



## Policy Paper

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**G | M | F** The German Marshall Fund  
of the United States  
STRENGTHENING TRANSATLANTIC COOPERATION

# TRANSATLANTIC POLICY CHALLENGES OF THE DIGITAL ENERGY NEXUS

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## About GMF

The German Marshall Fund of the United States (GMF) strengthens transatlantic cooperation on regional, national, and global challenges and opportunities in the spirit of the Marshall Plan. GMF contributes research and analysis and convenes leaders on transatlantic issues relevant to policymakers. GMF offers rising leaders opportunities to develop their skills and networks through transatlantic exchange, and supports civil society in the Balkans and Black Sea regions by fostering democratic initiatives, rule of law, and regional cooperation. Founded in 1972 as a non-partisan, non-profit organization through a gift from Germany as a permanent memorial to Marshall Plan assistance, GMF maintains a strong presence on both sides of the Atlantic. In addition to its headquarters in Washington, DC, GMF has offices in Berlin, Paris, Brussels, Belgrade, Ankara, Bucharest, and Warsaw. GMF also has smaller representations in Bratislava, Turin, and Stockholm.

## About This Report

The German Marshall Fund, whose mission is to strengthen transatlantic cooperation, has long been interested in the energy sector, in large part as Europe's reliance on imported oil and gas from Russia and the Middle East raises significant geopolitical concerns for the United States as well as Europe.

In that sense, GMF has a deep interest in Europe's move to promote renewable energy. The European Union emphasizes this shift mainly to reduce greenhouse gas emissions and address the climate change challenge we all face, but the shift has significant geopolitical implications as well.

A confluence of trends — including the digital revolution — has raised new and different opportunities, challenges, and questions in the energy sector in both Europe and the United States. Knowing that how the two sides of the Atlantic address these new challenges will have geopolitical implications, GMF issued its first report on the digital transformation of the energy sector in 2014: "Creative Destruction in the Energy Sector: From Disruption to Transformation" is a series of four essays examining the power of digitalization to dramatically change this core geo-strategic sector of our economies and societies.

Like all things in the digital world, the transformation we discussed then has only picked up speed since. We accordingly decided to look again more closely into how Europe's energy sector is adapting to this digitalization challenge, the policy issues that challenge raises, and how Europe's responses to those issues could affect its ability to bolster its strategic energy independence.

In partnership with Centrica and the European Investment Bank, we hosted five workshops in Brussels, bringing together a wide range of EU policymakers, European and American business representatives from all parts of the energy and information technology sectors, academic experts, and various civil society organizations focused on environmental, consumer, and data protection issues to identify and delve deeply into some of these issues. This report reflects both the many ideas that surfaced and were debated during those workshops as well as research conducted in parallel.

We want to thank Centrica and the European Investment Bank for the support that made this work possible and all participants for their interest, engagement, and willingness to share their thoughts and ideas with us. Any errors in the report are, of course, our own.

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2018 | No.28

Executive Summary.....	1
Digital Energy Sector Transformation.....	7
Electrification and Transformation.....	8
The Scope of Change in the U.S. and EU.....	9
The Explosion of Renewables.....	10
The Importance of Storage.....	13
Smart (and) Microgrids: Bringing the Disruption Together.....	17
Demand Management.....	25
Structural Disruption of Digital Transformation.....	28
Forces Driving Transformation.....	33
Commercial Drivers.....	33
Policy Drivers.....	36
Digital Transformation Policy Issues.....	38
Business Model Disruption: Who Owns Access to Data.....	39
Protecting Privacy or Protecting the Planet.....	41
Financing Necessary Infrastructure.....	43
Cyber Vulnerabilities of Connected Digital Energy Space.....	45
Policy Recommendations.....	48
Conclusion.....	50



# Executive Summary

Digitalization is transforming the energy sector in both Europe and the United States, with all the economic, social, political, and even geopolitical consequences that disruption entails.

This transformation is far from complete. At the macro level, digitalization is spurring the electrification of our energy sectors and will help us integrate renewable sources of energy into the system on large and small scales. At the micro level, the digital connectivity underlying the Internet of things (IOT) makes every electric device a contributor to the energy system (rather than just an electricity consumer) by bundling distributed energy resources into larger ecosystems. Digitalization is transforming the one-way electricity supply of yesterday into an omnidirectional system for tomorrow.

Such changes open opportunities for new entrants — including those who used to be simple consumers — to provide new energy services to the system. This challenges the once staid business models of traditional electricity suppliers and consequently will transform the ways Europe and the United States have regulated energy utilities. This overhaul of the energy system raises new policy issues that have not yet been fully addressed in either the United States or Europe, including the ownership and use of the mountains of energy data now being generated, privacy protection, new infrastructure needs, and new cybersecurity vulnerabilities.

This report attempts to provide insights into the state of the digital transformation of the energy sectors in both the United States and Europe. We analyze the implications of those changes to the sector and identify key drivers behind the transformation, including climate concerns, efficiency, competitiveness, and resilience, the weights of which sometimes differ on the two sides of the Atlantic. Finally, we look at how both sides are addressing the data, privacy, infrastructure, and cybersecurity challenges digitalization is generating before suggesting a few recommendations for industry and policymakers to consider.

