste, resources, and the environment.

In addition, a boom in 3-D printing could lead to a boom in plastics production, and the plastics used in 3-D printing are generally derived from hydrocarbons. Demand for hydrocarbons, especially oil, may go way up – not from an energy but from a materials perspective. That huge increase in hydrocarbon demand, however, may not be a sure thing (at least in the longer term). Places with climate concerns are making pushes toward bioplastics and alternative materials, and there are also pushes for increased plastics recycling and more of a move toward a circular economy and reuse (particularly in light of China's recent ban on accepting materials for recycling).

Additive manufacturing will also raise a host of policy issues around export control, customs and duties, data ownership, intellectual property, and more. Regulators will have some key roles (e.g., certifying 3-D printed parts for use in aircrafts), but they should be very cautious not to impede new disruptive technologies before they take root and the actual market failures become clearer.

AUTOMATION

Automation is a trend across industries, including energy-related sectors. The potential for autonomous vehicles, for instance, has received significant media attention. In the oil and gas sector, many things will soon be automated, including transporting water and natural gas.

Drones, too, enable remote monitoring and automated inspection using machine learning. Companies are increasingly using drones to automate inspections of energy infrastructure, which is cheaper, faster, and safer. For instance, drones can perform inspections for methane leaks using laser and optical gas cameras, increasing the ability to detect methane emissions in the oil and gas sector. Drones and robots are also already being used to inspect transmission lines and the integrity of concrete in hydro facilities.

This is an area where regulation may be needed – by aviation and occupational regulators more than energy regulators. Regulators need to create frameworks that allow drone-based technologies to scale and operate.

VOICE

Smart thermostats have been the initial drivers of smart and connected homes, but next up is voice (e.g., Amazon's Alexa, Google Home). That will be the key way customers interact with devices in their homes. Smart speakers are growing faster than smartphones in the United States and will be in around 20% of wi-fi connected homes (around 60-80 million homes) by the end of 2018. This is no longer an early-stage market; it is growing fast and will be very big.

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Voice goes beyond the speakers and can be incorporated across people's lives, including in their homes, phones, and vehicles. Smart speaker households are twice as likely to have a smart thermostat and six times as likely to have connected lights in the home. The voice assistant can become the unifying center, coordinating the various devices in the home and bringing a new channel of value to utilities and other energy providers. As smart speakers evolve into ones with displays, the in-home displays can enable simpler energy management and visualization of energy usage and can bring utility brands and programs into the home, highlighting recommendations for energy management, coordination across devices, and programs in which to participate. Some utilities are already starting to explore voice as a new channel for engaging customers, starting with simple things such as billing. It is still early days for how voice can be leveraged as a channel for home energy management, but it is the next major channel for utilities in the connected-home space.

BLOCKCHAIN

There is a lot of hype around blockchain, but also a lot of opportunity. Blockchain has several important attributes. The concept of a decentralized ledger means transactions are essentially immutable. Blockchain can enable smart contracts, which can largely automate systems, and it can make executing deals on the systems extremely low cost (i.e., fractions of a cent per transaction). Blockchain enables a peer-to-peer trading ledger and network, without the need for a central authority, relying instead on a community-derived verifiable accounting system. In other words, it lets people transact among themselves without asking for permission while accounting in a legitimate way for transactions. Some intermediate structures needed today may not be needed in the near future; blockchain streamlines political and financial control of a system and could cut out many middle people managing the risks of various transactions. Blockchain also has the highest level of cryptography available, which enhances cybersecurity.

The Energy Web Foundation, a consortium of 70 global companies, has been working together to help build a global blockchain that meets the needs of the energy system. Blockchain merges physical and financial markets in interesting ways that, in the end, could potentially help enable a fully transactive, decentralized grid. A blockchain-based system can orchestrate and manage trading of assets at the local level, from a house or factory up to the bulk level of the grid. It would be a cascading and fully integrated market, with physical and financial clearing of the market at each successive voltage level, dispatching the grid from the bottom up instead of from the top down. That is still far from reality, but development is moving at the speed of software, not at the speed of infrastructure development. Existing energy assets may get integrated into a distributed internet of energy quicker than many expect.

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Peer-to-peer electricity sales would not be actual transactions of energy – the electrons would still be going where they went before – but rather financial transactions. Smart contracts could automatically transfer value when particular conditions (physical or financial) are met. It would be equivalent to an if-then statement; for example, if the voltage level in a node on a certain feeder line is at a certain level, then people could get rewarded for turning off their air conditioners. Appliances and devices will be a key way these sorts of technologies spread in the market. Smart contracts could be embedded with cars, EV chargers, buildings, and the grid, so all are swapping ancillary services and money automatically in the background, following the business models they are told to. If blockchain is done right, there will be ways for everything to operate more intelligently through algorithmic learning.

That type of system, though, is not where blockchain will start in the energy sector. Blockchain will first be seen in things such as certificate-of-origin trading, the ability to manage renewable energy credits, and the like. Those uses will emerge quickly and will provide a basis for transforming some of the broader functioning of the grid going forward. It is not clear, though, if blockchain is more like radio-frequency identification (RFID) or more like the internet in how it gets into markets. RFID needed Walmart and the Department of Defense to force it through at an operations level; the internet entered markets more organically.

Blockchain-enabled systems could increase asset utilization in the electricity sector from about 50% now to about 80-90%, which is where other asset-intensive networks tend to operate. The electricity sector is the only capital-intensive industry in the world allowed to operate at such a low level of asset utilization, as energy cannot be stored over time. That will change with the ability to pull in physical storage (e.g., batteries) and demand side energy management efforts, which blockchain-enabled systems could boost.

Regulation still plays a role in a blockchain-based energy system since, unlike with cryptocurrencies, there is still a nexus with the physical world. In blockchain-enabled smart contracts, for instance, regulatory specifications (e.g., carbon intensity of the system) would be one of the constraints embedded in the algorithms that cause execution of the contracts. Regulators still have the job of setting the goals and standards. There is also, therefore, the opportunity for problems. For instance, using blockchain for carbon management will be challenging because there are not accepted standards for doing carbon counting, which could enable a wave of fraud and scandals.

IMPLICATIONS OF DISRUPTIVE TECHNOLOGIES

Many of these technologies are coming into the market in a disorderly way. This is not about technologies emerging slowly from national labs, but rather industry launching disruptive products without waiting for government approval or worrying about the regulatory environment. The technological disruptions could converge in unpredictable ways and could dramatically change the way energy is produced, sold, and used.

There is nothing inherently green, though, about technology and innovation. Artificial intelligence, machine learning, additive manufacturing, and the like can reduce energy consumption and advance clean energy sources, but they can also boost the oil and gas sector. Unless policy intervenes to make sure innovation points in a certain direction, innovation will bring down the costs of all sorts of energy, both clean and not.

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These technologies will also necessitate retraining the energy workforce. It will no longer be workable to have an IT department in one city and workers in a Permian field elsewhere; people will need to do both. All equipment will have to be retooled to enhance cybersecurity. All well design will involve sophisticated modeling with big data. Utilities will increasingly need technicians more than mechanics. The needed workforce skills will be quite different than what the sectors have needed historically.

It will be important for regulators to gain a better understanding of where it is appropriate to intervene in the markets regarding disruptive technologies (e.g., where there is a market failure) and where it is better to stay hands-off and not intervene. The social benefits (and disruptions) of the new technologies will be huge, but it will require regulators to take new, flexible approaches – and perhaps not to act at all.

