

Turbulence & Transition: Winning the Clean Energy Race



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PREFACE

The Aspen Institute Clean Energy Innovation Forum convenes top energy, finance, and policy experts each summer for an in-depth and forward-looking examination of the transition to a clean energy economy. The overall objective of the Forum is to identify policy and technology innovation that drive change towards a cleaner, more resilient, and more connected energy system. This report summarizes discussions at the 7th convening that took place in Aspen, Colorado, from July 22-25, 2016.

Roger Ballentine and Andy Karsner co-chaired the Forum. Their extensive knowledge and experience enabled them frame and guide the discussion and elicit useful contributions from all the participants. The highly qualified speakers listed in the agenda provided a wealth of information and a variety of perspectives, contributing substantially to the overall richness of the dialogue at the Forum.

We acknowledge and thank our sponsors for their generous financial support. Most have been participants and supporters for several years. Their commitment to our work ensures the Forum is able to continue to provide valuable high-level discussion.

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Dave Grossman, ably captured the richness of the wide-ranging discussions and distilled the highlights into this eminently readable summary. Greg Gershuny, Tim Olson, and Nikki DeVignes efficiently and cheerfully managed the preparation details that enhanced the substantive focus of the Forum.

Neither the Forum speakers, participants, nor sponsors are responsible for the contents of this summary. Although this is an attempt to represent views expressed during the Forum, all views expressed were not unanimous and participants were not asked to agree to the wording.

Over the years, the direct impact of the Aspen Energy Forums on policy-making has always been difficult to quantify. However, the true lasting and ultimately more important influence of the Forum has likely been on individuals who attended – and how they have carried what they learned about issues and themselves in Aspen into the broader policy and business arenas. Forum participants gain perspectives, test ideas, participate in thought-provoking discussions, make predictions (often proven wrong), and are inspired to act on key issues. Many of the key learnings and connections have occur outside of the meeting room, with important professional and personal relationships established over meals, during free time, or on hikes. The Aspen Forums have fostered both knowledge and friendships, and they will surely continue to do so for many years to come.

David Monsma
Executive Director, Energy & Environment Program
The Aspen Institute

CO-CHAIRS' FOREWORD

We continue to be both blessed and challenged to be leading the Aspen Institute's Clean Energy Innovation Forum during a time of nearly unprecedented change in an energy sector that is increasingly vital to the world's social, economic and environmental priorities. Our goal for the Forum is to use the lens of these various macro priorities to examine not just the current developments in energy, but to project the trends, promises and pitfalls that lie ahead for this critical set of industries. We take great pride in the fact that over the past seven years of the Forum, we have consistently forecasted change and challenges that since come to pass. Our intent is to stay at the very forefront of change.

We held our 2016 Forum on the heels of the historic Paris climate change accord, at a time of dramatic decreases in the cost of clean energy technologies, during the rapid integration of digital technologies into the energy sector, and in the midst of a fundamental rethinking of relevant regulatory structures that have been the norm for the better part of a century.

Our success in delving deeply and with informed insight into the many issues facing the energy sector is almost entirely a result of the Aspen Institute's ability to get the finest minds and most influential actors to join us every summer. We convene the best of technologists, policy experts, financial sector leaders, Fortune 100 executives, and energy company innovators to explore the energy sector in a substantive, creative and in depth fashion. We have attended hundreds of "energy conferences" throughout our careers, but in our view, the Aspen Institute's Clean Energy Innovation Forum remains without peer.

Roger Ballentine
President
Green Strategies, Inc.

Andy Karsner
Managing Partner, Emerson Collective
Space Cowboy, Google X

EXECUTIVE SUMMARY

The tripartite paradigm of technology, finance and policy remains the foundation for the clean energy sector. Driven by dramatic price decreases and national policies, and despite a generally low-cost energy environment in much of the world, clean energy deployment is booming. This expanding global clean energy deployment has been enabled by robust clean energy investment – \$350 billion in 2015 – most of which came from the private sector and more than half of which went into Asia. Most investment was in the form of asset financing, using various forms of debt and tax equity, though green bonds are gaining traction in clean energy as well.

Continuing innovation in finance, policy, and technology will be needed for clean energy to play its needed role in stabilizing atmospheric carbon dioxide concentrations at a level that can keep global temperatures at a manageable level. But the pathway to long-term global climate targets is complex. The global framework agreed to in Paris in late 2015 pulled together plans from countries representing the vast majority of the greenhouse gases in the world and set a long-term target of decarbonization by midcentury. The plans put forward by countries do not put the world on a 2°C path, much less a 1.5°C path, but they are robust and clearly a step in the right direction.

While renewable energy has been the tip of the spear in the move toward a clean energy future, other zero-carbon energy solutions will be needed as well if global climate goals are to be achieved.

Meeting the pace of Paris will require spurring clean energy innovation, as embodied in the goals of the Mission Innovation initiative launched at the beginning of the Paris meeting. Experts believe that we will need an increase in research and development of new, cheaper, more efficient clean technologies at a rate of \$500b a year for the next 25 years. It will also require greatly accelerated clean energy deployment, though harnessing low-grade, dispersed renewables (e.g., solar, wind) at scale may well require increased investments in transmission. Policy

support – ideally technology-neutral and perhaps including a price on carbon will be essential to scale clean energy to meet global climate objectives economically.

While renewable energy has been the tip of the spear in the move toward a clean energy future, other zero-carbon energy solutions will be needed as well if global climate goals are to be achieved. Fossil fuels are not going away of their own accord globally, given the increasing dependence on natural gas in the West and the inevitable use of fossil resources in India, China, Africa, and elsewhere. Carbon capture and storage (CCS) technology for coal and for gas is needed to allow fossil fuel use without jeopardizing the climate and we must continue to address the impacts of methane from natural gas production and distribution.

Nuclear power, meanwhile, is already a vital source of zero-carbon energy around the world, but its fortunes are flagging in some developed countries, particularly the US, where some plants have closed and others are scheduled to close in the near future. Federal and state policy support will be needed to safely and economically keep existing nuclear plants alive for at least another decade or two, stand up new ones, and advance next-generation nuclear. Other zero-carbon

solutions similarly require greater attention, including hydropower and geothermal power, and should not be ignored – all such options including nuclear should be considered in any new clean energy standards. That being said, some renewable energy advocates are not open to zero-carbon solutions other than wind, solar, and energy efficiency. There is a need for leadership highlighting the importance of deploying all zero-carbon solutions.

The traditional grid characterized by centralized generation, one-way power flows, and energy provided as an undifferentiated commodity appears to be transitioning to one characterized by distributed generation, two-way power flows, greater clean energy optionality, and energy provided as services. A consumer-facing package of integrated solutions – including rooftop solar, energy storage, electric vehicles, and demand response – could represent a breakthrough opportunity. There are hurdles to a distributed future, however, and it may be premature to write off the centralized generation system – it is likely that a hybrid system will emerge with elements of both. Although rooftop solar gets a lot of attention and subsidy, more than 2/3 of solar generation in the last two years has been from utility scale solar, with only 1/3 from roof top distributed solar. Technologies growing in the marketplace can also increasingly enable the matching of demand to the available supply (instead of ramping generation to match demand). There is a need for major rate reform, though, regarding how utilities are compensated, how customers can monetize services provided to the grid, how utilities can actively participate in solutions, and how customers are incentivized to take action.

Within the context of this evolving grid, we should recognize and praise the fact that the nearly century-old social compact of providing universal access to reliable, safe, and affordable electricity has largely been achieved. Going forward, we as a country should set our sights toward a new 21st Century social compact for an electricity grid that promises additional attributes, such as sustainability and robust resilience. This evolution is raising challenging questions regarding equity and equal access, the attributes that should have primacy, and whether change can occur incrementally. Evolving demands, including by large corporations that have made clean energy consumption a core business strategy, and the growing consensus around environmental priorities such as addressing climate change, suggest that the time is right for Social Compact 2.0. To some extent, the attributes of resilient and clean are already being reflected in policy changes and efforts to restructure energy markets. The role of the conventional utility is a pressing question if we are to embark on this new level of social ambition.

