U.S. and EU Visions for a Twenty-First Century Power Sector

Across Europe and the United States, the electric power sector is undergoing a fairly profound transformation driven by a changing fuel mix, higher penetration of renewable energy resources, changing consumer preferences and interface with the electric power system, and evolving business models. Policy and regulatory frameworks need to be updated to reflect these changes and facilitate future transformation. In both places this transformation is uneven, with some localities moving along faster than others, and complex, driven by a variety of factors. While the transformation is multidimensional, two conversations relating to the long-term vision for the sector are central to navigating a path forward. First, what are the challenges and opportunities associated with higher penetration of renewable energy and distributed energy resources? Second, what are the opportunities and challenges associated with the electrification strategies, particularly for measures to electrify transport and industry? In addition, the increased digitalization of the energy sector writ large, and specifically the electric power sector, raises issues about access to data, cybersecurity, and grid resilience, all areas that have become an integral part of the conversation in the European Union and the United States on the transformation of the electric power sector.

The following brief outlines some of the issues related to these topics that were discussed at a recent U.S./EU stakeholder workshop held at the Center for Strategic and International Studies in June 2019. The information and reflections here do not necessarily represent the views of the participants and are meant to serve as useful background to stimulate further discussion.
The European Union and the United States launched a dialogue on wholesale power markets in 2016 that continues to date. The 10-year anniversary of the U.S.-EU Energy Council—the primary forum for transatlantic energy cooperation established in 2009—presents an important milestone and an opportunity to reflect on the future direction of the U.S.-EU energy partnership. The European Union and the United States share similar challenges associated with the transformation of the electric power sector. While approaches may differ in each region for a variety of reasons, several areas of common interest can serve as grounds for future transatlantic cooperation on these important issues.

**High Renewables Penetration, Distributed Energy Resources, and Electrification**

The penetration of renewable energy sources has increased in recent years, with several countries and states approaching levels where, because of the intermittent nature of renewable energy, consideration must be given to adding more flexibility to the electric power system to accommodate them. The International Energy Agency (IEA) characterized this challenge in the recent report *World Energy Outlook 2018*. In the Sustainable Development Scenario, which models a future in which the world holds a global temperature rise below 2 degrees Celsius and delivers universal energy access, renewable energy makes up 66 percent of electricity generation by 2040.\(^1\) The outlook points out that increased penetration of variable renewable energy requires increased flexibility in the energy system, which comes from four main sources: flexible power generation, flexible demand, energy storage, and smart, interconnected grid infrastructure. As the need for flexibility increases, grid operators need to utilize each of these categories through resources such as residential demand response, long-term storage technologies, or synthetic fuels for zero-carbon, dispatchable power generation. In some cases, this will require regulatory and market changes such as acquiring better resource data, facilitating better electricity trading, or redesigning wholesale markets. Even without the world reaching the targets of the Sustainable Development Scenario, the IEA points out that many countries and sub-regions of countries are reaching very high levels of renewables penetration and are starting to implement a combination of these strategies.

It is in thinking about how to balance new resources in a rapidly evolving system that the issue of electrification often comes up. The electrification of end-use sectors like transportation and buildings is a major topic of discussion in the energy sector and has several drivers. Climate change policy proponents see the electrification of end-use sectors as a strategy to drive decarbonization, as shifting from carbon-intensive feedstocks like metallurgical coal, oil, or natural gas to electricity has the potential to drive deep cuts in greenhouse gas emissions if the electricity comes from low-carbon sources. The utility industries in the United States and European Union also see electrification as a potential strategy to counteract the trend of stagnant or declining demand for electricity. Finally, as mentioned above, electrification of the transportation sector in particular is often seen as another large source of distributed energy resources that could, under the right conditions, provide system flexibility.