TRANSFORMATION OF UTILITIES & THE GRID

This is a time of rapid change. The social compact is evolving beyond just affordable, reliable, and universal availability of electricity to also include how clean electricity is, how it affects other citizens, how resilient the system is, and how well energy services are delivered. These changes are being enabled by new technologies and external environmental imperatives, as well as concerns about cybersecurity. As a result, utilities and the grid as a whole are beginning to adapt to the stresses they are experiencing.

OVERVIEW OF TRENDS AFFECTING ELECTRICITY

There are overarching trends in, and affecting, electricity systems, and utilities of all sizes and types are faced with similar challenges and dynamics. As noted earlier, the U.S. electricity supply is shifting away from coal and generally decarbonizing. Utilities are adjusting to low natural gas prices and plummeting costs for renewables and batteries, at the same time they are dealing with a lack of load growth and with consumers pushing for greater control and choice. Energy systems are also growing more decentralized, as DER trends are changing the landscape and creating havoc for planning. In addition, systems are shifting from being resource-based to more technology-based, as IT and connectedness in the electricity sector, digitalization, and big data analytics are growing in importance – though cybersecurity is also rising as a threat. The current inflection points in technologies and markets have invalidated some of the choices the industry made historically about multi-decadal assets, and some of those assets are either already underwater (economically) or soon could be.

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Numerous other factors are driving transformations in the system as well, including greater urbanization and emergence of smart cities, growing electrification of other sectors, and increased awareness of the resilience needs of the physical grid (e.g., to deal with growing wildfires, heat waves, floods, and storms).

At the same time, the energy industry is a multi-trillion dollar per year, highly capitalized commodity business, has clear supply chains and established customer bases, and provides essential services at all levels of society. This leads to a system with considerable inertia, aversion to risk, extensive regulation, and complex politics.

CUSTOMERS DRIVING CHANGE

Customers are leading the energy transition in many ways. The transition is a form of energy democracy. In Colorado, for example, the legislature took up and failed to pass a 10% renewable portfolio standard (RPS) in the early 2000s, but a few years later, it went to the voters and passed. It has since grown significantly. This has happened time and again in many places.

Big customers have been some of the most significant drivers of change. For instance, the four largest publicly traded companies by market cap in the world have 100% renewable energy goals, and about 70% of the Fortune 100 has some sort of goal in this area. (That said, none of those companies are disconnecting from the grid, as for the time being, they are still reliant on dispatchable resources.) Corporate Power Purchase Agreements (PPAs), which have been about 14 GW to this point, are predicted to be an 87 GW market between now and 2030 – more gigawatts than have been put on the system under RPSs since 2000. Only about 50 companies have done these deals so far, though, as they are very burdensome to implement. There is massive untapped demand; if society is serious about climate change, that figure has to go from 50 to 50,000 companies.

A lot of the innovation in the energy space is coming on the consumer side, such as corporate PPAs, distributed generation, electric vehicles, and smart homes.

The consumer voice is really strong, and there is clear evidence of demand. A lot of the innovation in the energy space is coming on the consumer side, such as corporate PPAs, distributed generation, electric vehicles, and smart homes. Wherever the law allows for a hint of consumer choice, consumers will break through it. This has been evident in California (with community choice aggregation), Nevada (where large customers have been willing to pay to exit the system), and elsewhere. (Where large customers exit, though, equity issues arise given the continued fixed costs to maintain the grid for other customers.) Consumers, whether residential or corporate, want choice and access to clean power, and not giving customers what they want is not a good business plan.

A path has to be found for customers to achieve those ambitions, and that may or may not be through regulated utilities. There is a reason that almost every announcement of a new datacenter powered with clean energy – which represents a lot of new load and billions of dollars in investment – is happening in deregulated markets, municipal utilities (munis), and co-ops, and not in vertically integrated markets.

UTILITIES RETHINKING THEIR SERVICES, OPERATIONS, & ROLES

Utilities are constrained – investor-owned utilities by regulators, munis by mayors and city councils, and co-ops by their boards and members. Nevertheless, utilities are looking to give their customers what they want before someone else does.

Utilities are looking to respect the past by maintaining the safety, reliability, and affordability of the original social compact, but they are also looking to embrace the future – without knowing what that future will be. Some utilities have stopped seeking long-term engagements with power suppliers, as 20-40 year contracts make no sense given the unpredictable changes in the technological mix; instead, they are pursuing arrangements such as 10-year PPAs with options to own. Many utilities are looking at grid modernization, grid software, new power supply options (including distributed generation and storage technologies), new customer-side services, different rate designs (e.g., time-of-use rates), electrification of other sectors, and more. Many are also focusing on ensuring equitable distribution of benefits from the energy transition and pursuing appropriate solutions for different parts of their service territories. For instance, some are investing in smart city and smart neighborhood projects that include microgrids, smart street lighting (which provides a range of services and sensors in addition to lighting), and electric vehicles. Some have also noticed and are trying to respond to interest from their customers in ideas such as on-bill financing and a flat monthly bill for provision of electricity services.

Some utilities are engaged in remodeling every element of their operations, including seeking to digitize all their processes and systems, both internal and customer-facing. This includes creating smart operations centers that constantly monitor the health of the assets on the system in real time. Digitization is not particularly capital intensive

– it is largely about software and sensors – and the benefits are considerable. For example, digitization enables utilities to spend money more strategically on major operations and maintenance, based on the health of components instead of on what manuals say. Failures can be predicted before they occur. In almost real-time, it is possible to see that a particular plant is not operating as efficiently as it should be, diagnose why, and fix it. These economic benefits add up to significant value. Still, digitization requires change management and time to get people bought into a different way of thinking and a different set of tools.

Many utilities are also exploring changes that are potentially even more fundamental. For instance, many are recognizing that they will not solely own the customer relationship. The increasingly technology-based energy systems are bringing new players into the market. Utilities will still be providing a lot of the basic services, such as answering the phones, trimming trees, and the like, but they are exploring what they do well versus what other third-party providers do well. In some states, there are prohibitions against utilities competing behind the meter, and even where that is not the case, the capabilities and technologies that utilities have may pale in comparison to those of, say, a big tech company – especially in a world of flat or declining demand (which puts pressure on utility budgets and programs).

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At the same time, however, a lot of the capabilities, technologies, and services that third parties have can only be deployed and monetized in partnership with utilities. For instance, a large part of the business case of most DERs relies on provision of grid services – connecting to and integrating with the grid – and that is the role of utilities. Utilities are therefore figuring out what partnerships and business models should look like. Customer data, though, is a constant issue. If utilities remain custodians of data (which is likely in many states), it is essential to require that the data be accessible to any third-party vendors that fulfill requirements for obtaining it. (Some utilities have taken the approach that customers are the ones who own their data and so will provide it to them directly, for them to share with third parties as they see fit.) Third parties can use data to put all the various system constructs into a simple wrapper to make it an easy, instant experience for customers.

These disruptive third-party providers can bring value to customers, and incumbent utilities are exploring how to adjust their business models and roles to accommodate that. Ultimately, utilities could function as either balancing authorities or integrators. Some are moving more towards the latter approach and are exploring how incumbents and new entrants can work together, with the utility as the orchestrator of the centralized and decentralized assets connected to the grid, and with partner companies being the content providers on the utilities' integrated platforms. Regulated utilities could cease being distribution utilities and become network utilities. They would be like airports, which do not own airplanes, businesses, or customers but nevertheless serve central core functions. For instance, some utilities are envisioning a platform model for the future that consists of four basic layers: (1) the physical grid (e.g., wires and poles); (2) the operating functions (e.g., planning and systems operations); (3) commodity transactions; and (4) a service and solutions marketplace to connect customers with third-party providers. The first couple of layers would involve more regulation and monopoly function, while the latter ones would be more competitive.