Major takeaways and recommendations from the 2016 Aspen Institute Clean Energy Innovation Forum included the following:

- **The trend toward a more distributed, two-way grid with more consumer choices, clean energy options and new energy service providers is well underway – but regulatory structures must continue to evolve to increase the pace of change.**
- **Utility scale renewable energy has largely achieved cost-competitiveness although pricing and contracting mechanisms must be such that projects are not only bid at competitive prices but can be successfully financed and brought online.**
- **While our immediate challenge is to greatly accelerate the deployment of existing clean energy and demand side technologies, meeting worldwide decarbonization goals will require a significant increase in research and development at a rate of \$500b a year for the next 25 years, and will likely require governments around the world to put a price on carbon to most efficiently redirect investment toward reducing emissions.**

Federal and state policy support will be needed to safely and economically keep existing nuclear plants alive for at least another decade or two, stand up new ones, and advance next-generation nuclear.

- **The future of a modernized electrical grid will require major public and private investment in our energy system infrastructure as well as greater demand side efficiency and use optimization. The near future energy system will require that we preserve and enhance nuclear energy's contribution and that we seek to decarbonize ongoing fossil energy generation through carbon capture, use and storage.**
- **In the US, we have largely fulfilled the 20th Century social compact of providing affordable, reliable and accessible electrification and the economic benefits resulting from that achievement. It is time to consider the next social compact (Social Compact 2.0) to provide affordable, reliable, accessible and clean energy, as well as advanced energy services and products, to all consumers.**

STATUS OF CLEAN ENERGY

Robust clean energy deployment and investment are occurring around the world, driven in part by dramatic price decreases.

UPTAKE OF CLEAN ENERGY

The penetration of renewable energy remains pretty small globally. Of all global energy consumption, nearly 80% is fossil fuels, 2.5% is nuclear energy, and 20% is renewable sources, including hydro and wood-burning stoves. Only 1.4% is wind, solar, modern biomass, and geothermal power.

Still, renewables are booming. Price points keep moving lower, and solar and wind accounted for about half of all new generating capacity added in 2015. Many utilities have started embracing renewables; even traditional utilities that used to be at the forefront of the fight against them are now trying to own renewables. Utilities are starting to recognize that the more they fight renewables and distributed energy resources, the more customer demands for clean energy will be met in other ways.

Energy storage is seeing increasing uptake as well, which could be a game changer. The costs for lithium-ion batteries have been dropping rapidly, largely due to China being the biggest consumer of batteries (some of which are exported from the United States). There are also thermal and other cost-effective technologies that can provide energy storage services.

CLEAN ENERGY INVESTMENT

After a steep ramp up in clean energy investment between 2004 and 2011, investment levels are generally leveling out, though decreased costs mean the same amount of investment can deploy greater amounts of clean energy. In 2015, around \$350 billion was invested in renewables, biofuels, and smart technologies. Most of that investment came from the private sector (enabled by lots of subsidies), while only about \$13 billion came from direct government investment. The biggest portion of the investment – around \$300 billion – was asset financing, compared to only about \$4 billion from venture capital.

While the United States, Europe, and others are making substantial investments, more than half of global clean energy investment in 2015 went into the Asian region. Most of that investment occurred in China, which is driving global markets and technologies in renewables. There is a question, though, as to whether China can continue to be a big part of what is driving scale in the clean energy industry. Electricity demand in China is growing much slower than the economy, and new clean energy investment in the region declined in the first two quarters of 2016.

Overall, capital is no longer really an issue in the clean energy sector. Capital markets have tons of money for long-

duration, low-risk projects; the key is to keep finding ways to fit clean energy into that kind of framework. The turning point for clean energy finance was 2013, which saw the first yieldco, the first solar securitization, the first energy efficiency securitization, and the release of the Green Bond Principles.

Most of the money invested in building clean energy projects is done in a fairly rudimentary fashion, using bank debt, syndicated debt, and some tax equity. For example, residential rooftop solar is well-financed with tax equity; all risk analysis is done by consumer lenders, and solar financing is starting to get securitized after tax equity. A risk to the renewable energy industry over the next few years, however, is the lack of tax equity availability; only about 25 institutions invest, and more are needed.

In 2015, around \$350 billion was invested in renewables, biofuels, and smart technologies. Most of that investment came from the private sector.

Bonds are also starting to gain more traction in clean energy. In 2015, about \$50 billion in new green bond offerings were issued worldwide. Demand for green bonds far exceeds supply in the secondary market, so green bond prices in that market are getting bid up.

There is certainly more work to do in the clean energy finance sector. For instance, multi-billion dollar techniques used by the conventional energy industry, such as master limited partnerships, are still limited in clean energy. Figuring out financing for everything between rooftop and utility-scale solar – commercial and industrial solar, microgrids, community solar, and the like – can still be challenging. The financing opportunity in energy efficiency and other behind-the-meter technologies remains enormous. In addition, Wall Street has not been rewarding business model innovation in the power sector (in contrast to investors in the transportation world, who are embracing the need for incumbents to shift dramatically).

Policies can play a key role, as they drive capital. Renewable portfolio standards, for example, are what gave non-renewable bankers the confidence to make multi-year investment commitments in renewables. While the federal solar investment tax credit and renewable electricity production tax credit have accelerated investment, they will not last forever and are viewed as short-term gimmicks. Financing flows with the risks and the returns, and in the clean energy industry, those are determined by public policy.

All in all, though, an environment in which lots of sovereign debt is trading below zero and countries are issuing negative interest rate bonds is perfect for investment in clean energy, which has no cost of fuel. A lot of clean energy investment is basically infrastructure investment. Pension funds or institutional investors that invest in basic infrastructure will soon see clean energy moving into their portfolios; there may not be a need for specialized clean energy investors as much as for infrastructure investors who understand that clean energy is a part of their world.

A RACE TO THE BOTTOM?

The world – particularly the United States – is clearly in a low-cost energy environment. Natural gas is cheap, and it does not appear that will change soon; even with fewer rigs, gas production has been rising and shows no real sign of abating. There have also been unprecedented cost reductions in renewable energy, especially solar and wind, with dramatic improvements in efficiency. This low-cost environment has ramifications for the clean energy industry.

One repercussion has been incredibly low unsubsidized bids for solar and wind around the world, including in Morocco and Mexico. This race to the bottom in the market is important for those building generation. The potential downside of utility-scale renewable energy success is that returns are getting competed away. There is some dispute as to whether it is even possible for developers to make money at the low level of some recent bids. The impacts on innovation are similarly unclear; competitive pressures could spur innovation, or low returns could hinder it.

From a societal perspective, however, nothing brings price discipline to a market like a monopsonistic buyer getting really good prices in bids, which can translate into low costs for consumers and ratepayers. (To the extent that savings from a low-cost energy environment are not passed along to consumers, however, opportunities are created for those trying to get into the game through distributed solar and similar technologies.) The main societal issue might only be ensuring that companies that win bids can actually deliver (i.e., preventing contract failure). Stronger prequalification criteria to be allowed to bid – such as big deposits to bid and even bigger deposits to sign a contract – could be one solution, as good projects should attract that kind of capital. There may also be a need to build more services and capabilities than just cents per kWh into proposal requests, to ensure the grid is built for quality and reliability and not just for the lowest price. An evaluated bid system would allow bids that are not the lowest to win based on the additional services and capabilities provided and the quality of the projects and sponsors. One has to be careful, though, not to create a procurement process with so many intangibles that it stamps out innovation and new solutions.

To the extent the race to the bottom is a problem, it may be a slowly self-correcting one. A similar thing occurred years ago with independent power producers building tens of thousands of megawatts of natural gas combined cycle plants that were economically underwater. The backlog got worked off over the span of several years, and some companies went bankrupt. Bidding low prices to win projects means revenues are low, limiting the ability to run projects on equity, but bidding low also limits the ability to raise debt. Some companies making the super-low renewables bids have great balance sheets that enable them to do things others cannot. In general, though, the super-low projects are not getting financed, or they are financed by investors who are knowledgably taking risks. Companies that cannot survive in a low-cost environment will get eaten by those that do; industry consolidation is a sign of the industry maturing.

MEETING THE PACE OF PARIS

A global framework was agreed to at the Paris Climate Conference – officially known as the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) – in late 2015 to try to align countries' energy strategies with the science of atmospheric carbon dioxide concentrations. The right mix of finance, policy, and technology will be needed to stabilize concentrations at a level that gives humanity a chance, but the pathway to long-term global climate targets is complex.