**UNITED STATES**

The United States does not have a unified vision of its electric power sector. Instead, the United States is a mix of regulated and deregulated markets organized across states with different policy approaches and fuel mixes. U.S. states take the lead on a great and varied amount of policy experimentation to advance these objectives in the electric power system, whether through the share of renewable energy, the management of distributed energy resources, or the pursuit of electrification.

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Renewable Penetration and Distributed Energy Resources

The share of renewable energy has grown in the United States electric power sector on a national basis. According to the U.S. Energy Information Administration (EIA), the share of renewable energy in the electric power sector grew from 9 percent in 2008 to 17 percent in 2018. The range of renewable power generation penetration differs a great deal by state. As shown in Figure 1, Vermont has the highest overall share of renewable energy in its generation mix at 99.7 percent as of 2018, compared to 2.2 percent for Delaware at the low end of the range.

States also vary in their goals for renewable energy’s share of power generation. Approximately 39 states have renewable or alternative portfolio standards which mandate a certain share of renewable or alternative power generation in the mix. A small but growing number of states are going even further, requiring 100 percent clean or renewable electricity by 2050. Eight states plus Puerto Rico and Washington, D.C. have committed to 100 percent clean or renewable energy by a particular year, ranging from 2032 in D.C. to 2050 in Nevada. In addition, the governors of Minnesota and Wisconsin have pledged their support for reaching 100 percent clean or renewable energy in their states, but their goals have not yet been institutionalized in law or executive orders. Five major utilities have committed to 100 percent clean energy as well: Vermont’s Green Mountain Power is targeting 2025; Public Service Company of New Mexico is targeting 2040 (five years earlier than the state as a whole); northwestern utilities Avista and Idaho Power are targeting 2045; and Midwestern utility Xcel Energy is targeting 2050.

Penetration of distributed energy resources varies even more. As shown in Figure 2, small-scale solar photovoltaic capacity ranged from 8,273 megawatts in California to about 0.4 megawatts in North Dakota as of April 2019.

As the penetration of renewables increases, grid operators must introduce significantly more flexibility into the system to deal with the variability of wind and solar power. Some renewable resources, like hydropower or geothermal energy, do not present the same variability issues, but together they only contribute less than 10 percent of U.S. power generation, and there is little appetite for new development of these resources in the United States. Therefore, a grid with high penetration of renewable energy will mostly rely on wind and solar generation, likely backed up by batteries and natural gas. As was noted in New Energy Outlook 2019 by BloombergNEF, this can present as of yet unresolved challenges for power generation resources that provide peaking or balancing power on a seasonal basis.

There is an ongoing debate in the United States about how these state energy policies, along with other factors, are changing electricity markets. States are increasingly passing laws to sponsor particular

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4. The term “clean energy” has been adopted in these policies to expand the definition of what is acceptable beyond that of just renewables.
6. Fields, “100 percent renewable targets.”
Figure 1: Renewable Energy Share of Electricity Generation by U.S. State, 2018

Source: “Net generation for all sectors,” EIA.
Figure 2: Distributed Solar Capacity by U.S. State, April 2019 (Megawatts)

* Not meaningful due to large relative standard error.

Source: "Electric Power Monthly: Table 6.2.B. Net Summer Capacity Using Primarily Renewable Energy Sources and by State, April 2019 and 2018 (Megawatts)," EIA.
resources that they value, such as renewable portfolio standards or subsidies to nuclear generators. In areas where Independent System Operators run wholesale power markets, grid operators are concerned that these state policies are interfering with the efficient and proper operation of their markets by driving down bid prices for sponsored resources. This has sparked a contentious conversation among states and allied advocacy groups that want to protect their ability to pass laws that work toward policy goals, ISOs that want to counteract the effect of these laws on wholesale power markets, and the Federal Energy Regulatory Commission (FERC), which has a statutory mandate to ensure ISO policies are just and reasonable.