GRID MODERNIZATION

The old electricity world, with a centralized one-way power system, does not exist anymore. Everywhere in the world, there is some version of a system with distributed, cleaner, two-way power flows, even if penetrations of DERs, EVs, in-home technologies, and the like are currently low. This newer world requires a modernized grid.

Several states are pursuing grid modernization initiatives. Each state has different politics, dynamics, and interests and so is pursuing these initiatives in different ways. Some, for instance, focus more on decarbonization and renewables, but those would not play well in other states, which focus instead on things such as innovation and enhanced customer experience. While some state grid modernization efforts are relatively robust, others are fairly tenuous, driven by interested public utilities commissions but without widespread buy-in, which means progress could be derailed if something goes wrong. There are also risks from high turnover among commissioners, poor-quality appointments to commissions, and fear and angst among commissioners worried about reactions from legislatures and governors. In addition, it is concerning that there does not appear to be much momentum for state grid modernization efforts beyond where it is already occurring.

Getting buy-in and investments from utilities is essential to advancing and sustaining grid modernization efforts. Utilities are well positioned to advance a modernized grid, given their scale and the amount of capital they can raise and spend on deploying grid architecture. Given their existing interfaces with customers, utilities are also in a great position to drive change around customer experience and satisfaction, ensuring that customers see benefits from technologies such as advanced metering infrastructure (AMI). Deliverers of electricity, though, face tremendous uncertainty about how to proceed with decisions related to grid infrastructure. Different customers want different things, and utilities are trying to give them what they want, while also pushing for higher objectives such as decarbonization, grid security, social equity, and economic development. The market will not accomplish all of those things on its own. There is a need for cohesive policy (e.g., a national carbon charge that increases over time) to guide utilities' billion-dollar investments that take decades to recover. In the meantime, some utilities are hedging, doing some localized community engagement and DER planning and investing in smart sensors, communications infrastructure, and other aspects of a two-way, dynamic power system, while at the same time pushing forward on classic transmission-based solutions.

The old electricity world, with a centralized one-way power system, does not exist anymore.

Going forward, variable renewable resources demand a more flexible grid system, and there are a number of ways that flexibility can be achieved, including greater transmission capacity, more traditional (but flexible) generation, more storage, and greater use of demand-side management. Battery storage, for example, is already making gains in providing some grid services (e.g., frequency regulation), and although earning a return from energy arbitrage is very challenging in restructured markets with today's battery storage economics, there is an interesting set of specific opportunities where batteries immediately offer lots of value on the wholesale system (e.g., in Texas for wind). There has also been a dramatic increase in energy efficiency and demand response programs, including smart thermostat programs, in several regions of the country; these programs are getting very large – several hundred thousand customers – and will only grow larger as penetrations of the devices increase, providing significant flexibility in the grid. Indeed, some argue that if demand response is taken seriously, the duck curve can be eliminated and the need for non-renewables capacity reduced.

While technologies will keep evolving, many of the ones needed for a flexible, two-way, dynamic, decentralized power system already exist; the key is figuring out how to integrate them, develop business models around them, and orchestrate the entire system. In a fully developed version of this system, central station generation and transmission would not go away, but this would also be a network of peer-to-peer energy transactions, DERs, smart cities, and more – a system that is sustainable, flexible, autonomous, individualized, and supported by lots of technologies.

Technological developments could also spell even bigger changes in the grid. It is possible to make ground-mount solar PV systems that connect directly to the distribution system – no transmission required – at about 2-2.5 cents/kWh. The solid polymer electrolyte batteries that are coming in – with no expensive, scarce, flammable, or toxic materials – could make it possible to make rooftop solar 24/7 for about 0.5 cents/kWh, which could strand the grid. Distributed resources that do not rely on the grid have greater ability to avoid disruption, and customer desires for resilience will affect system architecture.

CYBERSECURITY

A modernized grid has to address cybersecurity. There are countries out there looking to retaliate against or affect the United States, and there is huge cyber vulnerability in the grid. Those risks go up as billions of connected devices link up to the system.

It is impractical, though, for every electricity provider and state commission to be responsible for national security. In some respects, such security issues have to be addressed at the federal level. There will still be some state-level oversight functions by regulators, such as requiring distribution utilities to improve technologies or enhance physical security, since utility investments on security have to get approved by state commissions. A uniform approach across states, though, requires a federal role. Leadership has to come from Congress, FERC, DOE, and the various interagency coordinating councils focused on the electricity sector and on terrorism.

The easiest solution to cybersecurity is to disconnect, and a couple of critical missteps on cybersecurity in the energy sector could push people in that direction. There is a need to get and stay ahead of the risks, ensuring that the various players – including government agencies, utilities, and content and technology providers – play their roles in protecting the national security interest of the grid. The utility industry understands that and has been working diligently with the federal government to address cyber vulnerabilities, including in the supply chain. The risks are front of mind in the digitization process.

Further dialogue is needed that is particularly focused on the nexus between clean energy and cybersecurity. There are already high-level dialogues on various security elements (e.g., national security, climate security, energy security, resilience), including efforts to lash together and bridge the financial, energy, and telecomm worlds, but the clean energy sector is not usually part of them, despite the fact that a lot of the broadening of the attack surface is at the decentralized level. The moment a determined adversary attacks the United States through a solar cell or a lithium-ion battery, the clean energy industry will get hammered. The people, processes, and devices involved are under state (or homeowner) jurisdiction, not federal. There is a need to figure out how utilities, states, localities, and the clean energy sector can be brought more productively into dialogues about security.

ADVANCING INNOVATION

Being a utility regulator is one of the hardest jobs in the energy space at the moment, as the pace of change in technologies and policy imperatives is incredibly difficult to manage. The next 20 years will be very different from the last 20. It is not possible to control every aspect of change, but it is important to figure out how to manage the system to allow for innovation, customer empowerment, and decarbonization while ensuring reliability, affordability, and the like. There may be a need to rethink the

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REGULATORS & INNOVATION

One area of potential change involves cost recovery for utility investments. A relatively simple fix would be to treat utility system investments in digital infrastructure, such as software and Internet-of-Things solutions, as cap-ex instead of op-ex, to allow utilities to get cost recovery for them through the rate base. For instance, this is not the case in New York at the moment, where customer billing software is not a recoverable cost. This forces independent power producers to foot the bill for customer acquisition software and is an example of regulations getting in the way of market initiatives. Elsewhere, though, some utilities are encouraging commissions to allow them to recover for digital system investments the same way they do for poles and wires.

The rate base itself may not make sense going forward. Some utilities see current rate design, which rewards capital deployed and is based on volumetric rates, as the root of all evil, as it makes utilities sellers of a commodity instead of deliverers of services. This is an upside-down revenue model. If utilities sell a commodity, then they lose revenue as customers use it more efficiently. If they sell services, however, they would lose cost instead. Thomas Edison knew that but was overruled in the late 1800s, and the model has been wrong ever since. The rate design structures of the 20th century are not appropriate in the 21st; the system has to evolve in a way that promotes technology and energy efficiency while protecting customers. Hawaii may be a postcard from the future in passing performance-based rates; it will be interesting to see how Hawaii manages those and how replicable they will be elsewhere. As utilities shift to providing more services, the system can shift to one based on tariffs for programs that customers opt into.

Regulators may also need to rethink their role and their goals. Some regulators view their job as promoting economic development. Others view the purpose of retail regulation as protecting customers from monopoly pricing (though the first set would argue that the point of promoting markets and economic development is to protect customers). Either way, others argue that economic development and protecting customers from big bills have largely been achieved as part of the original social compact and that new aggregate social goods, such as decarbonizing to combat climate change and promoting social equity, should be among regulators' new preeminent goals. Incumbent utilities will play critical roles in addressing these crises, and regulators have to get the rules right to prevent incumbents from grabbing as much of the pie as they can and squelching innovation. Regulators need to be enlisted, empowered, and educated to harness and support innovation and the low-carbon energy transition.