PARIS OVERVIEW

Paris produced a new framework for global action on climate change, recasting the diplomatic process from a top-down strategy to a bottom-up approach in which countries came forward with what they feel is possible to achieve. This shift broadened the scope of countries taking action. Paris pulled together plans from countries representing 95% of the greenhouse gases in the world, created a system for countries to update and tighten those plans every five years, and put in place a system of verification and transparency to gauge progress (which still has to be fleshed out). The agreement also set a long-term target of decarbonization by mid-century.

The plans put forward by countries do not put the world on a 2°C path, much less a 1.5°C path, but they are robust, comprehensive, and clearly a step in the right direction.

Paris sent a signal to the world that governments take climate change seriously and that all are taking action. The plans put forward by countries do not put the world on a 2°C path, much less a 1.5°C path, but they are robust, comprehensive, and clearly a step in the right direction. The United States came forward with a target of 26%-28% below 2005 levels by 2025. The European Union target was at least 40% below 1990 levels by 2030. China committed to peak its carbon emissions by 2030 and included a significant target for non-fossil energy (which means build-out of non-fossil grid capacity equivalent to the entire US grid). Mexico came forward with a commitment to peak carbon by 2026. India had a weak intensity target but an ambitious non-fossil capacity target. Brazil pledged an absolute reduction in emissions alongside robust forest and renewables targets. There is certainly more work to be done, but these are significant commitments. All countries are also currently putting together their 2050 roadmaps, which should provide further guidance about how to make up the gap between the country commitments and a 2°C path.

Meeting the goals of Paris and maintaining Paris as a functioning mechanism require trust that there will be political will to carry the Paris commitments forward. This is particularly the case given political transitions around the world, including in the United States, the Philippines, and Europe (e.g., Brexit). Paris contains countries' macro-level targets and broad policies, but actual policy implementation and technology deployment are needed. Many countries, however, lack the requisite technical capacity and will require significant engagement on technology, policy, and finance to ensure that commitments get realized.

SPURRING CLEAN ENERGY INNOVATION

Even if all country commitments under Paris are actually achieved, there is a sizable delta between that outcome and the outcome needed for a 2°C scenario. Adding to the challenge is that the 20 most populous countries in 2015 will, as a whole, see a 24% increase in population by 2050. Nigeria will go from 182 million to 398 million people (more than the United States population), while India will become the most populous nation on the planet. Prime Minister Modi has committed to providing universal access to electricity in India by 2022, which means access for 400 million more Indians, not to mention the 400-500 million more people that will live in the country by 2050.

These challenges are spurring increased focus on clean energy innovation and investment. At the start of COP21 in Paris, President Obama and 19 other world leaders rolled out the Mission Innovation initiative, committing to double government clean energy R&D investment from around \$15 billion to around \$30 billion. (Each government will choose how it defines clean energy.) At the same time, Bill Gates and other big investors announced a parallel private-sector clean energy innovation investment initiative; capital markets generally want to invest in low-risk projects with returns, so attracting patient private capital to applied R&D and demonstration projects has been hard.

In the United States, the baseline for clean energy R&D is more than \$6 billion, mostly in the Department of Energy; increases will require Congressional approval. In the FY17 budget request, large portions of the additional money would go towards energy efficiency and renewable energy (including advanced manufacturing, energy storage, and more), and funding for ARPA-E would triple. Because budgets are a zero-sum game (particularly in the current budgetary political environment), these increases do not represent new money so much as money shifted from one area to another – which is as it should be when lining dollars up against strategic goals in a portfolio planning process. That said, there is generally bipartisan support for Mission Innovation, and it is possible new funds could be appropriated to it.

Support for R&D, of course, has to be partnered with project capital to get technologies to commercialization.

Support for R&D, of course, has to be partnered with project capital to get technologies to commercialization. Demonstration projects and loan programs, such as the Department of Energy's loan guarantees, have a role in drawing in capital to develop and commercialize technologies. In addition, the Department of Defense is willing and eager to take market-mature (not early-stage) technologies, try them out in real-world situations, and turn them into things that can be financed.

It is important – and challenging – to find the appropriate balance between efforts to develop transformative new technologies and an all-out focus on deploying existing technologies. Some argue that since the climate challenge is urgent and time is short, a big focus on innovation puts the focus on the future and distracts from the essential task of taking existing technologies and deploying them at scale in the present.

SCALING RENEWABLES

Over the next 25 years, there is projected to be roughly \$9 trillion of investment in new clean electricity technologies, leading to record amounts of wind and solar growth. To achieve a 2°C scenario, however, roughly \$5.5 trillion more in renewables investment would be needed – which is basically an increase from about \$300 billion a year to around \$500-\$550 billion. Around \$600 trillion of capital is deployed in the world to date, and capital markets hold around \$130 trillion, but only around 2% of new capital deployed in the markets is going to clean energy. There is lots of upside left; it is clearly feasible to scale up.

This kind of transition and investment will take decades, during which there will be multiple technology transitions that cannot be predicted now. For instance, silicon is actually terrible for solar, and better materials could enter the

market over time. Battery technology is also advancing rapidly, and new flow battery technologies that look very different from lithium-ion could emerge on the grid over time. That said, both lithium-ion and silicon are already multi-billion dollar businesses, and though other technologies or chemistries might work better, the market has a bias towards mature technologies.

Solar and wind are the two mature renewable energy technologies that can operate at scale. Scale can bring improvements; manufacturing and deploying at scale, whether iPhones or solar panels, helps make things cheap. There is also some interesting technical work occurring to have large-scale solar and wind provide inertia, volt/VAR, and frequency services that emulate what fossil plants can provide. On the other hand, harnessing solar and wind at scale can also bring challenges. For instance, uranium, oil, and gas are concentrated energy, while wind and solar are low-grade and very dispersed. The United States uses an average of 3 terawatts of power; that amount of incoming solar radiation would cover 10,000 square kilometers, which is roughly equivalent to Rhode Island and Delaware (or, at 20% efficiency, Iowa). It is equivalent to using about 5% of the US land area for wind farms. Renewable energy sprawl clearly can have environmental and land use impacts, though getting environmental mitigation policies right can allow for better, faster, and more widespread clean energy infrastructure development.

In addition, wind and solar are geographically concentrated and hard to move around. Big deployments of wind and solar will likely require dealing with the challenges of siting and interstate transmission. Long-distance DC lines may be needed. Some US states that are making big progress on renewable energy goals are doing so at least in part because of transmission. Iowa, for instance, undertook a huge wind build out, underpinned by a big transmission expansion. Similarly, China plans to have the most modern grid on the planet by around 2020 – a smart grid with high-voltage corridors, being built out to where the renewable resources are.

Beyond wind and solar, electric vehicles (EVs), sales of which are small at the moment, could account for roughly 1 out of every 3 cars sold by 2040 or so. An inflection point should be reached around 2022-23, as battery costs come down. (Alternatively, some automobile companies are pursuing a hydrogen fuel cell approach instead of EVs, believing the mass market hurdles are less.)

If renewables are to be scaled up enough to bend the global curve on climate change, the scaling will have to occur in India, China, and other developing countries. It is imperative to understand the context and thinking in those countries regarding poverty, energy access, development, and a range of other issues. Ideally, the United States would be exporting clean energy technologies like mad to Africa, India, and other countries, but that is not always so simple, as some countries demand a domestic manufacturing presence to bid for renewable energy projects. Strategies and experiences are still exportable, however, and states that are in the process of significantly scaling up renewables, such as Hawaii, can provide playbooks of effective and scalable solutions that can be used in countries with bigger global climate implications.

CARBON PRICING

Every forecast and projection about how technologies will evolve is inevitably wrong. Analysts have preferences (or at least make assumptions) about technologies, but no one knows which ones will win (or which ones will win now but lose later). To meet the pace of Paris, it may be better for policy not to pick technology winners, but rather to pick objectives and provide signals to allow those objectives to be achieved. The key to achieving climate goals may be to define that carbon matters and to push for performance-based, technology-neutral approaches to solving climate change. Putting a price on carbon could be one such approach. Several large corporations already use internal carbon prices to influence their deployment of capital.