Despite the lack of unified vision for the future of the U.S. power sector, several groups have investigated the ability to achieve deep decarbonization in the electricity sector. Analysis by the National Renewable Energy Laboratory (NREL) in 2012 found that the renewable energy generation sources available today can achieve an 80 percent share of power generation in 2050 while meeting demand on an hourly basis. The report states this would reduce greenhouse gas (GHG) emissions by 80 percent and reduce water use by 50 percent. The report also notes that the flexibility in the system could be met through a combination of dispatchable resources, demand response, energy storage, transmission infrastructure, and new operational practices. The authors estimate that the impact on retail electricity prices is comparable to other U.S. government estimates at the time, which found an increase to $41-$53/Megawatt-hour by 2050 but notes that this will be affected by cost declines in renewable energy technologies.

A 2017 review of “deep decarbonization scenarios” for the United States by power sector researchers found that scenarios with a high penetration of renewables require either a backup system of dispatchable resources or long-duration, seasonal storage. The only long-duration, seasonal storage technology currently proven viable at scale is pumped hydro storage. There are approximately 22 gigawatts (GW) of pumped hydro storage in the United States. In 2016, the U.S. Department of Energy (DoE) estimated that 36 GW of pumped storage capacity could be added through 2050, and the department has taken steps to speed up pumped storage development. For shorter durations—usually between four and eight hours—lithium-ion batteries are a quickly growing solution for storing electricity. NREL’s Standard Scenarios for the future of the power sector model a range of 8-hour battery deployment estimates based on inputs such as battery costs, natural gas prices, and policies encouraging renewable energy deployment.

In addition to a bigger role for increased storage, these deep decarbonization scenarios rely heavily on a build out of flexible generation capacity and transmission and distribution infrastructure which can be both costly and politically/socially difficult to implement.

**Electrification**

The United States does not have an official electrification strategy. DoE is, however, studying possible futures in different electrification scenarios. The first report of the two-year study, titled *End-Use Electric Technology Cost and Performance Projections through 2050*, analyzes scenarios that vary in the speed and extent of consumer adoption of electricity-consuming technologies in the transport, buildings, and

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industrial sectors to model the end-use stock transformation and service demand in each sector, along with the profile of electricity consumption for each scenario.\footnote{Paige Jadun et al., \textit{Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050} (Golden, CO: National Renewable Energy Laboratory, 2017), https://www.nrel.gov/docs/fy18osti/70485.pdf.} The report predicts that if technology advancements, policy support, and consumer enthusiasm are high, electricity demand could grow 1.5-1.8 percent per year from 2016 to 2050, compared to 0.65 percent in the reference scenario. Most of this demand growth would be driven by electrification of the transport sector, especially of long-haul medium- and heavy-duty trucks.

Individual states are pursuing electrification strategies. Most progress has been made on EV deployment through the implementation of zero-emissions vehicle policies and buildout of EV charging infrastructure. California has been the most successful so far, with battery electric and plug-in hybrid vehicles taking a 4.3 percent market share in the state from 2013 to 2018.\footnote{“Advanced Technology Vehicle Sales Dashboard,” Alliance of Automobile Manufacturers, March 12, 2019, https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/.} California has many policy and regulatory constructs to incentivize EV uptake, including purchasing incentives, a low-carbon fuel standard, charging infrastructure buildout incentives, and EV manufacturing incentives. The International Council on Clean Transportation has found some correlation between these actions and EV uptake—especially consumer incentives—although there are many factors that determine EV uptake.\footnote{Pete Slowik and Nic Lutsey, \textit{The surge of electric vehicles in United States cities} (Washington, DC: International Council on Clean Transportation, 2019), https://theicct.org/publications/surge-EVs-US-cities-2019.}

Less progress has been made advancing zero emissions technology in fleet transport and non-road transport like aviation, maritime, and rail. Even less attention has thus far been paid to electrification in other end-use sectors such as industry or buildings. Some industry groups have begun assessing the potential effects of building electrification, but estimates are heavily based on technology assumptions and the carbon intensity of the grid, and thus there is considerable disagreement over benefits and costs.\footnote{Justin Gerdes, “What Will Building Electrification Mean for Consumers and the Climate?” Greentech Media, August 6, 2018, https://www.greentechmedia.com/articles/read/what-will-building-electrification-mean-for-consumers-and-the-climate.} It is important to note that the electric power sector also faces a fundamental question of how electrification interacts with environmental and consumer affordability goals. While many utilities see electrification as a potential way to combat declining electricity consumption, there is increasing recognition that cost-effective electrification must be coupled with energy efficiency policies, especially in the buildings and heating sector.