Part of this involves figuring out how to create business models that support third-party companies that provide value to the electricity system. Currently, in many cases, such business models are missing, making it hard for companies to see how their investments will be realized, whether through the utility or through regulation that allows more private-sector entrepreneurial activity. Resiliency provides a good example. Technology can provide it, and everyone values it, but it remains unclear how to fund it, who pays for it, how to value it, and whether there will be a return on investment.

More broadly, regulators that want to see things move faster need to create opportunities for failure in providing services and solutions – adapting regulatory processes to emerging needs. There is no innovation without failure. Fears of failure should be confined to the bottom layers of the grid platform (e.g., the poles and wires), where there are large investments in wide-scale infrastructure, but currently all layers of the platform are treated the same in regulatory processes, even the more competitive, innovative services and solutions. Innovation should be as permissionless as possible, letting innovators sell, compete, and fail and letting consumers choose, while still ensuring that the core functions deliver reliability. Regulators may need to forbear from regulating things they otherwise would. The system has to allow room for technologies to grow, but also for them to fail.

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There is not really a fund or structure in the regulatory model, however, that supports utilities seeking to do experimentation and innovative research and development (R&D). Utilities have generally been risk averse, but changing that culture is hard because they often have been unable to get cost recovery for innovation research and mechanisms within their companies (as opposed to outside-the-fence collaboration, such as research done at the Electric Power Research Institute). There needs to be some form of risk and benefit sharing that gets factored into ratemaking to encourage or allow regulated utilities to experiment. Regulators might also benefit from additional technical assistance in evaluating utility experiments. This is the time for utilities and regulators to partner if either wants to be relevant in defining their future roles; the world is changing rapidly around them.

It may be that utilities that are government- or member-owned – that is, munis and co ops – are better positioned to take the lead on innovation compared to utilities subject to regulatory regimes. For example, co-ops have been able to move quickly and aggressively in pursuing some novel microgrids, and they built their own integrated test center for carbon without any money from the Department of Energy.

DOE & INNOVATION

The basic ingredients for innovation – across sectors – are a supply of innovation (e.g., robust and sustained support for upstream and private R&D), demand for innovation (e.g., financial incentives, carbon pricing), and competition (e.g., among ideas and among technologies). With regard to that first ingredient, DOE has long been the main driver of fundamental research, development, and demonstration, as well as of related financing (e.g., the loan program office). There are also some models at the state level for R&D funding. Multi-decadal support from DOE has made projects and technological developments happen that have been beneficial to the energy sector that would not have happened otherwise, from shale gas (which emerged from a successful pairing of federal RD&D, public-private partnerships, and a time-limited tax credit) to solar power, to supercomputing, to smart cities. Developing these technologies took decades, but there is not time for such waiting periods going forward. The urgency of the climate imperative requires significant alignment of players, programs, and policies focused on innovation.

DOE and states have to be careful, though, not to impede progress. For instance, some argue that the DOE program on AMI impeded progress because of moral hazard – namely that the utilities that applied were going to do the AMI work anyway but waited two years for the grant. In that time, customers lost more energy efficiency savings than the grant was worth, and those that did not get the grant kept waiting for a new grant. Government programs have to be careful not to prevent the marketplace from doing what it would have done otherwise.

The urgency of the climate imperative requires significant alignment of players, programs, and policies focused on innovation.

DOE is also constrained. It has billions to spend on applied energy R&D and billions more in credit authority on the books, but there is an extensive set of rigid rules on how they can be used (e.g., certain technology readiness levels, cost sharing requirements, stringent credit standards). Market risk failures are also very tough in the federal environment; if a project fails, it can become a controversial poster child of government waste and hurt the entire program and its ability to move forward. There is a need to think more creatively about public-private partnerships that allow both sides to be more flexible, creative, and nimble and that allow for existing resources to be better used in advancing clean energy innovation and infrastructure. For instance, DOE's High Performance Computing for Manufacturing program could be expanded, providing more money to national labs to work on companies' problems. The federal government could also provide something similar to crop insurance to help new energy technologies, setting a price floor for a certain amount of participating technologies.

SOCIAL EQUITY

The low-carbon transitions needed in the energy system, in conjunction with the broader technological changes underway (e.g., 3-D printing), could transform the nature of energy, work, and life. There is every reason to think these transformations, while necessary and in many ways beneficial, will be very socially disruptive. Issues of social equity have to be considered – not only because it is right and just to do so, but also because failure to do so could create political headwinds to those transformations.

JOBS

The U.S. energy employment report, which started as a federal report, is an important source of data that could be used for social equity programs, as it highlights what kinds of jobs have been created in which geographies and which demographics. More than half of solar jobs are located in five states, almost half of wind jobs are likewise in five states, and about 70% of hydro jobs are in five states. Clean energy employment gains have been concentrated, with the exception of energy efficiency. Energy efficiency is the largest sector, at more than 2 million jobs, and is in all states, but for some reason it is rarely talked about as a fulcrum to move public support for the clean energy transition.

Amidst the debates about stranded assets, it is important to also have a focus on stranded workers.

The energy transition is and will be extremely painful for a narrow set of people. While the United States has created a large number of clean energy jobs and lost a smaller number of coal jobs, that net gain is of little comfort to those in parts of the country more reliant on the coal industry. Looking at clean energy jobs numbers in isolation misses the broader economic and political contexts and the need for strategies that bring a broader swath of people along. Jobs are the top issue (or among the top issues) in polls, and there is a massive amount of job dislocation coming to the electricity sector, affecting family-wage, community-backbone jobs in both urban and rural areas. Amidst the debates about stranded assets, it is important to also have a focus on stranded workers. Right or wrong, the people about to be hurt the most are very squeaky wheels. The big developments in U.S. energy policy under the Trump Administration – the withdrawal from the Paris Agreement, the attempts to support coal plants, the passage of the 45Q tax credit for CCS – have all been driven by a small constituency of policymakers and industrialists in states such as West Virginia, Ohio, and Pennsylvania based on concerns about the impending collapse of the coal industry.

There are other jobs affected too, beyond the coal industry. For instance, many of the technologies involved in the clean energy transition – many of which are manufactured overseas, particularly in China – require less servicing, which means a lot of U.S.-based jobs focused on servicing engines, mechanical issues, and the like are being lost, replaced by jobs related to software and digital.

The transition will proceed more smoothly if it is a big tent that creates an upside for everyone. Job creation and job training are vital, for both equity and political reasons, and clean energy policies should have clear links to economic development. For instance, that kind of lens led the Prop 39 clean energy jobs program in California to put money not into training just for solar installation or energy efficiency but rather into broader, multi-craft apprenticeship programs that train workers for a range of things (e.g., solar and broader electrician work). Revenues from carbon pricing policies could similarly be put toward job creation and training – not just providing dividends, but also enabling people to work.

Job creation and job training are vital, for both equity and political reasons, and clean energy policies should have clear links to economic development.

Other clean energy efforts and technological innovations could further support jobs in hard-hit communities. For example, some RPSs and some procurement efforts (e.g., the Buy Clean California program) promote local manufacturing. The local, place-based innovations spurred by technologies such as 3-D printing could further boost local economies and manufacturing bases, potentially rejuvenating struggling communities and regions. Likewise, relocating clean energy manufacturing – and retrofitting refineries or steel mills to combine pollution control measures and CCS – could enable manufacturing plants to continue to support local communities. Spending on energy and transportation infrastructure can promote high-wage jobs, and energy efficiency financing can similarly enable high-wage union jobs in the construction sector.