## The State of the Transformation

Digitalization and the electrification of our societies go hand in hand, feeding off each other and together driving the transformation of the energy sector. In advanced economies like the European Union and the United States, electricity is now almost a quarter of all energy

consumed, up from just over ten percent in 1973. This electricity share is set to expand further as the IOT grows and as transport —now guzzling gas and diesel — is increasingly electrified. But even as the electricity sector grows in importance, it is changing at the same time. The traditional electricity supply model — where electricity from large scale power plants is fed through transmission wires and distribution systems to passive commercial, industrial, and residential consumers — is transforming into a more active, distributed model.

A critical part of this change is the burgeoning of distributed renewable energy power — solar and wind power generated at homes, office buildings, and factories. The spread of renewable solar and wind power in both Europe and the United States, however, while associated with the digital transformation, does not define it. In the case of both solar and wind, Europe has a twofold lead over the United States. Solar provides 3.7 percent of Europe's electricity while wind kicks in 11.8 percent; in the United States, those numbers are 1.5 percent and 6 percent respectively. A considerable amount of this renewable power is generated by utility-scale wind farms and solar installations that fit nicely into the traditional energy supply model. At the same time, however, government support and expanded take-up have dramatically driven down the prices of wind turbines and solar panels, even as their technology and quality improves. As a result, more distributed electricity production from commercial/industrial as well as residential sites for solar and wind generation (including micro wind turbines), is growing quickly in the United States, while installations in Europe have slowed from their former highs.

“**Digitalization is transforming the one-way electricity supply of yesterday into an omnidirectional system for tomorrow.**”

The expansion of renewables technologies has also highlighted problems associated with them: their variability (always understood as a problem); the mismatch between their time of production and when their energy is needed; and their ability to overwhelm the local grid, leading to major curtailments. Further, there is the issue of their zero marginal cost, putting them

first in line to supply mid-market and peak demand, which drives down wholesale prices and undermines the economics both of renewables and of traditional power sources. One example of the existing inefficiencies is the case of wind turbines in Europe, which already have the capacity to be the second largest source of electricity, but are active only a third of the time.

Into this system come batteries and energy storage. In some ways these had been neglected in the push to renewables, but they critically smooth renewables electricity supply and demand across time, potentially putting variable wind and solar power on the same level as dispatchable nuclear, coal, and gas and vastly improving their economics. While installed storage capacity in Europe and the United States is still low (2.6 gigawatts in Europe and 1.3 gigawatts in the United States), battery prices have declined dramatically (in part because of expanding electric vehicle demand) while residential and other distributed demand grow rapidly. The last element of the battery transformation is the electric vehicle, which could both be a drain on the grid and an enormous storage asset to it.

In this new world of disbursed renewables generation and storage technology, digitalization is the new and crucial glue. Digitalization emerges first in the form of smart meters, but secondly and more importantly as platforms that bring together and optimize distributed energy resources. Second-generation smart meters, which can both provide granular information on usage and communicate wirelessly with devices in factories, commercial establishments, and homes, now cover over half of America's consumers, with the number closer to forty percent in Europe. Digitalization has introduced different actors into the energy system. Companies new to the electricity sector but with deep experience in information technology are applying high-powered computer analytics to data from smart meters as well as from thermostats and other smart controls to help consumers reduce and manage their demand and to sell self-generated electricity back to the system. Some platforms allow individual consumers to come together as networks through which small contributions to supply and demand can be aggregated into a significant force on the market.

These new networks bring synergies to and magnify the effects of distributed energy production and storage. They represent in effect highly local, miniature electric

companies, and are sprouting most notably in the United States, with large-scale pilots taking off in Europe. While these new models are difficult to count, there are approximately 2000 known, larger-scale microgrids (which can be disconnected from the main power system), with the United States leading Europe at 7 gigawatts capacity versus 1.8 gigawatts.

## Impact on Business Models

Electric companies, especially at the distribution level, could (and perhaps should) provide the efficiencies that come from bringing distributed energy resources together — the companies have the contact to customers, often own the smart meters, and are increasingly deploying distributed energy resource management systems. But they are often hampered by regulatory barriers which restrict their ability to generate revenue from new services. And indeed, in some places in both the United States and Europe the companies that bring customers electricity over their distribution networks are explicitly enjoined from producing electricity, even from batteries.

Electric utilities are deeply concerned that over-the-top digital energy service companies could woo customers off grid and allow them to avoid costs associated with maintaining and strengthening that infrastructure. Many are trying to combat this risk to their business in part by trying to limit outside competition or ensuring it faces the same regulatory burdens they do. Others are trying to beat the competition by joining in, either acquiring or teaming up with new upstart electricity service companies.

## Transformation Drivers

While this transformation is happening in both Europe and the United States at the same time (which says something about the rate of technology diffusion, despite regulatory barriers), it is occurring largely for different reasons. In the United States, the chief drivers are profit motivation — as IT companies see a new market to which to bring their disruptive models — and resilience — as microgrids and other such arrangements provide backstops to potential grid failures associated with an aging above-ground electricity transmission and distribution network. In Europe, in contrast, the chief driver is the desire to combat climate change — an important policy goal, but one that does not always fit with profit-driven economics.