**EUROPEAN UNION**

Compared to the United States, Europe has a developed vision for its electric power sector housed within its broader strategic plans to advance an energy union that provides secure, sustainable, competitive, and affordable energy to all Europeans and the region’s effort to address global climate change. Europe’s political commitment to decarbonize the economy and to implement the Paris Climate Agreement is the main driver of the changes in the energy sector. In 2018, the European Commission released \textit{A Clean Planet for All}, a document that identifies scenarios for achieving a climate-neutral European economy by 2050.\footnote{European Commission, \textit{A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy} (Brussels: European Commission, 2018), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773.} The strategic priorities include: achieving net-zero GHG emissions from the energy sector; decarbonizing transport through alternative and automated vehicles; reducing energy consumption by 50 percent from 2005 to 2050; achieving net-zero GHG emissions from the industrial sector and emphasizing circular economy principles; developing smart infrastructure; creating natural carbon sinks through agricultural practices; and deploying carbon capture and storage and negative emissions technologies.
In 2018 and 2019, the European Union began implementing the Clean Energy for all Europeans package that consists of eight legislative acts, including changes to the electricity market to better facilitate integration of intermittent renewable energy sources, cross-border cooperation, continue to orient electricity system regulations toward market competition, and grant customers greater choice in the market. The Clean Energy Package sets a legal framework to facilitate the achievement of 2030 energy and climate targets. The package includes updates to the Electricity Directive and Electricity Regulation designed to phase out capacity market payments to power plants emitting more than 550 grams of CO2 per kilowatt-hour (effectively removing coal plants without carbon capture technology from the capacity market) and require nations to ensure that capacity markets are used as a measure of last resort and that national laws do not hamper the cross-border flow of electricity. The updates also guarantee consumers new rights designed to increase consumer choice, including limits on the time it takes to switch suppliers, the right to request a smart meter and a dynamic pricing structure, and the right to free access to at least one tool to compare retail electricity providers. The Clean Energy for all Europeans package also grants new powers to the Agency for the Cooperation of Energy Regulators (ACER) to facilitate a more integrated electricity market, creating Regional Coordination Centers for dispute resolution among Transmission System Operators and transferring power over regional energy regulations from individual national regulators to ACER.

Renewable Penetration and Distributed Energy Resources

As part of its overarching goals to reach deep decarbonization, the European Union sets renewable energy targets as a share of total energy consumption. In 2009, the European Union mandated that 20 percent of gross final energy consumption should come from renewable energy by 2020. The member states are assigned targets and have developed national action plans to meet these goals. Sweden has the highest target, at 49 percent, and Malta has the lowest, at 10 percent. In 2017, the share of renewables in gross final energy consumption across the European Union reached 17.5 percent, and 11 member states reached or exceeded their individual targets. Sweden had the highest share of renewables at 54.5 percent and Luxembourg had the lowest at 6.4 percent. In December 2018, the European Union set a 2030 goal of 32 percent.

In the electric power sector, approximately 31 percent of the European Union’s electricity comes from renewable energy, up from 16 percent just a decade ago. The range includes: countries at the lower end of the spectrum with around 8 percent of renewables in the electric power mix, like Cyprus, Hungary, Luxembourg, and Malta; countries at the higher end of the spectrum, with large shares of hydropower or wind power in their renewable electricity mix, including Austria, Denmark, and Sweden at 60-80 percent renewables; and a wide variety of nation states in between (see Figure 3 below for the full range). Policies and market mechanisms have played an important role in increasing the role of renewable energy in Europe’s electric power mix, with each country taking a different approach and starting from a different base in their historical electric power mix.