There are certainly hurdles, though, to advancing job training and clean energy innovation in some communities. For instance, in West Virginia, Kentucky, and other areas hit hard by reductions in coal, trying to get energy efficiency or renewables to take off is really hard. People are not interested, seeing those resources as taking away their jobs and economy – as competition. Also, the Supreme Court just essentially reduced the funding available to labor unions, which have been major providers of training and apprenticeship programs, so that burden may fall a bit more on the private sector and on governments now. In addition, broadband internet access and innovation ecosystems are a vital part of transforming technologies and economies, but many of these areas lack broadband access and are not doing much innovating. These areas are often served by rural electric co-ops – indeed, more than 90% of persistent poverty counties in the United States are served by co-ops – which suggests a need to think about how best to boost the role of co-ops.

Rural America is in a tough spot, but it must not be left behind. The issues in these coal-industry states are real, urgent, and lasting. The transition is inflicting a high social cost in America's rural, resource-heavy communities, and as hopelessness and despair come into these communities, there are snowballing, damaging repercussions. The stresses of adults in the workforce who are losing or worried about losing their livelihoods are leading to increased substance abuse, domestic abuse, homelessness, and other problems that inflict long-lasting traumas on their children. There is a need to return hope to these areas. There has to be community-based thinking about how to empower incumbent industries and citizens, so they feel that they are driving their own futures.

It is important to recognize that the United States is not alone in experiencing the rise of inequality. Across countries, there is growing distrust in governments and the current model of globalization, with working people feeling very little trust in the ability to be provided a living and a job.

BURDENED COMMUNITIES & CLEAN ENERGY ACCESS

The reality of the world is that some communities bear more of the burden of the current energy system than others, and different communities, households, and individuals come to the clean energy conversation with different backgrounds regarding injustices and privileges. It is important to start seeing low-income, pollution-burdened communities as places with a voice and places that things are done with (not to).

Building social equity into energy policies should involve a few key steps and priorities. First, it is important to define the target areas – those that are not receiving adequate resources, are dealing with higher electricity rates, are overburdened with pollution, and so forth. Each jurisdiction might define the target areas differently. Second, it is essential to understand those target areas – what the barriers are to reducing pollution, why there is not more access to clean energy, and what the opportunities are for overcoming those barriers. Third, those areas should be explicitly prioritized in clean energy policy, as states such as Hawaii and California have done. California law, for instance, requires maximization of energy savings and seeks to increase access to EV charging and EVs in low-income and over-polluted communities. Fourth, jurisdictions actually have to execute the strategies. It cannot just be language in bills; there is a need to make sure the efforts are actually happening (e.g., setting specific percentages of funding that have to go to target communities). Finally, it is important to measure and adapt – to make sure that there are reporting requirements and/or advisory committees paying attention to progress on goals and, if needed, adapting strategies.

Advancing the clean energy transition has to involve engaging with and creating stakeholders and beneficiaries at the individual and community levels. Some firms are developing model playbooks to help local communities and cities engage stakeholders and invest in, implement, and measure new place-based, community-sensitive energy solutions and projects through a range of lenses, including social equity. The step-by-step playbooks would provide tools to bring all the relevant players together with local governments. Many local governments are already doing lots of convening but are struggling with the lack of fundamental alignment among different stakeholders with different goals; they could use help getting the various parties to speak the same language and focus on common ideas, processes, and platforms.

Advancing the clean energy transition has to involve engaging with and creating stakeholders and beneficiaries at the individual and community levels.

There are some demonstration projects that aim to reinvigorate and give some control to urban communities through construction of microgrid clusters, EV ridesharing and charging, creation of energy curriculums for local schools, empowerment of customers to direct where their energy savings from efficiency programs go (e.g., to local churches or community centers), and testing of other technologies and concepts. Efforts to advance clean energy, clean mobility, economic development, safety and security, and education – all with community involvement and input – can advance clean energy solutions while also advancing greater equity.

While EVs are trendy, the promotion of clean mobility in rural and low-income communities has to be broader, including reducing energy cost burdens by improving the efficiency of vehicles and advancing low-carbon and clean public transit. There is a need to figure out how to get low-income households into efficient cars they can afford to run – which will also have a huge impact in broadening their job prospects. Many cars are 25 years old or older, and people are buying cars not from dealers but from neighbors. That is a hard system to disrupt without an intentional strategy focused on incremental change, such as advancing battery-electric hybrids in the secondary car market as opposed to going right to EVs.

Energy efficiency – for both electricity and natural gas – is another significant equity tool, as energy bills often account for a sizable portion of low-income people's disposable income. Based on data from smart meters, people living in low-income areas use more electricity relatively speaking during the highest price hours (e.g., from having worse insulation), which means fixed bills might be more beneficial for them than volumetric rates. It is also worth considering whether the Low Income Home Energy Assistance Program (LIHEAP) and other subsidies for low-income customers should be reoriented to invest in clean energy rather than subsidizing the greater use of fossil energy.

There are equity considerations tied up with reliability and resilience as well. For example, different customers require different levels of reliability and resilience, and all customers should not have to pay for the greater needs that some customers have. Customers with greater needs can be offered heightened reliability as a service, with them paying an extra amount for it. Such an approach enables customization of solutions for what individual customers need without incurring expenses across the entire customer base for things that not all customers need, want, or benefit from.

Indeed, the same principle could apply to the entire clean energy transition. As that transition occurs with public support, utilities should ensure they are providing new services and opportunities in disadvantaged communities and are not rate-basing things that end up mainly benefitting wealthier customers and being paid for by poorer ones.

Obviously, the clean energy transition alone will not solve all social equity issues, but it can have an outsized impact if managed right, since energy systems touch virtually the entire economy. Ensuring clean energy access for burdened and struggling communities has to be a priority. The market, however, tends not to deal with the intermediaries that help people get access to clean energy. That is typically paid for by governments, not companies. Policies that limit what programs can spend on administrative costs therefore limit the technical assistance that people need.

As always, it is important to remember that equity issues are global as well. Energy access and pollution burdens are real – and in many cases worse – elsewhere in the world. Energy resources also have global equity externalities upstream – including clean energy resources. For instance, a lot of clean energy technologies rely on minerals and metals that are mined and imported from overseas, often from places with weaker community and environmental protections than the United States.

COMMUNITY SOLAR

Solar is, for some, the poster child of the clean energy transition, but more than three-quarters of Americans cannot put solar on their rooftops, whether because the roof is facing the wrong direction, because of shading, because they are renters, or because of financial obstacles. Community solar can be part of the clean energy access solution, allowing people to subscribe to a portion of a neighborhood solar farm, often located within a utility's territory or load zone. It is like a community garden, but for solar. The electricity from the neighborhood solar farm goes back to the grid, and participants see a credit on their utility bills. Most people save money on their bills because developers are giving people part of their margin as an incentive to sign up. No upfront costs, rooftops, or installation are required.

Community solar has been growing in the United States, effectively doubling each of the past four years. It is mostly happening in states that have encouraged it, whether through leadership by state legislatures or by utilities (who were trying to block community solar a couple of years ago but now are trying to deploy it themselves). There are 42 total states that have at least one community solar program. Some states are allowing utilities to put solar installations on their own facilities and dedicate them to disadvantaged communities.

Early adopters of community solar are generally older (50-70 years old), and more than half of customers are women. To make going through the hassle of signing up for community solar worth it, the average amount people want to save is around $15/month or 10%, which is basically where the market is now. People sign up for different reasons. Some want to save money, some want to save the environment, and some just want to get further away from their utilities. While millions of people might be willing to pay more, there are many more that are not – or cannot.