## Energy Digitalization Policy Issues

Digital transformation of the energy sector raises numerous policy issues, including how the new market where utilities and fresh entrants meet should be regulated. But it also raises issues that are outside the usual energy regulatory remit.

One of the first and most consequential is ownership of and access to data that increasingly underlies the industry as bytes become more valuable than electrons. In both Europe and the United States, this may be easier to handle for the commercial and industrial client base where contracts that define ownership/usage rights are an accepted norm. At the residential (and small business) level, however, data ownership and access become more complicated. And this can become an especially difficult issue where the energy supply company has traditionally held control of data related to energy usage. The consumer — increasingly also a producer — may dispute the energy supply company's role and want to provide their own data to whichever service supplier can offer the best deal. On both sides of the Atlantic, regulators are trying to find ways to ensure that the market is open while companies invest substantially to win the right to eke out efficiency benefits brought by the right to access data.

A related and critical policy issue is data protection. Smart meters alone can read deeply into what is going on in a household by its energy usage — from morning toast to evening tea (and according to some reports, the television channel being watched). This will become even more granular as devices in the home — hot water heaters, washing machines, heating and cooling systems, even lights — are smartened. Consumer and privacy rights groups are concerned about how this data can and will be used. But opt-in approaches to guard privacy may lead to fewer consumers engaging in smart energy management, which would hamper a society's ability to reduce greenhouse gas emissions. This public purpose has yet to overtake privacy concerns, but the tension should be addressed.

The need to build out and maintain an ever-smarter electricity infrastructure is running into economic problems. Electricity demand is mostly stagnant and could weaken further as additional efficiency is squeezed out of the system and as renewables plus storage increasingly outcompete investment in even low-cost, gas-fired turbines. These new trends work against the

existing revenue models of the utilities responsible for the grid, a situation that could be exacerbated if energy communities like microgrids increasingly undermine the grid's customer base. The trend is reminiscent of the telecommunications industry, where phone companies saw over-the-top and Internet service suppliers erode their revenues while avoiding obligations to maintain phone line infrastructure. The two sectors, however, are also merging — utilities often need spectrum and cables to support their own operations, and the Internet of energy will also require new investments in 5G mobile as well as new Internet protocols necessary to connect everything. The infrastructure needs of the two sectors are increasingly intertwined, and regulators unaccustomed to looking outside their own silo will need to be more coordinated.

**“ Ownership of and access to data increasingly underlies the industry as bytes become more valuable than electrons.”**

Newer capabilities also bring new risks. The emerging Internet of energy creates new vulnerabilities in the electricity sector on both sides of the Atlantic. Critical energy infrastructure has been subject to significant attacks in both Europe and the United States. Both regions are striving to harden their systems but have taken different approaches. The United States is focusing more on precise and detailed norms for cybersecurity in the electricity sector, while the EU has done more work on cybersecurity for low-carbon technologies and electricity distribution. Nevertheless, consumer devices remain vulnerable. Policymakers and industry need to work with consumers to teach them how to reduce vulnerabilities for themselves and their communities and to produce more secure devices.

## Policy Recommendations

Europe and the United States both have deeply embedded regulatory structures for their electricity sectors. The digitalization of the energy sector is putting these structures under stress. Industry and policymakers on both sides are striving to figure out how to adapt to the disruption wrought by digitalization. And despite the

differences in their systems, they can each learn from the other side's experiences. Some thoughts to keep in mind, however, include:

### ***Accept Digitalization — It Will Not Go Away***

Disruption and dislocation brought by change are difficult. Those who are or think they may be harmed will highlight the potential costs of change. But the Internet of everything is coming and with it the Internet of energy. Every electrical device will become a node connected to an AI-enabled platform that will drive efficiency and the demand for electricity down. More customers will become competitors, generating their own supply and sending surpluses back to the system. The accelerating trend toward digital transformation of the energy sector will not go away.

### ***Keep It in Perspective***

The pace of change is accelerating, but often from a small base. Policies related to digitalization need to keep that in perspective. But it is also worth bearing in mind that renewables and storage, empowered by digital systems, have had an enormous impact on wholesale prices and on decisions over billions of dollars of investment, even while relatively small players on the market.

### ***Facilitate Integration of New Models and Platforms***

The endpoint of a substantially decentralized energy system is certain. Policymakers, the private sector, and the public can and should anticipate that endpoint and let it guide them. This implies, above all else, being willing to allow new ways of organizing distributed energy resources to come on the market. All players, including utilities, should be allowed to experiment.

### ***Support Markets, Not Subsidies***

New distributed energy resources — including e-vehicles and batteries — and the digital technologies that underpin them have their own economic and commercial rationale. They should be allowed to find their own way. Supporting research is one thing, subsidizing commercialization another.

### ***Smart Digitalization for Climate Change Wins***

Digitalization of the energy sector can have a large impact on reducing greenhouse house emissions if the appropriate policies and planning are put into place. Cities, regions, the EU, and U.S. state and federal governments should encourage systems-based approaches to redesigning energy grids so that distributed energy systems are integrated to help achieve decarbonization. In the EU, where meeting new energy efficiency targets will require sustained ambition over the next decade, policymakers and industry should work with citizens to illustrate how digital efficiency solutions such as demand response systems can help meet climate change goals.