According to a recent International Renewable Energy Agency (IRENA) and EU study, the European Union could cost-effectively double the share of renewables in their energy mix from 17 percent in 2015 to 34 percent by 2030. Under the reference case scenario in this study, renewables (including hydropower, biomass, and geothermal) are expected to account for 41 percent of total generation, with variable renewable energy (only solar and wind) accounting for 21 percent of total generation (see Figures 4 and 5 below). A more aggressive wind and solar deployment envisions the renewable share of electricity reaching 50 percent of total electricity generation by 2030, with variable renewable energy at 29 percent. This would include a build out in total installed renewable power generation capacity from 266 GW in 2010 to 608 GW in the reference case and 814 GW in the more aggressive case.

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As discussed earlier, such high shares of variable renewable energy penetration could pose challenges for EU grid operations. The adopted Clean Energy for all Europeans package seeks to address these through better organized wholesale markets (large cross-border electricity trading areas and more intra-day trading), demand response, flexibility at the retail market level, smart grids, energy storage, and the optimization of interconnections.
Electrification

Electrification is at the core of the EU strategy to decarbonize its economy, and yet electrification has been slow in the European Union. The share of electricity in final energy consumption in the European Union has only increased from 21.7 percent in 2006 to 22.7 percent in 2017.23 The share of electricity in final energy consumption is highest in Malta, at 40.5 percent, and is lowest in Latvia, at 14.4 percent. Transport has the lowest level of electricity penetration at just 1.5 percent, and most of this electricity was used for train travel.24 While electric vehicles still account for a small share of new vehicle sales overall (1.2 percent in 2015), some countries have experienced rates in the 90 percent range. As is true in other regions of the world, governments and car manufacturers have been supporting this transformation by announcing plans to support EV charging infrastructure, purchasing incentives, and expanded consumer offerings. According to the IRENA/EU analysis, up to 60 percent of light duty vehicle sales could be fully electric by 2030.25

The European Union does not foresee a full electrification of all economic sectors, although electrification will increase in Europe as electricity will help to decarbonize the transport and industrial sectors. According to EU analysis, a decarbonization strategy that relies on full electrification of the economy comes with a number of challenges for the energy system, including the need for large amounts of additional flexible capacity in the electricity system, extensions and reinforcement of the transmission and distribution system, and high cost related to reaching certain “hard to electrify” portions of the economy. A strategy of energy system integration and “sector coupling” (deeper integration between end-use and supply sectors) provides potential advantages. Again, according to EU analysis:

“The combination of end-use sector coupling, and cross-vector integration increases the flexibility of the energy system and can help to optimise the use of renewable energy when it is abundantly available. For example, when electricity is cheap and abundant, it can be converted into gas (hydrogen or synthetic methane) and stored and/or transported via the gas infrastructure for immediate or later end-use. It can also be converted back into electricity during periods of insufficient renewable electricity supply (and hence high electricity prices), by using the so-called power-to-gas-to-power (PtGtP) route. In addition, power-to-heat options combined with heat storage can shift heat production to moments with abundant and cheap electricity supply, while ‘cheap’ electricity can also be converted to a liquid fuel (e.g., methanol) for use in the industry.”26

The European Union also helps to advance its electrification agenda through its “energy efficiency first” policy principle and a goal to become one-third more energy efficient by 2030. In particular, its focus on the buildings sector, responsible for 40 percent of energy consumption and 36 percent of greenhouse gas emissions, should make an important contribution to keeping the costs of energy sector decarbonization more manageable, improving energy security and benefiting consumers.