National-level carbon pricing could have many beneficial effects. It could help generate more demand for clean energy, create a more level playing field, and dramatically increase the impact of technology investments. The simplicity and directness of a national carbon price could also allow for faster business model adaptation. In addition, a direct carbon tax would put carbon pricing into the existing equation for infrastructure investment and make the outcomes of that investment easier to measure. Not all the effects would be positive, however. Because carbon pricing could make carbon-based energy more expensive, some of the proceeds would have to be redistributed to address the regressive effects of the carbon price on the poor. (Of course, climate change itself is regressive, as climate impacts affect the poor more than the rich.)

While carbon pricing is a necessary component of driving deployment of low- and zero-carbon technologies, it alone is not sufficient. For one thing, a truly effective carbon price, regardless of its policy form, would likely be too high to be politically achievable, while more politically acceptable carbon price will have limited effect. In addition, carbon pricing would not address market failures unrelated or only somewhat responsive to price changes. For instance, there would still be a need for R&D funding. Similarly, interventions to save the existing US nuclear fleet (if decisions are made to do so) would likely have to go beyond a carbon price.

There are other barriers to a national carbon price as well, at least in the United States. For example, it is not clear who speaks for the business community in political carbon price conversations; it was the US Climate Action Partnership (USCAP) in 2009, but that band is not getting back together. There also is not mass political buy-in for carbon pricing, and most people do not really understand much about it. In addition, in the wake of the failure of the last national effort at carbon pricing in 2009, there has been a proliferation of climate-related regulations that have the support of some stakeholders and policymakers. On the one hand, those regulations open the door to conversations about a trade for a carbon price – especially with Corporate Average Fuel Economy (CAFE) standards reform, Renewable Fuel Standard (RFS) reauthorization, and resolution of the Clean Power Plan litigation coming up over the next couple of years – but some stakeholders would strongly resist calls to scrap regulations that are already in place (and making progress) in exchange for an untested new policy. If a simple, direct carbon price is indeed the killer app worth trying for, then there is a need to understand the deal to be made to achieve it.

OTHER US POLICY INNOVATION

There are, in fact, hundreds of carbon prices in the United States at the moment, as federal and state mandates and incentives directed at clean technologies are essentially implied carbon prices. Americans tend to like emissions reductions certain and taxes hidden. Lots of policymaking will therefore be done using suboptimal policy instruments, and for the foreseeable future, people will have to be opportunistic in figuring out how to use second-, third-, and fourth-best policy instruments to encourage innovation and fast adoption and deployment of technologies to achieve climate goals. Doing policy through regulation, while perhaps full of downsides, involves much less wrangling than a Congressional approach. This is not to say that critical mass will not be achieved to force national carbon pricing, but there is already a lot of experience on how to take the next steps, and it is vital to keep using the tools available, however imperfect they may be. (There are also debates about which types of policies actually work best to achieve climate goals in the real world; a national carbon price might be best in theory, but other approaches might be more effective in practice.)

US regulatory policies, particularly under the Clean Air Act, have decades of experience dealing with the challenge of getting needed technologies into place, whether by spurring innovation and getting technologies that are relatively

To meet the pace of Paris, it may be better for policy not to pick technology winners, but rather to pick objectives and provide signals to allow those objectives to be achieved.

nascent into the marketplace or by taking technologies that are fairly mature and promoting deployment and diffusion. The perennial marker of success (or failure) of air pollution control programs under the Clean Air Act is the way in which a particular set of standards or rules intersects with independent emerging technologies and market trends. For instance, the acid rain program, enacted by Congress in 1990, is praised as being incredibly successful for reducing a lot of sulfur dioxide at low cost; while that success is partly due to the instrument choice of emissions trading, it is largely due to the development of new technologies and the transportation of low-sulfur Powder River Basin coal.

The Clean Power Plan is designed not to generate a wave but to ride one – the wave of cheap natural gas and renewable energy, driven by state policy decisions and new business models.

Similarly, in the first decade of this century, the Bush Administration tried to tackle mercury emissions from power plants, in a world of coal being sold at natural gas prices, and that regulation did not get far; the Obama Administration, in contrast, tried in a world where the cost of gas and coal had flipped, and its mercury regulation fared much better – not because of brilliant policymaking, but rather due to the good luck of the fracking revolution occurring just before that rule was finalized.

The Clean Power Plan (CPP) continues in this Clean Air Act tradition. The CPP is designed not to generate a wave but to ride one – the wave of cheap natural gas and renewable energy, driven by state policy decisions and new business models. The CPP is crafted to fit into a 20th century state-by-state legal architecture to induce a program that, when fully implemented, could function almost like a national carbon pricing program. The EPA had to set up conditions whereby a

bunch of decentralized actors end up making decisions in concert to produce that result. While policy innovation beyond the CPP and the Clean Air Act will be needed to get to the desired 2050 decarbonization levels, policy innovation will not occur on a blank slate; rather, policy innovators will be stuck with some continuity, building on the institutional muscle memory of the CPP and other Clean Air Act programs.

One effect the CPP has already had is driving different parts of state governments to talk to each other for the first time. This is vital. For the United States to get on a 2°C path, policy innovation is needed to help utilities cope with much larger amounts of distributed generation and to figure out what comes next regarding net metering – and in the electricity sector, that kind of policy occurs largely at the state level. There is a need for clean energy businesses to engage more systematically and actively in state legislative and regulatory proceedings. Conversations in those arenas are generally dominated by utilities (though not to the same degree in every state and not always at the same level of influence as in the past). There are all sorts of technologies that can be used for a range of services, but key players are not at the table to address real world regulatory barriers. Regressive policies in states, whether on rooftop solar, energy efficiency, or fixed rates, create risks for new players and technologies. In fact, it is possible that state-by-state electricity regulation will not continue to work, as the ways the system and technologies are evolving are not respecting state boundaries; a regional approach may make more sense. Vendors fighting in 50 states to get technologies through will make it harder to act with urgency.

Whether at the federal or state level, the challenge with policy innovation on climate change and clean energy may not be so much in policy design – which has been a mistaken fixation by the environmental community – as in adequately engaging other key constituents to agree on some principles. Well-meaning but elite environmental organizations need broader coalitions to bring policy change, and stakeholder discussions are a key part of that. These coalitions have to include younger and racially diverse participants. Especially during such a politically polarized time, there is an increased need to bring people together to advance national and state policy innovation.

That being said, the Obama Administration has been pursuing a climate agenda that seeks to forge coalitions among broad stakeholders, which is time-consuming and empowers those invested in the status quo. Progress is occurring, but outreach that breeds incrementalism will not get policy moving fast enough to achieve climate goals (and even with the outreach, many stakeholders are still unhappy). It may be that a future where capital is cheap, energy is free

(e.g., from the sun or wind), and huge dislocations occur in the utility sector is inevitably coming, and there has to be a policy system designed to accept that pain, the stranded assets, and the changed utility role. Policymakers may have to bite the bullet and unleash the market (while keeping a monopoly for the wires). In terms of political and policy fights, advocates and policymakers often have to fight the same fight, and fight just as hard, for incremental progress as for dramatic progress – so they might as well fight for audacious policy goals and actions that make those goals a reality. In addition, it is always important to remember that while policy is sometimes the answer, it is also sometimes the problem. For every new policy imagined to advance a clean energy future, there is probably an existing one to kill in order to allow progress and innovations in technologies and business models.

DECARBONIZATION BEYOND RENEWABLES

Renewable energy has been the tip of the spear in the move toward a clean energy future. While some advocates argue that renewables are all that are needed to achieve humanity's climate goals, many believe renewables – even if taken as far and as fast as they can go – cannot accomplish the job alone. There is a need for “clean energy” writ large. A larger volume of zero-carbon energy needs to be created in a short timeframe, which requires a bigger picture of zero-carbon energy. The goal is so large and challenging that no one set of technologies is likely to hit it.

FOSSIL FUELS

There is a big gap between fossil fuels and renewables in terms of energy quality and density, and those traits, combined with low prices and geographic abundance, mean they are not going away of their own accord globally. For instance, India is sitting on a pile of lignite, and there is coal all over China and Africa. China added coal-fired power plants at a brisk clip every year for a decade. If those resources and recently built plants are to be used – and they will be, at least to some extent – then technology is needed that will allow that to occur in a cleaner fashion that does not destroy the planet.