From the community solar perspective, equity means giving more people the choice to sign up for clean energy that is affordable and accessible. The poorest parts of countries are the most affected by climate change but the least likely to get access to clean energy. In the United States, 44% are low-income; this is not a small, marginalized population, but rather an untapped market. Financing is the key to community solar equity. Community solar contracts are currently pretty regressive – 20 years, often with a cancellation fee, and customers have to have a FICO score of 700 or above (maybe 650). More than half of the country does not meet that standard, limiting the market to high-credit homeowners. There are ways, though, to let more people participate while still being financially viable. Scores could be based on utility repayment history and other demographic data to expand inclusivity while more accurately

The poorest parts of countries are the most affected by climate change but the least likely to get access to clean energy.

predicting who will pay their utility bills. There is also no need for 20-year contracts in community solar; someone who does not pay can easily be swapped out for someone who will.

Some leading utilities have put guardrails around some of their community solar programs to ensure they are for income-qualified customers only – those who could not avail themselves of community solar otherwise. The very idea of utilities owning community solar, however, seems odd to some. If the utility is providing people with electricity, then it is not really anything different from normal; it is, in some ways, just small-scale utility solar, but with different kinds of payments and a different regulatory model. Many utilities use community solar as a customer engagement tool and as a way to expand solar to lower-income populations. They are pursuing it in part because customers are demanding it, in part because they can site generation in areas that help their distribution and transmission costs, and in part because regulators look more favorably on utilities pursuing such efforts that appeal to customers. Also, while community solar used to come at a cost premium, recent projects have been coming in below the cost of typical core grid supply.

HAWAII AS AN EXAMPLE

In Hawaii, the status quo is causing significant social inequity. Most of the state's existing fossil infrastructure is located in disadvantaged communities. The state also has the highest electricity rates, partly because of its heavy dependence on oil, and energy costs are a burden that people feel. Some families have to choose between food and energy bills, and some businesses have been unable to pay their energy bills. In addition, affluent customers in the state are the ones taking advantage of energy efficiency programs, which means they are using fewer kilowatt-hours and contributing less to the public benefits fund, which hurts lower-income customers.

The clean energy transition is essential to addressing those problems, providing an opportunity to be cleaner and cheaper than the status quo and relieving the pressure of siting plants in disadvantaged communities. The transition, however, also brings new challenges, including siting renewable energy projects (which often end up in low-income areas too). Still, the largest renewables procurement in state history is ongoing, which will help customers of all types.

The Hawaii Public Utilities Commission, in its performance-based ratemaking docket, is seeking to elevate social equity as a key outcome for utility performance, though a lot remains to be discussed and fleshed out. The Commission is also pursuing or exploring new programs and services to expand and provide more access to clean energy opportunities, including community solar programs, on-bill financing, a new focus on energy efficiency, new grid services tariffs (to give renters opportunities to participate, including via grid-interactive water heaters and smart thermostats), and a possible microgrid services tariff (to create opportunities for microgrids to provide higher reliability in remote communities).

POLICIES FOR THE LOW-CARBON TRANSITION

There are proactive policy opportunities – even in the current political environment – that should be pursued to advance an energy transition that is both accelerated and equitable. All types of approaches are needed, including both regulatory and market measures, at all geographic levels.

POLICY FOUNDATIONS & SUPPORT

Getting policies to speed the low-carbon transition would be aided by getting some basic foundations in place, such as metrics. For instance, the social cost of carbon enables the value of greenhouse gas reductions to be monetized, compared to other efforts, and factored into policy measures. Likewise, there may be a need to find a different metric or basket of metrics to account for the multiple attributes of the electricity system when making comparisons across energy sources, as levelized cost of energy (LCOE) is acknowledged as an incomplete (but still widely used) metric.

The social cost of carbon enables the value of greenhouse gas reductions to be monetized, compared to other efforts, and factored into policy measures.

Beyond the foundations, some feel that policy innovations are needed to spur gigatons-scale reductions and achieve deep decarbonization. Others, however, disagree that climate is an area requiring much policy innovation. A lot of the policies with big impacts are relatively well known; most advocates, for instance, have been pushing for carbon pricing for a long time. There is not, however, much support for those policies.

By and large, most of the American public agrees climate change is real, but it is way, way down on the priority list. Moving it up on the list – getting people to actually care – may be a necessary pre-condition for smart policy ideas to move forward. There are differences of opinion on whether the best approach is to scare people or inspire people (or both), but people may too quickly dismiss the terror effect of climate impacts, such as wildfires, hurricanes, and floods. While polls always show climate as a low priority, people are very worried about the risks to life and property from disasters that are climate-related. Some kind of communications/marketing effort to connect the dots between climate change and the effects now occurring – with an added element of hope and optimism of what could be achieved by unleashing American innovation – could help mobilize the public. Focusing on economic competitiveness and other benefits of climate policy is also important.

There may not even need to be a consensus on climate change if people could focus on outcomes instead of motives, as climate action could be good for incomes, jobs, health, national security, and more. On the other hand, if there is not agreement on where things need to get to, it is hard to get there. Until there is consensus on how far and how fast emission reductions have to go, it will be hard to frame R&D efforts, mandates, incentives, and other policy efforts.

Given the urgency of climate change, any policies that can be achieved are needed – wherever they can be achieved – as quickly as possible. Getting the support and attention of the American public, though, is a huge undertaking.

Persuading the public at large, however, may be less important than persuading key policymakers – those who can actually adopt and implement policy. In New York, for example, the Reforming the Energy Vision (REV) policy was driven by a strong executive and a few key people in government. Persuading policymakers may well require addressing the equity issues involved in the low-carbon transition. For instance, if rural America is not taken care of in the energy transition, it will never be possible to get the senators needed to pass ambitious climate legislation.

FEDERAL POLICIES

There does not appear to be a likely scenario in which the federal government enacts climate policies in the near term that are commensurate with the scale of the challenge. Even comprehensive energy legislation seems unlikely. The last major energy bill was the Energy Independence and Security Act of 2007, which is overdue for a refresh. Still, the FY2018 budget greatly exceeded expectations in terms of funding for clean energy R&D, largely ignoring the steep cuts proposed by the White House, and the FY2019 budget should further strengthen clean energy R&D priorities.

In addition, there could be small legislative fixes made to the recent expansion of 45Q tax credits, eventually leading to a much bigger evolution in dealing with emissions from fuels. The 45Q tax credit currently subsidizes enhanced oil recovery, but not based on a lifecycle analysis of tons stored – which is different from other recipients of 45Q credits, who do have to do lifecycle analysis. Including lifecycle analysis for enhanced oil recovery could be teed up for legislative change. The next step could then be to create incentives for storing more CO2 per barrel of oil produced, and then to go further and create a mandatory minimum of CO2 stored per barrel (which can be done with low-carbon fuel standard authority). The final step in the evolution would be 100% takeback, where for every ton of CO2 that comes out of a fossil-fueled car, there is a requirement to put away a ton of CO2 elsewhere (e.g., from direct air capture).

There are many relevant technologies and approaches that involve issues and players outside of the traditional energy and environmental realms.