Clean Energy Revolution, Digitalization, and Cybersecurity of the Energy Sector

With the increasing digitalization of the power sector, the United States and the European Union have both committed to understanding and addressing the cybersecurity issues facing their respective grids. As grid technology shifts more from analog to digital and as data migrates to the cloud, the number of entryways into

25. Ibid.
the system and the potential for intrusion by hostile actors grows. Both the United States and the European Union have undertaken new efforts in recent years to address the regulation of grid infrastructure, grid operations, and electricity markets to better prevent, detect, and respond to potential cybersecurity incidents. In addition, the concept of system resilience has become politically salient in the United States and Europe for a variety of reasons. As the electric power systems change and become more complex, interconnections and vulnerabilities change, which necessitates a dynamic approach to thinking about grid resilience. Most electric power service resilience issues are associated with transmission and distribution infrastructure, but as we see more retirement of coal and nuclear power generation in both the United States and Europe, some in the U.S. government and the utility industry have raised concerns about fuel security within the power system as well.

UNITED STATES
In the United States, the current administration has been quite active regarding the resilience and national security of the electric power sector. DoE established the Office of Cybersecurity, Energy Security, and Emergency Response in 2018 to centralize cybersecurity, grid resilience, and emergency response efforts at the department. It also released the *Multiyear Plan for Energy Sector Cybersecurity*. The plan lays out three overarching goals: (1) strengthen preparedness for cybersecurity events through reporting requirements, risk management tools, and addressing supply chain vulnerabilities; (2) coordinate response and recovery capabilities at a national level through federal programs, training, and exercises; and (3) develop new technologies to strengthen the resilience of the grid to cybersecurity incidents through incident detection and hardening system defenses.

In 2018, FERC issued Order 848, which directed the North American Electric Reliability Corporation to require regional coordinating councils to report cybersecurity incidents on their grids. In 2019, FERC approved the new standards, which mandated that all cybersecurity incidents must be reported, even if they do not threaten the reliability of the grid.

In June 2019, FERC Chairman Neil Chatterjee proposed the idea of a task force with the National Association of Regulatory Utility Commissioners to solicit states’ concerns about grid resilience and fuel security. This task force could potentially give states a new line of communication with FERC to discuss the interaction between state policies and regional electricity markets.

EUROPEAN UNION
The EU cybersecurity regime is overseen by the EU Agency for Network and Information Security (ENISA). The agency, established in 2004, focuses on cybersecurity events that cross-national borders and involve multiple member states. ENISA provides recommendations on cybersecurity, supports implementation of cybersecurity policy across the European Union, oversees collaborative efforts, and manages cybersecurity certification of products, processes, and services.

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As part of the *Clean Energy for all Europeans* package, the European Union issued regulation on risk preparedness, which requires member states to craft plans for security incidents in their electricity sectors, envisioning them not only in their respective national contexts but also in regional contexts. The regulation requires member states to consider potential future scenarios and coordinate with neighboring nations to address potential cross-border effects of security events. The recast of the Electricity Regulation gives a mandate to the Commission to develop a network code on cybersecurity for the electricity sector to increase resilience and protect the grid. A dedicated expert group has been working since 2017 to prepare the ground for the network code.

In early 2019, the European Commission issued a recommendation that energy network operators should work to increase the cybersecurity of the grid by using the latest technology, when building new infrastructure, trying to upgrade older systems with new security technology, adhering to international standards, and “establish[ing] design criteria and an architecture for a resilient grid.” Member states would be required to report to the European Commission on implementation within 12 months and then every two years.

Industry representatives at the workshop (operating in both countries) recognize that the challenge for utilities over the coming decades is to decarbonize, decentralize, and digitalize. Doing so will reduce costs, increase resilience, and improve sustainability. Connectivity within the system enables all of this to take place, and limiting connectivity is no longer an option. This means that utilities must instead manage the risks and challenges that come with greater connectivity. For instance, a major issue and difference between the European Union and the United States is over access to and ownership of data. In the European Union, the customer owns their data, and recent energy regulations give them more control over that data. In the United States, the utilities own the customer’s data. Certain participants noted that ownership of the data was not a problem for utilities, but access to the data is paramount. Greater consideration needs to be given to data integrity, data value, data ownership, and issues of liability. Several speakers noted that protection of data generated by the sector is one issue, but management of it is another, and there are many different approaches. The principle, however, should be to protect the data and allow access on a non-discriminatory basis.