In the longer term, natural gas too will require carbon capture and storage in order to remain viable.

Carbon capture and storage (CCS) is the main technology that would allow fossil fuel combustion to have no or low carbon emissions. (Combining CCS and biomass could create a net negative profile.) There does not appear to be a surge of innovation around CCS, however, nor a big overarching programmatic framework for addressing coal. There is no broad R&D program for things like CCS in the United States because the Office of Management and Budget (OMB) does not support those broad kinds of programs – and has not for many years. It is very hard to get an increase in non-renewable R&D, and this was true even before the Obama Administration. In

addition, companies that might use captured emissions for enhanced oil recovery are not clear on whether they would be able to use carbon dioxide from a source covered under the Clean Power Plan. If the country is going to take full advantage of oil fields as carbon storage, those kinds of issues have to be resolved.

Natural gas is often viewed as a bridge fuel between the present and a clean energy future. The United States has more natural gas than it knows what to do with, and it is beginning to export it as LNG. Regardless of what one thinks of fracking, it unlocked a huge lower-carbon resource. Natural gas combined cycle technology and R&D continue to advance; higher efficiencies are being achieved, as well as greater flexibility and faster ramp times (with implications for renewables). Natural gas might also be used as a distributed energy resource that can provide extra reliability and demand management in the commercial and industrial space, if rate reforms can be technology agnostic. Gas only has a role in decarbonization, however, if it is really better on a lifecycle basis; the impacts of methane from natural gas production and distribution have to be addressed. In the long term, as emissions get zeroed out,

gas too will require CCS in order to remain viable. Already, there are high-efficiency natural gas power plants being planned that would generate electricity at costs comparable to existing natural gas combined cycle plants while also capturing all carbon dioxide emissions (at no extra cost) at pipeline quality and pressure.

There are hurdles, though, to US natural gas playing a maximized role in the clean energy future. For instance, while oil can be shipped anywhere in the world, federal natural gas policy distinguishes between shipping LNG to countries where there is a Free Trade Agreement and to ones where there is not. It also takes more than two years for FERC to issue an export facility permit. In addition, natural gas producers have shown no interest in finding the potential symbiosis between gas and renewables, and the same is true on the other side, with some environmentalists and renewables advocates refusing to sit down and talk with gas.

Furthermore, given finite (and falling) electricity demand in the United States, every megawatt-hour displaces something else. If the end game is completely sustainable electricity by mid-century, focusing only on the electricity sector could paint a bleak future for natural gas. An expanded focus – such as sourcing natural gas from excess renewable electricity, creating chemicals from syngas, or producing hydrogen at scale – could give natural gas a lifeline.

NUCLEAR

Nuclear power may be needed to meet the climate goals agreed to in Paris. Meeting the Paris goals requires avoiding 60 gigatons of projected emissions, and 128 nuclear plants is about 1 gigaton, displacing the building of 329 coal plants. In some parts of the world, nuclear power and innovation around it are expanding. However, nuclear is starting to decline in the United States, Germany, and some other places.

The nuclear industry in the United States is under significant stress at the moment. In competitive markets, nuclear power cannot compete against \$2 natural gas, and there are a number of nuclear plants operating in markets where the average cost of power is below their operating costs. In the United States, two-thirds of all non-carbon-emitting electricity comes from the country's 99 nuclear facilities, of which 11 are going to be closed or are in the process of being decommissioned. Roughly 9 gigawatts of existing nuclear capacity is currently on the bubble, and another seven or eight plants could shut down within the next couple of years. Tackling climate change is not just about what energy sources are added; the energy sources that are going away matter too.

The loss of nuclear plants could wipe out many of the gains in carbon reductions made by renewables and could make it harder for some states to comply with the Clean Power Plan. Policies will drive a huge amount of zero-variable-cost renewable energy onto the grid, but if those resources have to pick up the slack from retiring nuclear plants, the carbon challenge becomes even more challenging. Replacing nuclear power with renewables may just be swapping one carbon-free source of power for another, which does nothing to reduce emissions. Replacing is treading water. In fact, since nuclear plants operate at greater levels of efficiency and production than any renewable energy source, replacing a single nuclear plant with wind or solar would involve a much larger footprint. It would be better to expand the amount of zero-carbon generation than to replace one with another. Keeping nuclear plants going seems like a key near-term climate mitigation tactic.

Intense discussions are occurring in states about regulatory relief for nuclear plants, and there may need to be re-regulation of nuclear plants to keep them alive for at least another decade or two. There is also a national need to recognize the importance of nuclear for meeting carbon targets; there is an urgency that many people in the United States still have not grasped. Nuclear power was about to mount a comeback in 2008 when an OMB decision killed the

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market, and now nuclear requires federal policies that enable and galvanize it. The United States needs a government program to stand up the first 10-12 plants and sell them off after a decade or so. Another path is to break up the utility model to get the consolidation needed to create entities with balance sheets large enough to include nuclear power in portfolios.

There is also a need to restart R&D on next-generation nuclear, to move away from the light-water reactor problems that scare so many people. (The Navy, for instance, has nuclear technologies that are way ahead of the power generating fleet.) There is a need for investment in new test reactors in the United States if current and/or advanced nuclear technologies are going to progress. As for small modular reactors (SMRs), the industry hopes to improve their commercial viability, but they still would not come online until at least 2024. SMRs have lots of hope and promise, as they are small and scalable, but if a quarter of the existing fleet is decommissioned in the interim, then it will be for naught. In addition, much of the nuclear workforce will be lost by 2024, with implications for the nuclear power industry, national security, and understanding of proliferation issues.

The United States is on its heels on nuclear power, not thinking with forethought about how to stop the acute hemorrhaging of gigawatts of zero-carbon power and the loss of the nuclear workforce. If the United States does not get back into the nuclear business, it will be ceding the business to China and Russia.

OTHER CLIMATE SOLUTIONS

Nuclear and CCS are not alone in being too often left out of the climate conversation. Hydropower, for instance, is facing many of the same challenges as nuclear power. There is lots of hydro potential left in the United States, even in existing dams. The environmental community needs to be true to its word about caring about climate change and include hydro in the conversation. Similarly, geothermal power and geothermal for heating and cooling receive relatively little attention and support. Geothermal has been hurt by the lack of value placed on dispatchability. For this and other reasons, the geothermal industry is atrophying. If the barriers to baseload renewable energy technologies can be understood and addressed, then the energy storage discussion, while still important, will not be as essential, at least not at the same scale.

Energy efficiency, smart technologies, and demand response (DR) also have to be part of the global solution. Energy efficiency solutions, which are readily deployable and scalable, can reduce costs for families and households. In the 21st century, there is ample technology to control load and reduce demand; countries not only need to generate power in a clean way, but also should generate as little as possible to provide for their needs. Avoiding generation in the first place is almost always the lowest-cost way to reduce emissions.

Decarbonization is not only about electricity. Transportation is a huge source of emissions that have to be addressed. Beyond energy, better land management can deliver significant climate gains (and can help farming and ranching communities, who currently see climate policy as a threat, see it as an opportunity).

For a challenge as serious as climate change, all options may need to be considered, including active geoengineering, though intentionally intervening in Earth's systems at that scale creates concerns about unintended consequences. There are many dialogues occurring about what the rules would be for an Earth experiment.

POTENTIAL SUPPORT FOR FOCUSING ON ALL ZERO-CARBON ENERGY

The time frame for serious action on climate change is getting shorter and shorter, but some well-meaning environmental groups go off track by trying to be purists. Advocating for certain technologies that are deemed the purest and most loved will not actually address the math of the carbon problem. If the United States is going to reach its

Paris climate goals, let alone the goal of reducing emissions 80% by 2050, the nation ignores hydro, nuclear, CCS, and other zero-carbon options at its peril.

Not many climate advocates would support rifle-shot policies around nuclear power or CCS, at least not on a big scale. Some advocates also view increased natural gas exports as a climate negative. However, the climate/environmental community is generally looking for broad-based policies that will drive aggressive, rapid reductions, and framing policies with that outcome could open the door to having reasonable conversations about compromises with some (but not all) environmental organizations.