### ***Emphasize Both Resilience and Reliability***

As important as climate change considerations are, however, reliability and resilience are critical motivations too, and in some ways they respond better to economics. Microgrids, for instance, can provide communities with greater resilience against outages caused by extreme weather, technical disruption, or cyberattacks on large infrastructure, but they are also the tool for achieving the greatest efficiencies in the digitalized energy world. And it is clear that resilience to outages increasingly also implies resilience to climate change.

### ***Stay Focused on Cybersecurity***

Policymakers and industry should prioritize developing security in the many small entry points into the digital energy system. This will require a focus on setting and implementing minimum cybersecurity standards for IOT devices (such as smart thermostats or washing machines), electric vehicles and EV charging stations, and smarter traditional energy devices such as meters. Consumers must be taught to be responsible for their cybersecurity and security of their communities.

Digitalization of the energy sector brings disruption that may return us to a more distributed energy model resembling the past. With the efficiencies and controls digitalization brings, both the United States and Europe can build new systems that achieve diverse policy goals if they embrace and encourage this creative destruction.







# Transatlantic Policy Challenges of the Digital Energy Nexus

PETER CHASE, KRISTINE BERZINA

While this report is not written for electrical engineers, it is impossible to write about electricity without using technical terminology. The most important thing to remember is that electricity is effervescent: it needs to be used — consumed or stored — the moment it is produced. If not, the system has an **OVERLOAD** (leading to circuit breaks), or **UNDERSUPPLY** (brown- or blackouts), affecting the reliability of the system. We have all owned a lightbulb that consumes 100 watts of electricity at any one time, but if we keep it on for an hour, it has consumed 100 **WATT-HOURS**. One thousand watts is a **KILOWATT**; a thousand thousand (or million) watts is a **MEGAWATT**; and a thousand thousand thousand (or billion) watts is a **GIGAWATT**. A megawatt plant can produce up to 1,000,000 watts of electricity at any one time; kept on all year, it will have delivered many more megawatt-hours of electricity. All generating plants in the United States have the capacity to supply up to 1.1 **TERAWATTS** (1,000,000,000,000 watts) at any one time; in 2017, they actually produced 4200 terawatt-hours. For the EU, those numbers were 932 gigawatts and 3000 terawatt-hours respectively. In a traditional **ONE-WAY** system, large, utility-scale electricity generation facilities supply electricity over the grid of transmission lines to us as consumers; in the changing, **DISTRIBUTED** world, we supply electricity from our rooftop solar panels back to the grid. As consumers, the amount of kilowatt-hours we buy from the electricity company is measured by our meter; **BEHIND-THE-METER** things happen in our homes (or office buildings or factories), while **FRONT-OF-THE-METER** stuff happens in the world of the electricity company itself. Utilities supply a **BASELOAD** of electricity throughout the day, but that load needs to **RAMP UP** (increase quickly) to serve **PEAK DEMAND** when we come home and turn on all the lights, begin cooking, and start the laundry.

## Digital Energy Sector Transformation

The energy sector in both Europe and the United States has long been exceedingly capital- and technology-intensive. Massive computer power is needed to analyze geological data, control nuclear power plants, and manage minute-by-minute changes in energy supply and demand across hundreds of transformers and millions of households and businesses.

Yet perhaps because the sector is so capital- and IT-intensive, it may in some ways have been blind to the speed and broader implications of the digital transformation taking place around it. The energy industry thinks in terms of decades; digital innovations seem to happen over the course of days.

That difference in time perspective may be one reason why the International Energy Agency, the major energy organization of developed economies, published its first report on “Digitalization and Energy” only in Fall 2017. That report looks broadly at digitalization in the energy sector, including its impact on the search for and exploitation of hydrocarbon resources on the energy supply side, how digital technologies are creating efficiencies and potentially reducing demand in such key energy-consuming sectors as transport, construction, and industry, and other, larger macro issues.

This study is focused instead on how digitalization is *transforming* the energy system in the United States and Europe, specifically in terms of spurring the shift toward electricity, helping integrate renewables and other forms of distributed energy production, and promoting efficient consumption, all of which fundamentally change the relationship between energy suppliers and consumers and thus the system itself.

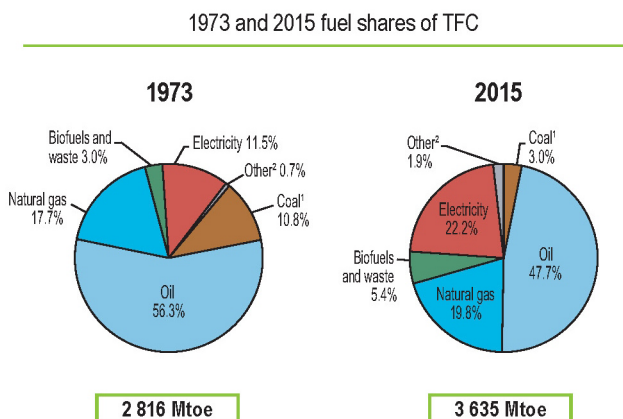
## Electrification and Transformation

### Electrification

Energy underlies virtually everything we do, and electricity, as one of the most versatile forms of energy, has become increasingly important in modern society. Globally, as energy consumption essentially doubled between 1973 and 2015, the share of electricity in final energy consumption went from 9.4 percent to 18.5 percent. This “electrification of energy” trend is even more marked in advanced economies (including Europe and the United States), where the share of electricity went from 11.5 percent to 22.5 percent of total energy consumption.