**Opportunities for Collaboration**

Despite the differences in approach, the United States and Europe are dealing with many of the same issues about the future of their respective electric power sectors. In Europe, there is a clear strategy in which the electric power sector is integrated into a framework for deep decarbonization and an interconnected, secure, and efficient internal energy market. Individual countries each contribute plans to organize towards those objectives, but each comes from a very different background and historical energy mix, which makes their experiences unique. In the United States, there is no such unified vision, but instead the priorities of the states are expressed through regionally interconnected markets and occasionally shifting federal policies. And yet the combination of new market realities brought on by changing policies, the declining cost of renewable energy and distributed energy resources, a changing resource base, and the spreading digital overlay to the electric power sector right down to the

household level means that all participants in the electric power sector are experiencing some degree of transformation. The United States and European Union have a great deal that they could collaborate on in the context of navigating this transition. The informal recommendations from the discussion are not fully-fledged proposals but ideas worth considering for further exploration.

SECTOR COUPLING
Given the important role that sector coupling will play in advanced, decarbonized energy systems, there is a great deal of work the United States and the European Union could do to explore the technical, policy, and regulatory barriers to advancing this objective. These include efforts toward better planning of infrastructure build out and operation of various parts of the energy system, reforms to current energy market design, and looking at the connections between gas, electric, and heating networks. The United States and the European Union can expand upon the recently announced EU-U.S.-Japan trilateral cooperation on hydrogen.35

COLLABORATION IN SCIENCE AND TECHNOLOGY
Both the United States and the European Union are world leaders in innovation and invest substantially in driving down the cost and improving the performance of clean and advanced energy technologies, including the types that will transform the future of the electric power sector. To the extent possible, ongoing collaboration on this front should continue, as should efforts to find additional ways of bolstering this collaboration through increased domestic programs as well as transatlantic and multilateral partnerships. An example of this collaboration is the operation of the EV-Smart Grid Interoperability Centers in Europe and the United States, run by Argonne National Laboratory and the European Commission’s Joint Research Centre.36

INNOVATIVE REGULATORY APPROACHES
Workshop participants pointed out that there is an opportunity to encourage innovation in regulation, not just technology. Participants raised the point that regulators often face pressure to avoid controversial or potentially unsuccessful ideas for fear of losing their next election (if they are directly elected) or being removed from their posts (if they are appointed). If new ideas in regulation are needed to manage the energy transition and build the “grid of the future,” regulators should be given more space to innovate. This could include joint exercises (the so-called sandbox approach) where a policy and regulatory framework is designed, and participants are allowed to test the business models where the only agreed-upon outcome is to share the findings.

GRID OPERATIONS
Participants from the European Union pointed out that as the Clean Energy for all Europeans package is implemented, seeking to better manage regional operation of power grids, the European Union is looking at the Independent System Operators and Regional Transmission Organizations in the United States as an example of successful, cross-border grid operations. This could be an additional area of ongoing exchange.

RESILIENCE METRICS
The topic of resilience is often raised in discussions of the electric power sector, both because there is concern about the resilience of physical infrastructure to threats such as extreme weather, supply shortages, or attacks and because some believe markets are not adequately valuing resilience in the system. U.S. and

EU participants agreed that resilience was difficult to define, and a proposal was raised to consider a variety of elements instead of one single resilience metric. In the United States, the Grid Modernization Laboratory Consortium is developing a set of resilience metrics. U.S. researchers and regulators could partner with their counterparts in the European Union to help identify a common matrix of indicators for resilience. This was a controversial proposal, however, with some participants suggesting that no set of metrics could truly capture the complexity of grid operations and potential risk factors, and therefore any attempt to define and use a list of metrics must be supplemented with a better appreciation among policymakers for the complex nature of grid management, particularly as the systems become more complex.