That being said, much of the environmental advocacy community and many Democrats on Capitol Hill are not open to zero-carbon solutions other than wind, solar, and energy efficiency. Inside government, there is no desire to engage at the same level on other zero-carbon energy technologies partly because there is no comfort zone that doing so will be acceptable to environmentalists and businesses. The responsibility falls at least partly on renewable energy businesses, especially wind and solar, to figure out the set of policies that will accelerate not only their sectors but also other zero-carbon sectors. There does not need to be a renewables agenda, a CCS agenda, and so forth; there ought to be a holistic policy with climate change as the organizing principle. There is a need for leadership highlighting the importance of getting to zero-carbon, though agreeing on that goal is hard because the Republican Party refuses to acknowledge that carbon is even a problem. There is the potential, however, to blend conversations about climate change, security, minimization of volatility, and price hedging in order to boost political viability. Talking about how much zero-emission energy is securely available to the country is a great basis for political progress. (There may also be a political opportunity to advance clean energy innovation by focusing on something like reducing the regulatory hoops that energy innovations would have to go through.)

Outside of government, many major corporations have made 100% renewable energy commitments – but not 100% zero-carbon commitments. If they were to make zero-carbon pledges instead, that would jumpstart the policy conversation about supporting a broader range of zero-carbon energy sources. Major companies, though, are often interested in attributes beyond just zero carbon. Free fuel that is always available is just one of many beneficial attributes of renewables that drive companies to make their renewable energy pledges.

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IS THE FUTURE ON THE GRID EDGE?

On the way to a clean energy future, the United States appears to be moving towards a world of distributed energy resources (DER) and smart technologies. That path is not a given, however.

DISTRIBUTED VERSUS CENTRALIZED

In the traditional grid, power flows from a central generation source through transmission lines to distribution lines and then to consumers. This grid is characterized by incumbents, wholesale electricity, centralized generation, and energy provided as a commodity. This system, however, has begun to fundamentally change. The grid appears to be transitioning to one characterized by insurgents, retail electricity, distributed generation, and energy provided as services.

Until distributed energy resources are both cheaper for customers and more beneficial for utilities, change may not occur at scale.

Distributed energy resources are poised for a huge moment in suburban America, where there are lots of people and lots of horizontal services (roofs, parking lots, etc.) for solar. Power flows now have the potential to go in reverse, as some consumers are producing power. There are also lots of multi-car households in suburbia, and if many of those “second cars” were EVs, then many homes would have energy storage in their driveways. A customer-friendly package of integrated solutions – including rooftop solar, energy storage, control systems, electric vehicles, demand response, and energy efficiency – could represent a breakthrough opportunity, whether at the household

level, on college or other campuses, on military bases, or elsewhere. Similarly, commercial buildings could be an asset in the power system that could be thought of in a different way: as proactive participants that can provide services to the energy system. After making sure that the buildings serve the customers’ primary needs and missions, then storage, distributed generation, additional controls behind the scenes, and other technologies could be brought in that could provide services to the grid (e.g., capacity shifting, frequency regulation, two-way power flow). DER technologies are very dependent on geography, and different solutions will work in different places.

A range of factors could accelerate this kind of transition. For example, unreliability of the centralized grid system in the United States could move people to get their own sources of generation, as hospitals already do; it is not a big leap to take backup generation and make it primary generation. When Superstorm Sandy hit in 2012, millions of homes lost power for weeks. The distributed industry was not ready with resilient solutions, but it may be by the time the next superstorm hits. An additional factor could be the growing need for personalized solutions that the grid may not be able to provide, such as for companies declaring that, by a certain year, they will not take electricity from any grid system that has coal-fired power. Costs could be yet another factor, as the grid-based system is where fixed-line telephony was 15 years ago – with fixed costs that never go down even as demand does. Utilities are loading transmission and distribution costs onto customers to perpetuate a model based on 130 million wooden poles.

There are hurdles to a distributed future, however. For instance, some markets' wholesale rate structures need better price signals for DER. In addition, the distributed model is more of a bottom-up, peer-to-peer approach that presumes that there will be enough device innovation at the consumer level to force changes in business models. Given how fundamental the electricity system is to the nation's security and economic health, how regulated the sector is, and how the industry works, it is harder to disrupt than just having Silicon Valley invent something clever for consumers to buy. While DER technologies have reached or are reaching the stage where they are cheaper than alternatives, utilities often get no returns under the current regulatory regime for going that route. Business models are beginning to respond because they have no choice, given customer demands and lower-cost technologies, but the core processes of the industry revolve around how capex is allocated, and until DER is both cheaper for customers and more beneficial for utilities, change may not occur at scale. The challenge is exacerbated by the fact that change is a full-time job, but with the exception of some utilities (e.g., in New York and California), many utilities have been stripped down and have no one whose job is to push change.

It is premature, though, to write-off the centralized generation system. There are places (e.g., islands, military bases) where distributed resources make perfect sense, but it is a leap to go from that to asserting that the whole country or world will be switching to distributed power. Consumers generally want simple solutions, and that currently involves having a wire connected to a building much more than it involves new technologies that have to be integrated. (Customers are overwhelmed by choice, and there is tons of inertia, even for projects or technologies with essentially zero risk.) The reason the grid was built on large, centralized installations is because scale – in engineering and finance – matters, and large grids are perfectly capable of balancing a system with many intermittent resources.

In some ways, the debate between a centralized and distributed future is unproductive. To get anywhere close to where humanity needs to be to address climate change, the scale of clean energy deployment has to be so huge that it is all needed – centralized, distributed, transmission, all of it. In general, 15% of the population is made up of early adopters and innovators, 15% are laggards, and 70% are in the middle – and solving the climate challenge requires working on both the 85% and the 15% on the leading edge. Besides, very few people think of DER as a way to leave the grid; people want lower cost, cleaner, and more resilient energy, but most do not want to leave the grid. Furthermore, creating a dichotomy between centralized and distributed risks ignoring solutions that fall in the middle, such as community solar.

SOLAR

Since 2010, US solar deployment has increased at a 54% compound rate, and most of it has been utility-scale. The industry is experiencing unprecedented efficiency gains, at both the module level and the systems level (e.g., racking). There have also been incredible price decreases for solar, with amazingly low prices coming in at auctions around the world (as noted earlier). The lower prices, bolstered by policy support, are driving increased demand. Climate change may have inspired the clean energy revolution, but price may have made it inevitable.

Solar is a technology uniquely suited to scaling down. Solar is not the only DER that is developing or already being deployed, but it tends to get most of the attention. Distributed solar has some parallels to the organic food industry, which started in the United States around 1990 and has had a meteoric rise to account for about 15% of supermarket sales. Distributed solar may be trending towards that 15%, which would still leave 85% for the centralized grid. A lot of rooftop solar has been deployed because of enormous subsidies – subsidies much greater than for utility-scale solar, even though utility-scale provides much greater carbon reductions.

Since 2010, US solar deployment has increased at a 54% compound rate, and most of it has been utility-scale.

Solar deployment is clearly bifurcated. Utility-scale solar deployment is largely economic, driven by low prices, and the benefits of low prices are distributed to all ratepayers. Non-utility-scale deployment, particularly rooftop solar, is driven primarily by policy, and there is an argument to be made that the benefits go primarily to the wealthiest. (Solar customers also tend to have much longer calls with customer service representatives, which everyone is paying for.) The equity question can be more complex from a long-term perspective, however. For example, a lot of progress was achieved in the clean energy sector because of scale achieved by subsidies for wealthy people (e.g., in Germany), which helped drive down the cost of solar to the point that cheap solar lanterns are now being deployed in the least developed countries. (LED bulbs experienced a similar path, with subsidies helping the technology reach a market threshold and a price point that started nudging more of the market to adopt them.)

ENABLING TECHNOLOGIES TO SUPPORT A DISTRIBUTED ENERGY SYSTEM

The technologies exist to create and manage a distributed energy system. Any asset connected to the grid would have a sensing element (e.g., to sense voltage), a computing element (e.g., to determine whether the voltage is right), and a communications element (e.g., to send data on voltage somewhere). The promise of the “Internet of Things” is that devices can be put anywhere on the grid in an open system, and data can be gathered from various pieces of the grid. Data flows will enable grid evolution, and using data properly can lead to important changes and products that benefit consumers. However, such a system requires balancing the distribution grid line by line, which can be challenging when various parties in the system have an incentive to keep rather than share data about customers and assets. In

addition to being manageable, the system also has to be secure. It can be a challenge to create an electricity system that can serve as a platform for innovation and can meet a wide range of new customer demands. The technology is there, but there is a need to figure out the business model(s) to enable data to get where it needs to go to manage both the grid and customer expectations.