The overall process of digitalization is accelerating the electrification of our economies. The rapid advance of computing power (modern mobile phones have more computing capacity than the Apollo spacecraft that first visited the moon), immense improvements in sensing and measuring technologies, and leaps in communications, especially in wireless, have dramatically enhanced mankind’s ability to create, transmit, and process data of all sorts. The Internet, once the purview of a handful of specialized researchers at a few elite universities, was by the end of the 20th century a vehicle that allowed individuals in every corner of the world to communicate with each other. It has now turned into the Internet of everything, where billions of inanimate objects are also sensing, recording,

Figure 1. OECD Final Energy Consumption by Fuel Type. Source: International Energy Agency, Key World Energy Statistics 2017, 34-35.



1. In these graphs, peat and oil shale are aggregated with coal.  
 2. Includes heat, solar thermal and geothermal.

and transmitting data that is being analyzed and used by people everywhere. According to Cisco, total Internet traffic in 1992 was approximately 100 gigabytes per day. Ten years later, it was 100 gigabytes per second. And in 2016, it was 26,600 gigabytes per second. The Cisco Visual Networking Index projects global Internet traffic to triple in the next five years, growing from 96 exabytes per month in 2016 to 278 exabytes per month in 2021 and bringing us into the zettabyte era.<sup>1</sup>

This digital transformation has significant implications for the energy sector. Generating, transmitting, and processing this data consumes huge amounts of energy; the IT sector now accounts for nearly 3 percent of total global energy consumption.<sup>2</sup> But the ability to sense, capture, analyze, and communicate data is also a major driver of electrification as it is by definition an electric operation. The efficiency and other benefits this brings are pushing more functions toward electric power, with the electric vehicle the most prominent example as it will significantly shift final energy consumption away from liquid fuels. Finally, the new sensing technologies are being brought to literally every object in a home, office, and factory, not least to measure — and increasingly to control — energy consumption. Electrification and digitalization go hand and hand, feeding on each other and driving transformation of the energy sector.

### The Traditional Model

As electric power generation began to burgeon in the United States and Europe, and certainly since its dramatic expansion after World War II, the sector became increasingly “industrial,” with large volumes transported one way to passive consumers. More specifically, the sector was characterized by large, remotely-located power stations using hydrocarbons (coal, oil, and gas), water (hydropower), or nuclear fuel to generate thousands of megawatts of electricity transported over high-voltage transmission lines to regional distribution system operators, where

1 Cisco, “The Zettabyte Era: Trends and Analysis,” June 7, 2017. A thousand gigabytes is a terabyte; according to Cisco, 480 terabytes would be a digital library of all the world’s books in all languages. 1000 terabytes make up a petabyte, the equivalent of 250,000 DVDs. 1000 petabytes are an exabyte (250 million DVDs); 5 exabytes would be a text transcript of all the words ever spoken. A zettabyte is 1000 exabytes.

2 International Energy Agency, “Digitalization and Energy,” November 2017, Ch. 6.

transformers would step down the electricity to medium voltage, pass it on to substations, and ultimately send it at lower voltages to household, commercial, and industrial consumers.

The capital intensity of this system favored vertically-integrated utilities, often state-owned regional monopolies that were highly regulated in terms of pricing and investment decisions. More recently, in both Europe and the United States, governments have begun to liberalize the sector by allowing independent power producers to sell to transmission system operators (TSOs), which in turn might compete to serve independent distribution system operators (DSOs), but this has not changed the fundamental one-way nature of the model.

### *The Distributed Digital Model*

This traditional model is crumbling, with all the economic, social, and political turmoil that implies. The shift toward renewable forms of energy, especially wind and solar, in response to climate change is one driver of this. As discussed below, this shift is accelerating in both Europe and the United States as the cost of renewables technologies drops dramatically. But the shift to renewables is not in itself transformative of the sector — wind and solar power can be, and often are, utility scale, multi-megawatt installations generating huge volumes of electricity delivered, as before, through high-voltage transmission lines.

Disruption begins when power generation can happen on a smaller scale and be distributed among consumers, be they factories, commercial office buildings, apartments, or households. This is happening with smaller-scale wind and solar installations, which are made increasingly more efficient and viable through storage solutions (that also produce electricity supply when called upon). But such changes become even more powerful when digitalization allows these new individual electricity producers to eke out increasing savings in energy consumption and connect directly to each other.

These factors — smaller-scale generation, storage, demand reduction, and connectivity — are all part of the new distributed energy resources system that is revolutionizing the sector precisely because they decentralize production and permit consumers to go off-grid, independent of the traditional utility model. The ability to leave the grid

gives once-passive consumers a new power relative to the utilities. This leads to a new, more interactive model, one where smaller generators have the power to engage proactively with traditional electricity providers, selling their surplus power individually, or increasingly as a group, back into the system.