There are numerous measures that conceivably could be pursued under existing legislative authority, such as another Clean Power Plan under section 111(d) of the Clean Air Act, regulation under section 115 of the Clean Air Act, adoption of a low-carbon fuel standard, regulations banning engineered releases of methane (i.e., intentional flaring and venting), or support for Property Assessed Clean Energy bonds. There is also a need for policies and programs to advance efficiency and decarbonization solutions for cement, steel, and other industrial sectors, similar to the SunShot effort to reduce the price of solar. (Private industry is already doing a lot to make progress in these areas, in the name of industrial efficiency, but further exploration is needed of public- and private-sector levers that can be pulled to accelerate that progress.) A lot could also be done under existing FERC authority. For example, FERC could assert jurisdiction over all transmission, resurrect standard market design for the entire country, require an organized electricity market in every region of the country, and then impose a carbon adder on wholesale markets.

In addition, those advocating for a low-carbon transition ought to expand the scope of their federal policy advocacy. There are many relevant technologies and approaches that involve issues and players outside of the traditional energy and environmental realms.

For instance, utilities, industrial players, technologists, and states need to get savvier about engaging with the Federal Communications Commission (FCC) on spectrum. All big data resources and the connections within the Internet of Things run on spectrum. Whether valuable mid-range spectrum is auctioned in very small blocks (which allows players to build their own networks) or in large blocks (as major carriers want) is a key policy debate, and those looking to harness big data efforts for the energy transition should get involved. There could also be more radical options, such as not auctioning pieces of the spectrum at all and allowing the ability to spectrum shift, but it is important for industry to have access to a protected range of spectrum for running critical infrastructure networks.

The expanded scope goes beyond the FCC. For instance, automation issues involve the Federal Aviation Administration for drones, the National Highway Traffic Safety Administration for trucks and cars, the Federal Railroad Administration for trains, and more. 3-D printing and other additive manufacturing techniques involve intellectual property issues, the Patent and Trademark Office, the Occupational Safety and Health Administration, and more. Government mortgage underwriters could reorient their standards to eliminate the current implicit bias in underwriting standards in favor of single-family suburban communities instead of multi-use walkable communities. Other policy approaches are needed to advance reforestation, reduce food loss in agriculture, and restore degraded agricultural lands. Back in Congress, if federal infrastructure policies advance, it will be important to include digital infrastructure and to require new infrastructure to be made digital-ready. Likewise, policies related to the labor workforce will be important to deal with the equity impacts of automation, clean energy, and other technologies.

STATE AND LOCAL POLICIES

There is also a lot of potential for policies at the sub-national level. For instance, in the wake of the Trump Administration's promised withdrawal from the Paris Agreement, many states, counties, and cities committed to meeting the Obama Administration's Paris pledge. They all, however, have different goals, timelines, and baselines, and it is difficult to know if this is just cheerleading or actually something that will lead to progress in meeting the Paris goals.

At the local level, city and local governments can work to advance smart cities in urban areas. They can also seek to decrease local sources of friction that slow clean energy infrastructure development, such as permitting issues.

States have a considerable range of policy tools in their arsenals. For instance, every single state could establish a green bank – as a few states and at least one county have already done – to spur clean energy projects and innovations through low-cost capital, loan loss reserves, credit enhancements, and the like. States and cities committed to reducing carbon could also put their bonding authority behind that commitment. In addition, something like REV Connect in New York – where financing gets done with lots of stakeholders – could be replicated in other states.

Among the key tools that states have are renewable portfolio standards.

Among the key tools that states have are renewable portfolio standards. RPSs exist in many states that are Republican-controlled and where carbon taxes are not politically realistic. These policies can raise the levels of carbon-free power and are already moving the needle on emission reductions, so it makes strategic sense to try to push them even further. There are debates, though, about whether these should be renewable energy standards or broader clean energy standards.

Whether a renewable portfolio standard or a clean energy standard is preferable depends on how one defines "clean" and on the specific policy proposals and politics in specific states. The details of the clean energy standard matter a lot. For instance, if there is a specific carve-out for nuclear power, some would see a clean energy standard as an attempt by the nuclear industry to get mandated because they cannot compete economically. On the other hand, proposals that allow nuclear power, CCS, and other zero-carbon technologies to simply be eligible resources and then allow the least-cost carbon-free resources to advance via laddered auctions might draw more support. Demand-side resources and efficient integrative design ought to be incorporated and maximized somehow as well, which could require some creativity. A clean energy standard can also be designed as a tradable performance standard, giving extra or partial credit to different technologies if desired. In addition, attention has to be paid to how the design of the policy affects existing assets, as addressing climate change involves not only building new clean energy sources but also accelerating the rate of capital stock turnover. The lodestar needs to be achieving zero emissions as fast as possible – an outcome-based rather than technology-based approach.

The debates intensify when the prospect of a 100% renewable energy standard is raised. Some see a clean energy standard as a less risky and lower-cost proposition for achieving decarbonization of the power sector, but a 100% renewable energy vision is politically powerful, easy to articulate, and easy to understand. Also, the most active participants in legislative initiatives are the hardcore climate hawks, the advocacy community, and the renewable energy industry. Those pushing for a broader, more technology-inclusive clean energy standard have to convince the hardcore advocates that they can get a better outcome with a broader portfolio mandate. It would be worthwhile to get behind specific numerical targets and timetables, engage in discussions with environmental groups in key states, and show how a broader portfolio can achieve those targets. Negotiations are needed. The support for nuclear power in Illinois, New York, and New Jersey, in conjunction with enhancements to energy efficiency and renewable energy objectives, were bargained for and agreed to. It is doable, but it will not happen just by lecturing environmental groups on the analytic superiority of a clean energy standard.

Market-based incentives for emission reductions can further accelerate both deployment and innovation.

CALIFORNIA

California is the first and only state in the United States with a comprehensive climate policy, adopted after decades of generally addressing air pollution and vehicle emissions. In the early 2000s, the California Energy Commission started measuring greenhouse gas emissions. Legislation was then passed directing the California Air Resources Board (CARB) to adopt an emissions standard for CO2 (which was litigated for years). In 2006, legislation was enacted that created a state goal of returning emissions to 1990 levels by 2020 (about a 40% reduction over business as usual), giving the task to CARB to achieve that goal. State goals are now aligned with the Paris Agreement's goals, and CARB has to put out regular scoping plans demonstrating (at least on paper) how it will achieve them.

California met its 2020 goal a few years early, but it has to do a lot more to get to its 2030 goals. The state has a variety of different programs aimed at climate change – including direct emission reductions, market-based programs, and a cap over all of it – and is working to address short-lived climate pollutants (e.g., methane, black carbon), help landowners institute sequestration programs, add a CCS offset protocol under cap and-trade, and more. California is also investing some of the proceeds from its cap and-trade program in trying to improve public health and social equity. Californians generally see these efforts as being beneficial overall to the economy and the environment. CARB has had verified data to work from, which has been hugely important in showing people that what they have been paying for is achieving real results.

Some worry that the state will be blinded by its past successes. California's RPS, for instance, was successful in building a market that could promote, site, and integrate renewables into the market, but some argue that the state's political preference for renewable energy should be subordinated to the goal of deep decarbonization. Achieving California's 2050 goals will require all sources of zero-carbon power and economy-wide action, including figuring out how to use clean electrons to decarbonize transportation, building heating, industries, and the like. It will also require achieving negative emissions.

MARKET-BASED INCENTIVES

California's cap-and-trade system is just one example of a market-based climate policy. Carbon taxes, for instance, seem to be the most common topic of conversation in terms of an economy-wide market-based incentive. Economy-wide carbon prices (whether via a carbon tax or a cap-and-trade system) are one way to push progress across sectors, though some sectors are more price sensitive than others. There could also be efforts that have a narrower technological or sectoral focus, such as carbon adders within wholesale electricity markets or market-based clean energy standards.