**CYBERSECURITY REPORTING REQUIREMENTS AND COMPREHENSIVE RISK ASSESSMENT**

Another opportunity for U.S.-EU collaboration is in the reporting of cybersecurity incidents. In the United States, the new standards approved by FERC require reporting of all cybersecurity events on the grid, even if they did not threaten reliability. In the European Union, however, regulations only require member states to report incidents to ACER if they have “significant impact.” Regulators at FERC and ACER could convene to discuss how to bolster the EU reporting requirements to prevent cybersecurity attacks from escalating from events with non-significant impact to those with significant impact. U.S. regulators can also learn from the European Union on designing comprehensive risk assessment regulations. Another area for exploration could be investigating how new supply chain risk management standards approved by FERC could be applied to the European context. There may also be opportunities for EU cybersecurity regulators to work with DoE’s new Office of Cybersecurity, Energy Security, and Emergency Response.

**WORKFORCE DEVELOPMENT**

As the electricity workforce needs and skillsets change, there is ample room for collaboration on workforce development and training and developing common approaches to understanding how to prepare workers for an increasingly digitized industry. Some participants noted that this was not only a potential benefit to U.S. and EU workforces but also a potential area to assist third countries in building the capacity of their own workforces.

**INFORMATION SHARING**

Finally, the United States and European Union can collaborate on information sharing. As new technology emerges to help measure and monitor the electricity system, utilities and governments are gaining better and more granular information about supply, demand, and interruptions to both. Utilities can identify the causes of grid incidents more quickly and more thoroughly. Governments also have tremendous ability to identify potential threats from hostile powers. However, as some workshop participants highlighted, many governments are wary of sharing this information across borders because of concerns about privacy or information falling into the wrong hands. This is an opportunity for U.S. and EU regulators, especially those at the member state-level in the European Union, to coordinate legal or regulatory structures that would allow governments to share threat intelligence without concern that it would be used for nefarious purposes.

**Conclusions**

The power sectors in the United States and European Union are undergoing significant change, seeing an increasing penetration of distributed generation, showing a long-term trend toward decarbonization, and shifting from analog to digital infrastructure and data management. The increasing penetration of decentralized power generation, coupled with gigawatts of annual additions of renewable energy capacity,
can help the United States and the European Union become more flexible and work to meet climate goals. At the same time, these trends pose challenges to grid operators who face new challenges in maintaining grid stability and reliability amid a shifting generation profile. The European Union has laid out a comprehensive roadmap in the Clean Energy for all Europeans package, overhauling its regulations and markets to better facilitate the integration of renewable energy, flexibility of the power system, and electricity trading across national borders. The U.S. federal government does not currently have a comprehensive strategy for the “grid of the future,” but several states have charted the future of the systems in their borders with aggressive policy portfolios, and federal researchers have undertaken several studies on what the future of the power sector may resemble.

As the electric power system changes, regulators and policymakers must overhaul policies and regulations to fit the new system and drive future transformation. A potential area of exploration for U.S. and EU officials would be to explore how to allow for more innovation in the regulatory state, not just in technology. Both governments also have to deal with regional operation of power markets, an issue that U.S. and EU officials have already begun to tackle, with regional grid operators in the United States providing insight to EU officials seeking better interconnection of member states markets.

While the digitalization of the electric power system offers new possibilities in grid management and data sharing, it also creates new cybersecurity risks. There are notable differences between U.S. and EU market structures and grid infrastructure. However, there are clear opportunities for the two governments to collaborate on power sector issues such as identifying best practices on incident reporting, developing a mutually agreed-upon matrix of resilience metrics, and data sharing. Sharing expertise and experiences can help to build shared prosperity and security for the United States, the European Union, and EU member states.

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