Indeed, three factors have been identified as tipping points for moving off-grid:

- when off-grid energy reaches cost and performance parity with grid-delivered electricity;
- when electric vehicles (as distributed storage) reach price and performance parity with internal combustion engine vehicles; and
- when the cost of transporting electricity exceeds the cost of generating and storing it locally.<sup>3</sup>

Each of these tipping points will be reached in different regions of the world at different times, but in all cases the tipping points are approaching more rapidly than expected even two years ago.

How far are we from these tipping points? The remainder of this section provides an overview of the key developments in each of the three areas in the United States and Europe.

## The Scope of Change in the U.S. and EU

The rapidity of digital transformation of the energy sectors in the United States and Europe is demonstrated by data on four supply side changes and one crucial transformation on the demand side of the electricity equation.

On the supply side:

- the adoption of distributed energy supply resources, namely renewables such as solar and wind power;
- the expansion of storage, including through the spread of e-vehicles, which is a necessary complement to renewables;

<sup>3</sup> EYGM Limited, “When Energy Consumers Go Off-Grid, Will Utilities Be Left in the Dark?” January 18, 2018.

- the concomitant expansion of smart grids, which can absorb output from these distributed energy resources;
- the development of microgrids, an expression of actual and potential grid independence; and

On the demand side:

- the spread of demand management technologies, including smart meters.

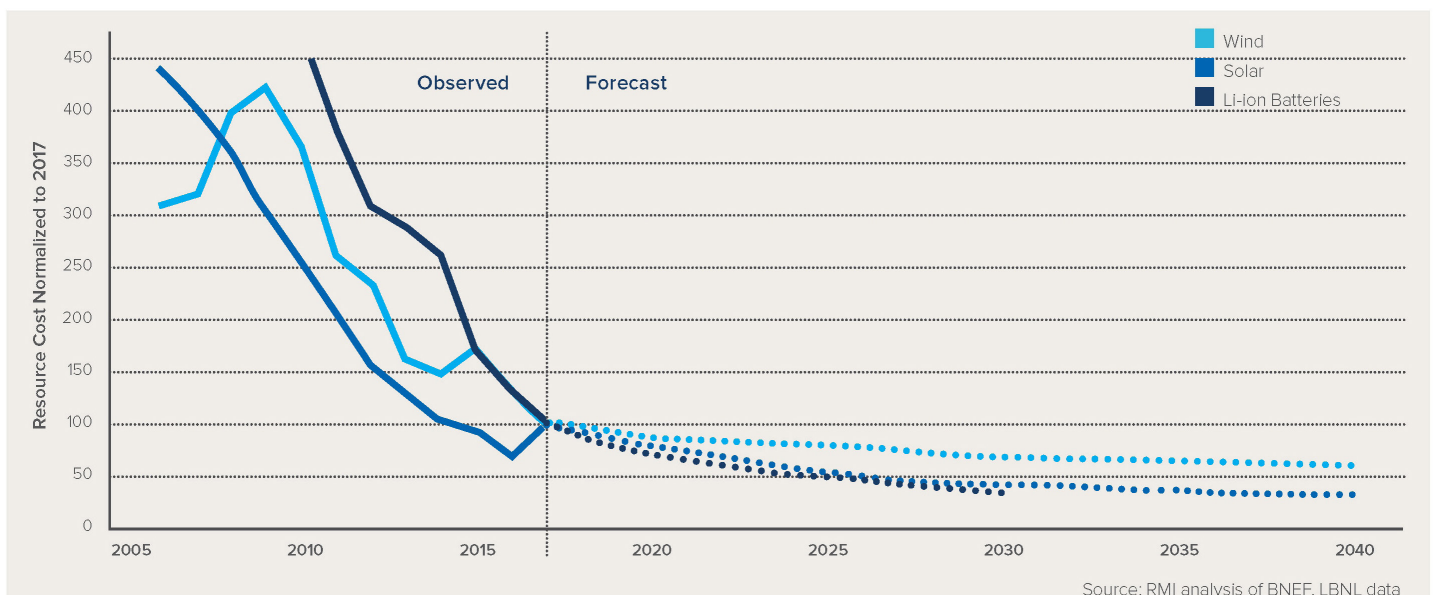
How each of these metrics is developing in the United States and Europe is reported below, before turning in subsequent sections of this study to the drivers behind them and the policy implications they entail.

### The Explosion of Renewables

Mankind has long used renewable energy — the first fires with wood (“biomass”), the river currents and windmills that powered milling and weaving — but were long considered antiquated and quaint as we moved to industrial electrical power, largely generated by such coal, oil, and gas, as well as hydropower dams.

Figure 2. Historical and Forecast Cost Declines for Wind, Solar, and Batteries. Source: Rocky Mountain Institute, The Economics of Clean Energy Portfolios, May 2018, 21.

HISTORICAL AND FORECAST COST DECLINES FOR WIND, SOLAR, AND BATTERIES



Source: RMI analysis of BNEF, LBNL data

Renewables, mainly in the form of solar and wind power, came back into vogue as consciousness about the climate impact of burning hydrocarbons rose at the end of the 1990s. Technologies to convert solar and wind power into electricity were expensive, however, and numerous forecasts of energy production significantly downplayed their potential impact, certainly through the first decade of the 21st century.