While some utilities are just dipping their toes in the water with regard to grid evolution and DER, others are at the forefront, making big changes. For instance, there are many different incentives on energy efficiency and demand response that are available. Some utilities are also investing in EV infrastructure (and exploring rate-basing those investments), while others are doing pilots on EVs responding to demand response

signals. Technologies growing in the marketplace (e.g., smart thermostats) can facilitate customer behavior on DR, widen the base of potential capacity that utilities can shift, and spur consumers to take further actions. Technology and two-way power flows and communications enable the matching of demand to the available supply; instead of ramping generation to match demand, the paradigm can be flipped.

Although several utilities are making moves on grid evolution, they have their hands bound. There is still substantial change that needs to occur, including regarding rate structures. Some states already have high penetration of smart meters and are starting to see interest in distributed generation, but they are trying to figure out how rate design and structures affect customers. A challenge is that not all DER attributes are properly valued. Storage, for instance, can be many different things to a utility and to a customer, but many of these components are not currently valued. Rate designs also currently tend not to value how demand response efforts can lead to utilities not needing to build new generation, and they often do not provide the signals needed to maximize demand response. There is a need for major reforms at PUCs regarding how utilities are compensated, how customers and buildings can monetize services provided to the grid, how utilities can actively participate in solutions, and how customers are incentivized to take action.

Technologies that would benefit from policy changes need to articulate a public policy purpose for use of those technologies.

One possible approach could be time-of-use (TOU) rates. Where TOU rates are in use, they work, and customers accept them. However, while around 40% of households have access to TOU rates, only about 4% take advantage of them (mostly in Arizona), possibly because customers have no idea what to expect. Technology that automatically shifts energy load (e.g., HVAC usage) in response to times of peak demand and costs can dramatically improve power load shifting.

Although many technologies exist to enable a distributed energy system, some stakeholders feel that they still need to be proven. There are also new technologies continually emerging. Demonstration projects can be very important for helping to inform the policy community and other stakeholders about technologies (and business models), as long as there are mechanisms built to take successful demonstrations to scale quickly – and avoid having to demonstrate the same technology over and over in every different regulatory environment. Still, all technology providers have examples of technologies that are totally proven, need no policy support, are financeable, make good business sense, and yet are not being deployed; there is a lot of inertia behind existing practices.

Technologies that would benefit from policy changes need to articulate a public policy purpose for use of those technologies. Some market failures are true social market failures, while others are just failures for particular products; it is not necessarily policymakers' job to help companies satisfy their customers. Some technologies also have countervailing policy implications, such as creating greater cybersecurity problems. In addition, public sector interventions sometimes generate costs, making it important to articulate what the public externalities are that some market inefficiency is causing that justify the tradeoffs involved in policy intervention.

SOCIAL COMPACT 2.0

The nearly century-old social compact of providing universal access to reliable, safe, and affordable electricity has largely been achieved in the United States. That compact has begun evolving to include additional attributes, such as clean and resilient electricity service.

AN EVOLVING SOCIAL COMPACT

The original social compact – what could be deemed “social compact 1.0” – is sacrosanct. While too often taken for granted, social compact 1.0 should be celebrated. “Social compact 2.0” is less of a succession than a continuing and growing evolution based on new tools and new challenges to solve.

The original social compact of universal, ubiquitous access to electricity that was reliable and affordable was advanced by a big thicket of policies, regulations, and monopolies designed to build a system to achieve it. Redirecting all of these elements towards a new social compact requires some clarity about the lodestar and the destination. This may

be as simple as adding sustainability and resilience to the original list of attributes, but other characteristics could be added as well. For example, in framing the next social compact, the health aspects could be highlighted more, making climate impacts and the impacts of energy decisions more relevant at personal, family, and community scales.

Different jurisdictions will have different views on which of the attributes of 1.0 or 2.0 trump all others. For instance, multiple states have been exploring the value of solar, and each state has valued the various dimensions and attributes differently. Regulators sometimes choose the path of radical incrementalism, judiciously moving toward clean energy goals while being very aware of potential blowback, concrete steps required, and protections needed for vulnerable people. State regulators can manage tradeoffs between 1.0 and 2.0, making the choices that are right for their states. On the other

hand, state-by-state decisions and the lack of a unified vision of what the goal point looks like may not be so great for something like climate change, which affects everyone; incremental state-by-state decisions will not get emission reductions to where they need to be fast enough.

In addition, the evolution of the social compact raises questions about equity and equal access. Will the new social compact include the same principles of affordability and universal access? As new technologies emerge, is there equal access to those technologies, or are the poor being left further and further behind? Many would argue that the core responsibilities of social compact 1.0 have to be preserved during the evolution to 2.0. To utilities commissioners, the vulnerable and middle class are ratepayers, not customers, and all players in the electricity space, whether incumbents or new insurgents, must have the same responsibilities of providing them with affordable, reliable, and safe

As new technologies emerge, is there equal access to those technologies, or are the poor being left further and further behind?

power. The telecom analogy is frequently used for the electricity sector, but as the telecom sector has changed, the number of 911 outages has increased; someone has to make sure that the basic, fundamental commodity works at all times. As the electricity industry ponders the evolution to social compact 2.0, improving the system cannot neglect the basic 1.0 obligations. (This assumes, though, that 1.0 is meeting the goal of providing the lowest-cost electricity to customers – which may not be the case in many states. Wholesale prices are trending down, but retail prices are trending up, and utilities are getting 11%-13% return on equity with little risk.)

Social compact 1.0 is already being stressed by new demands. For example, large consumers that want access to clean energy have started putting significant pressure on utilities. Major US brands have set very ambitious renewable energy targets – 60% of the Fortune 100 has some kind of greenhouse gas or renewable energy goal – and they are starting to make deals on their own, signing power purchase agreements (PPAs) for utility-scale clean energy. In 2012, there were 100 MW of such deals; in 2015, there were 3.2 gigawatts of corporate PPAs. The vast majority of these deals happened in deregulated markets, where such transactions can move much faster; only 9% occurred in regulated markets. Big IT companies, for example, are putting datacenters in deregulated markets where they can more easily access clean energy to power them. Big casinos in Nevada are paying millions of dollars or are otherwise trying to pull out of the NV Energy system so they can have access to clean energy. The original social compact was not just about affordable and ubiquitous energy; it was also about spurring economic development. Now, customers (especially big corporate customers) want differentiated offerings that have the attributes they desire, and their decisions have real economic consequences for the regions in which they operate. Some of the big companies are demanding clean energy for reasons tied to corporate social responsibility, but some are doing it because their energy demands and needs are changing, and the existing utility infrastructure is not keeping up.

The original social compact was not just about affordable and ubiquitous energy; it was also about spurring economic development.

These demands are only sort of new. To an extent, resilient and clean are already in 1.0 – especially after Superstorm Sandy and given a range of consumer and policy demands for clean – but exactly how varies utility by utility. It might be more accurate to characterize the status quo not as social compact 1.0 but rather as social compact 1.8, delivered by working partnerships between utility commissions (who are focused on the 1.0 criteria) and numerous state and federal statutes and implementing agencies that have long since established the proposition that while delivering the 1.0 elements, there is also a need to deliver to the same populations a variety of public health, environmental, and other protections.

It can be quite the balancing act for a utility to fulfill the evolving social compact of providing all customers with affordable, reliable, safe, clean, resilient power. Lots of policies that seem great in isolation can create conflicts in aggregate. In California, for instance, many customers are on a low-income rate and get a subsidy of about \$500 per year, while solar PV customers get about \$2500 from the rate structure. Many residential customers are not interested in having all the new gadgets; they just want power, low prices, and simplicity, and many still pay their bills at local offices and payment centers. Utilities have to meet the needs of all these customers. The evolving social compact is a grave burden that utilities bear every day.

There is an argument to be made that the focus of the energy community should be less on moving from 1.0 (or 1.8) to 2.0 in the United States and more on the benefits of bringing 1.0 to hundreds of millions of people around the world. On the other hand, doing so could be a death sentence for the planet if 1.0 leaves out clean; India ensuring ubiquitous access to affordable, safe, reliable electricity means an enormous amount of coal gets burned.