While many advocates and economists view carbon pricing as a necessary policy for decarbonization, some see it as being more desirable than actually necessary. They point out, for instance, that clean energy is already accelerating in the market without carbon prices in most places. Humanity is about two-thirds of the way to the combined levels of energy supply decarbonization and energy intensity reduction needed to limit warming to 2°C, and the pace is accelerating. This should not promote complacency, but it can be an antidote to despair.

Market-based incentives for emission reductions can further accelerate both deployment and innovation. For new investment to be attracted to an area, one needs demand and the promise of future profits. Pricing carbon is not the only way to provide that kind of demand signal, though. Governments can also use their procurement power to accelerate markets for low-carbon products. For example, in the advanced nuclear community, companies trying to innovate are having a hard time raising money because of the absence of a policy signal; the biggest problem in innovation is getting the first plant and the first order, which is where government procurement can play a key role.

Frankly, mandates could also send clear signals to the market. For instance, some suggest that reducing emissions quickly should lead to policies with four key attributes: big, binding, delayed, and down. Emissions should be regulated so they go way down, and the requirements should be binding but delayed so people can plan. Something like requiring zero emissions by 2025 (though it does not have to be precisely those numbers) would clearly drive investment and give people and companies the clear signal they need.

GLOBAL PERSPECTIVE

Again – and this point cannot be emphasized enough – policy discussions cannot be just U.S.-focused if the aim is to actually bend the global emissions curve downward. That curve is currently projected to increase because of China, India, Bangladesh, Sri Lanka, Vietnam, African countries, and other developing and emerging economies that will see rising energy demand due to increased development and greater efforts to bring energy access to hundreds of millions of people that currently lack it.

Looking with a global lens, there are many policies that could be pursued. For instance, auto efficiency rules around the world could be harmonized around size, not weight, which could accelerate light-weighting of vehicles. There is also the question of whether and how border adjustments should be implemented, as tackling emissions from the manufacturing and industrial sectors raises issues of how carbon reductions are accounted for in the global economy.

Policy discussions cannot be just U.S.-focused if the aim is to actually bend the global emissions curve downward.

Even U.S. policy discussions should take a global perspective. For example, promoting better, more flexible energy markets around the world is one key need; the availability of LNG, for instance, is what enabled China to force coal boilers out of the market. The United States could be working with multilateral financial institutions to help low-credit customers get floating storage regasification units (FSRUs), which can change countries' outlooks on how many coal plants they need to build. Nuclear 123 agreements are another key need. Likewise, ratification of the Kigali Amendment to the Montreal Protocol could achieve gigatons-scale reductions by promoting greater availability of low-global-warming-potential chemicals for cooling around the world. The global aspects of the climate challenge cannot be sidelined.

APPENDICES: AGENDA

FRIDAY JULY 13

Opening Session

Introduction — **Greg Gershuny**, Aspen Institute Energy and Environment Program

Welcome — **Ernest Moniz**, President and CEO, Energy Futures Initiative

Andy Karsner, Managing Partner, Emerson Collective

SESSION I: **Data Room: The U.S. Energy Landscape**

This session will present numbers and forecasts on the current energy mix in the US and globally, an overview of international energy developments, electrification and decarbonization.

Moderators: Andy Karsner & Ernest Moniz

Discussants:

Richard Newell, Resources for the Future
Amy Myers Jaffe, Council on Foreign Relations
Mark Stubbe, Tellurian

SESSION II-A: **The Role of States, Utilities, and Consumers in Designing Transition**

A discussion about the role of utilities, states and customers/consumers in designing transitions for the new energy economy. How do incumbents and insurgents complement each other? What are the emerging policy and market models for utilities and smart cities to work together, and what are the next steps in the transition? What do customers expect from energy and service providers? What do consumers and larger users of electricity want?

Moderator: Andy Karsner

Discussants:

Anne Pramaggiore, Exelon Corporation
Asim Haque, Ohio Public Utilities Commission
Bryan Hannegan, Holy Cross Energy

SESSION II-B: **The Role of States, Utilities, and Consumers in Designing Transition**

Moderator: Ernest Moniz

Discussants:

Michael Picker, California Public Utilities Commission
Michael Terrell, Google
Colette Honorable, Reed Smith
Adam Browning, Vote Solar

SESSION III: **Ensuring Social Equity in the Transition to Clean Energy Economy**

How are policy makers, regulators, investors, business leaders and energy service providers communicating with consumers and other constituents about the value proposition of providing reliable, safe, and affordable electricity (the Social Compact) expanded to include clean and resilient electricity (Social Compact 2.0)? How is public sentiment and consumer preference for clean energy changing and working for low income or rural communities? How do solutions for low income communities, like community solar, impact the compact?

Moderator: Ernest Moniz

Discussants:

Sekita Grant, Emerson Collective
Jay Griffin, Hawaii Public Utilities Commission
Steph Speirs, Solstice

SATURDAY JULY 14

SESSION IV: **Policy Innovation - A New Look at the Wholesale Electricity Markets**

Wholesale electricity markets have struggled to address tensions created by state policies that favor intermittent energy sources in the generation resource mix. How can FERC, states, and other policy makers address both policy goals to have cleaner energy and to ensure the reliability of the grid with regard to capacity markets and balancing supply and demand?

Moderator: Ernest Moniz

Discussants:

Kathleen Barron, Exelon Corporation
Francis O'Sullivan, MIT Energy Initiative
Pat Wood, Wood3 Resources

SESSION V: **Tough Technology and Innovation**

Investments in "tough tech" and innovation incubators are more common than ever in working with startups to develop and deploy new technologies in areas like energy storage, fast charging, advanced materials, and energy generation technologies, like advanced nuclear technologies. How can this technology and innovation be harnessed and fostered to enable the energy transition most effectively?

Moderator: Andy Karsner

Discussants:

Michael Bruce, Emerson Collective
Paul Chodak, American Electric Power
Maryam Brown, Sempra
Julio Friedmann, Energy Futures Initiative

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Designing the Next Energy Economy: A Reality Based Discussion on the Future of Energy

A discussion about the actions and solutions needed to transition the energy economy to a low carbon future. The discussants will talk about policy, technology, and market mechanisms and finance needed to make this transition possible.

Featuring:

Ernest Moniz, Energy Futures Initiative
Mary Nichols, California Air Resources Board
Andy Karsner, Emerson Collective

SUNDAY JULY 15

SESSION VI: **IT-Connected Technology and AI-Innovation in Energy**

The autonomous built environment and additive manufacturing will also impact the energy sector. In a network of smart, integrated devices what new information technologies are being developed to revolutionize efficiency? What will the digital utility tell us about the electricity system? By 2020, the world will have around 50 billion connected devices integrated into and managing the built environment, presenting opportunities for energy savings and efficiency gains. AI, smart buildings, and smart machines can optimize systems to operate effectively with each other, potentially decreasing energy consumption.

Moderator: Clint Vince, Dentons

Discussants:

Aaron Berndt, Nest
Jan Vrins, Navigant
Gil Quiniones, New York Power Authority
Jon Creyts, Rocky Mountain Institute

SESSION VII: **Policy Innovation for Low Carbon Transition**

What are the economic implications of building a deeply decarbonized electricity system? How could carbon pricing or clean energy standards impact the transition? What finance and policy tools exist for determining the mix of low carbon energy resources that will create tomorrow's most resilient, cost-effective, and low-carbon electricity systems?

Moderator: Jim Connaughton and Andy Karsner

Discussants:

Mary Nichols, California Air Resources Board
Jay Faison, ClearPath Foundation
Melanie Kenderdine, Energy Futures Initiative
David Hawkins, NRDC

MONDAY JULY 16

SESSION VIII: **Designing Transitions in the New Energy Economy & Wrap-Up**

Moderator: Andy Karsner

PARTICIPANTS

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