That has changed dramatically in the second decade of this century. The price of solar and wind power generation (as well as battery storage) has fallen significantly in recent years as the technologies to take advantage of the power of the sun and the earth’s rotation have leapt ahead and as mass production has driven down marginal costs, spurred considerably by subsidies given to the technologies in both the United States and Europe.

These renewable energy sources are also modular: they can be both utility-scale, with thousands of wind turbines or solar panels combined to create enormous electricity generating plants, as well as micro-scale, with one to three mills generating wind power for a factory, building, or farm, or two or three solar panels providing electricity to an office building, apartment complex, or even a single residential unit. And one of the most important characteristics of renewable sources of electricity is that their marginal cost is zero.

Installing a windmill may be expensive, but thereafter the electricity generated with each rotation of the blades is free. The same is true for solar power. This contrasts with a hydrocarbon-based power plant, where each unit of gas, oil, or coal burned adds to the cost base. As discussed below, the zero marginal cost economics of renewables is critical as it makes them the go-to power source for the grid when they are available.

## Solar

Harnessing the power of the sun is a holy grail of renewable energy production. Photovoltaic (PV) converters — solar panels — are now the primary technology that has helped achieve this. As noted above, the price of photovoltaic power generation has dropped almost exponentially in the past ten years, such that it is now in many places not only competitive but even superior to conventional power production on a per kilowatt basis.

Not surprisingly, solar power has taken off in both the United States and Europe. In the United States, the millionth solar installation is believed to have occurred in February 2016.<sup>4</sup> In the last ten years, the amount of solar power installed in the United States has increased from 290 megawatts in 2008 to an estimated 47.1 gigawatts in 2017 — enough to power the equivalent of 9.1 million American homes and representing more than 1.5 percent of the nation’s electricity supply.<sup>5</sup> Total solar power generated in the United States in 2017 was 77.1 terawatt-hours.<sup>6</sup> Solar installation declined in 2017 after a banner year in 2016, although California has now mandated solar in all new homes beginning in 2020.<sup>7</sup>

In Europe, solar power has also become a notable force in the electricity sector, generating 119 terawatt-hours of electricity in 2017 and providing 3.7 percent of Europe’s total electricity generation that year. In contrast with the United States, however, solar installations reached a high in 2011 and were weak in 2016, rising only marginally the

4 Julia Pyper, “The U.S. Solar Market is Now One Million Installations Strong,” Greentech Media, April 21, 2016, referring to installations of all sizes.

5 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Solar Technologies Office, “2020 Utility-Scale Solar Goal Achieved,” September 12, 2017.

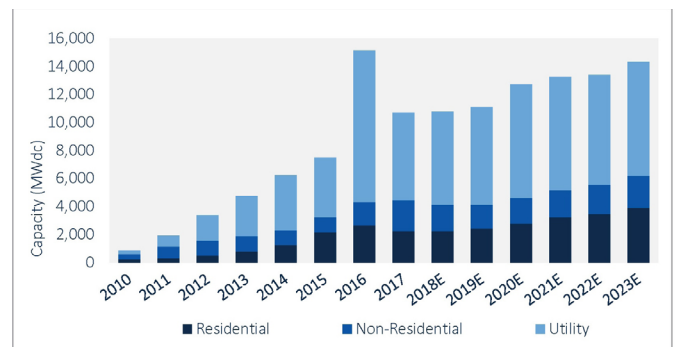
6 U.S. Energy Information Administration, “Electricity Data Browser, Net Generation All Solar,” <https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=0045u&geo=vvvvvvvvvv&sec=g&linechart=ELEC.GEN.SUN-US-99.A&columnchart=ELEC.GEN.SUN-US-99.A&map=ELEC.GEN.SUN-US-99.A&freq=A&ctype=linechart&itype=pin&type=s&mapttype=0&rse=0&pin=>, accessed June 6, 2018.

7 Julia Pyper, “Everything You Need to Know about California’s New Solar Mandate,” Greentech Media, May 21, 2018.

following year. To some extent, this reflects the phasing out of government supports for solar power in a number of member states.

In both the United States and Europe, however, the critical issue is not just the amount of solar power installed, but also its disbursement. In the United States, nearly two-thirds of solar power generated in 2017 was from large, utility-scale installations, although a number of these are commercial and industrial contracts not associated with the normal grid. In Europe, a greater proportion of solar power is distributed, especially in residential units.

Figure 3. U.S. Solar Power Installation, 2010-2023. Source: U.S. Department of Energy, “2020 Utility-Scale Solar Goal Achieved.”



Source: GTM Research

## Wind

While solar power was long the higher profile source of renewable energy, wind power is in fact more prominent in both the United States and in Europe. In the United States, wind power generates over 6 percent of total electricity, while in Europe this figure was over 11 percent in 2017. Improvements in design as well as turbine materials and technology (offshore wind turbines now stand up to 160 meters with blades up to 80 meters long) again drive down costs — in America, unsubsidized wind power runs \$30–60 per megawatt-hour, the lowest by source.<sup>8</sup>

Total wind generation capacity in Europe now stands at 169 gigawatts, making wind the second largest electricity generation capacity source (behind gas), after a banner year of installing 16.9 gigawatts in 2017 (12.4 onshore,

8 “Lazard’s Levelized Cost of Energy Analysis,” Version 11.0, <https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-11.0.pdf>, November 2017.