RESILIENCE

Resilience has been one of the key “new” attributes added to the social compact. Reliability is different than resilience. Reliability is about how often the grid is up and running, whereas resilience is about how quickly it can get back up and running in the face of unexpected disruption. Robust resilience would involve the ability to get back up and running in the face of disruption from a wide range of potential threats and attacks.

The threat environment to the utility grid has changed over the past few years. Concerns about grid outages are no longer just about storms knocking out power for two or three days (though storm outages are increasing), but also about the seven-fold increase in cyberattacks on utilities. Distributed renewable energy power sources can play a key role in addressing these challenges; a 19th century approach does not work anymore. Clean, distributed power does not have a supply chain; it is not possible to cut off the sun, the wind, or geothermal power. Renewable distributed generation that could boost resilience does not always pencil out economically, however, as resilience generally is not reflected in rate design.

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Customers, especially big ones, are very concerned about robust resilience. Various branches of the military, for example, have created offices focused on clean and resilient energy. In the military, missions are dependent not just on fuels for vehicles and planes but also on the continuity of electrons flowing to bases. A remote piloted aircraft (i.e., drone) mission, for instance, depends on communications with ground stations that are continents away, which are connected to server farms and data analytics somewhere else that process information in real time, which then relay information to a cockpit on the ground in yet another location. That entire chain is dependent on electrons.

Rather than rely solely on diesel generators on bases, robust resilience and energy security could be better achieved by using third parties to create microgrids within bases that have on-site storage and multiple sources of generation, including distributed renewables. The federal procurement process, however, has been a long-standing obstacle; the Department of Defense generally cannot pay more than the avoided cost of power, as opposed to evaluating options based on the levelized cost of secure energy

APPENDICES: AGENDA

SATURDAY, JULY 23

9:00 – 9:15 AM

Welcome and Forum Overview

David Monsma, ED, Energy and Environment Program, The Aspen Institute

Roger Ballentine, President, Green Strategies, Inc. (Co-Chair)

Andy Karsner, Managing Partner, Emerson Collective & Space Cowboy, Google X (Co-Chair)

9:15 – 10:30 AM

SESSION I: The Big Picture: Lessons Learned and the Future of Clean Energy

Putting aside the hype, and looking beyond the political rhetoric about climate and energy (pro and con), what is the state of clean energy? Are we truly in a time of radical transformation in the energy sector or does clean energy continue to face headwinds that will delay or even jeopardize its promise? Two leading clean energy executives will provide their take on the past, present and future.

Moderator: Andy Karsner

Discussants:

David Crane, Senior Operating Executive, Pegasus Capital Advisors

Michael Polsky, President and CEO, Invenergy

10:45 AM – Noon

SESSION II: Setting the Clean Energy Scene: The Data and the Dollars

What is the state of clean energy deployment today globally and in the US? How are renewables being integrated into the generation mix and to what extent are these resources adequately replacing fossil retirements? Are capital markets able and/or inclined to finance the clean energy transition?

Moderator: Roger Ballentine

Discussants:

The Global Uptake of Clean Energy

Peter Littlewood, Director,
Argonne National Laboratory

Capital Flows and Requirements

Ethan Zindler, Head of Americas,
Bloomberg New Energy Finance

The Wall Street View of Clean Energy

Michael Eckhart, Managing Director and Global Head,
Environmental Finance, Citigroup, Inc.

1:30 – 3:00 PM

SESSION III: Meeting the Pace of Paris

Putting aside the debate over whether the commitments of COP21 represent a radical reordering of our energy future or a formalizing of commitments to the types of changes already underway, meeting the science-based targets of de-carbonization underlying the accord will require a massive mobilization of technology and finance and fundamental changes in public policies. Of these three legs of the “clean energy triad”, technology develops at a non-linear pace where financial innovation has proven a major force behind clean energy deployment. Policy, however, proceeds (at best) at a linear pace. In this session we will explore how these three key elements can be optimized to meet or even exceed the pace of progress agreed to in Paris.

Moderator: Roger Ballentine

Discussants:

Overview of Paris Climate Agreement

Michelle Patron, Director of Sustainability Policy, Microsoft

Mission Innovation

Melanie Kenderdine, Director of the Office of Energy Policy and Systems Analysis and Energy Counselor to the Secretary of Energy, US DOE

Scaling Renewables

Michael Skelly, President, Clean Line Energy Partners LLC

US Policy Innovation

Joe Goffman, Associate Assistant Administrator for Climate and Senior Counsel, US EPA

3:15 – 4:45 PM

SESSION IV: Decarbonization by Design, Beyond Renewables

Under even the most aggressive policy scenarios, global fossil energy use will likely continue at levels that jeopardize climate stabilization goals. While doing all we can to scale renewable energy up, many believe that we need to be just as focused on non-renewable, climate friendly options, including the de-carbonization of inevitable global fossil energy use. In this session we will discuss the role of nuclear energy, the premise of “inevitable fossil,” and technologies and policies that can mitigate the climate impacts of the fossil energy that will remain in the global energy mix.

Moderator: Andy Karsner

Discussants:

Technology and Business Model Options

Bill Brown, CEO, NET Power

The Nuclear Option

Ron Kirk, Co-Chair, CASEnergy Coalition

Public Policy Priorities and Business Realities

Kyle Simpson, Senior Advisor, Hogan and Lovells US, LLC

Can Climate Advocates Provide Support?

Glenn Prickett, Chief External Affairs Officer, The Nature Conservancy

SUNDAY, JULY 24

9:00 – 10:30 AM

SESSION V: Life on the Grid Edge: Systems, Services and Storage

Major changes to the centralized generation mix are largely a product of top-down policy impacts and structural impacts of commodity markets. The disruption that is happening at the “grid-edge”, on the other hand, is mostly a result of technology innovation and changing customer expectations. In some places, grid-edge innovation and distributed grid assets are being encouraged by changing regulatory approaches (e.g., New York); in other markets, existing regulation and market design may be holding back these innovations. What are customers looking for? Do we have the technologies to make the grid edge the platform for innovation? What are the potential systemic benefits? What business models are needed?

Moderator: Bryan Hannegan, Associate Laboratory Director for Energy Systems Integration, NREL

Discussants:

The Need for Resiliency/Manageability

Miranda Ballentine, Assistant Secretary of the Air Force for Installations, Environment, and Energy, US Air Force

Beyond Green Buildings

Paul Camuti, Senior Vice President, Innovation and CTO, Ingersoll Rand

The Reality of the IOT

Geoff Sharples, Director, IoT Strategy, Intel

Technology, Data and Customer Engagement

Brian Farhi, Head of Distributed Energy Resources and New Channel Partnerships, Nest Labs

10:45 AM –
12:15 PM

SESSION VI: Social Compact 2.0?: Rethinking the Promise of the US Electricity Marketplace

The nearly century-old “social compact” of providing universal access to reliable and affordable electricity has largely been achieved in the US. However, changing consumer expectations, dramatic advances in technology, and growing environmental imperatives suggest that perhaps this fundamental underpinning of the electricity sector needs to be expanded to ensure that all Americans have equal access to a full suite of energy options and technologies while guaranteeing clean air and a stable climate. Are the first generation and second generation of “promises” in conflict? Where along the axis of regulated vs. competitive markets and centralized vs. distributed assets does the balance lie?

Moderators: Roger Ballentine and **Andy Karsner**

Discussants:

Do Current Market Rules Hold Us Back?

Michael Terrell, Head of Energy Policy, Google

The Role of Non-Utility Suppliers

Kevin Sagara, President, Renewables, Sempra

A Regulator’s View

Joshua Epel, Chairman, Colorado PUC

Is the Market Maximizing Solar?

Paul Kaleta, EVP and General Counsel, First Solar

MONDAY, JULY 25

8:30 – 11:00 AM

VII: Wrap Up

Building upon discussions in the preceding sessions and looking forward strategically, what are the ongoing obstacles to the proliferation of energy innovation and market uptake? What are the priority needs that this group can identify or help clarify as the transition to a clean energy future continues? Where should this discussion go next to add value?

Moderators: Roger Ballentine and Andy Karsner

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