Wind electricity generation and percent share of total U.S. electricity generation, 1990–2017

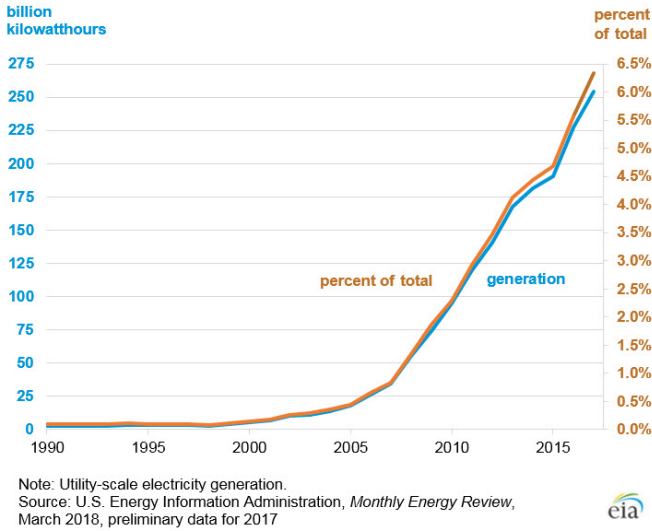


Figure 4. Wind Electricity Generation and Percent Share of Total U.S. Electricity Generation, 1990-2017. Source: U.S. Energy Information Agency, “Wind Turbines.”

3.1 offshore).<sup>9</sup> In the United States, wind generation capacity is about half that of the EU, at 89 gigawatts, the vast majority of which is onshore.<sup>10</sup>

Once again, however, it is important to distinguish between large, utility-scale installations that supply electricity to the wholesale electricity market and smaller ones that may be associated with local power distribution, factories, farms, and even residences. Offshore wind, ten percent of the generating capacity in Europe, is virtually always large, utility-scale, as are many of the on-land wind farms. But certainly not all — in part because citizen ownership was a hallmark of Germany’s Energiewende (“transition to renewables”), households and farms account for approximately forty percent of renewables investment in Germany. Much of this was subsidized by a feed-in tariff structure that phases out in 2020; as a result, Germany could see many of its 28,000 onshore turbines phased out beginning that year.<sup>11</sup>

9 WindEurope, “Wind in Power 2017,” <https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2017.pdf>, February 2018.

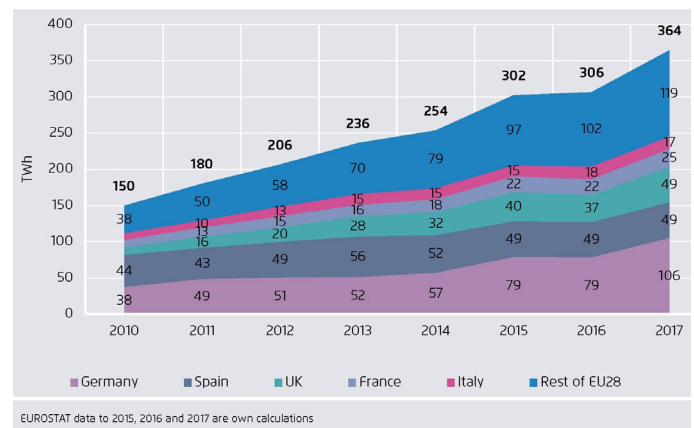
10 U.S. Energy Information Agency, “Wind Turbines Provide 8 Percent of U.S. Generating Capacity, More than Any Other Renewable Source,” May 2, 2017, which inter alia reports that the first offshore wind facility in the United States came online only in December 2016.

11 Justin Gerdes, “Germany Faces Gigawatt-Scale Loss of Onshore Wind Power,” Greentech Media, May 25, 2018.

Large-scale wind exists also in many of the areas of the United States, but there appears to be a greater focus on distributed wind generation. According to the U.S. Department of Energy, between 2003 and the end of 2016 some 77,000 turbines of all sizes were installed for a total of nearly 1 gigawatt of distributed generating capacity in the United States. Looking only at the half of this total behind the meter (that is, directly sited on residential, commercial, and industrial facilities), experts at the National Renewable Energy Laboratory in November 2016 estimated that the “addressable resource potential for distributed wind exceeds total U.S. electricity demand.” Deploying modern small wind turbines (less than one megawatt) is technically feasible at approximately 49.5 million sites; the three-terawatt capacity this would represent could produce 4400 terawatt hours of annual electricity generation, more than total U.S. demand in 2016. Larger turbines distributed away from central electricity production could provide an additional 5.1 terawatts of capacity and 14,000 terawatt hours of generation.<sup>12</sup> Of this, 42 gigawatts would be economically viable in 2020.

Even this would be a huge contribution. But when considering consumer adoption trends, the report suggests that even in the “Combined High” scenario, the market potential of behind-the-meter distributed wind is likely to be just 3.9 gigawatts in 2030 and 20 gigawatts in 2050.

Figure 5. Wind Energy Generation in Europe in Terrawatt-Hours, 2010-2017. Source: Agora Energiewende and Sandbag, European Power Sector.



12 Eric Lantz et al., “Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects,” National Renewable Energy Laboratory, November 2016. The paper looks in detail at siting possibilities.



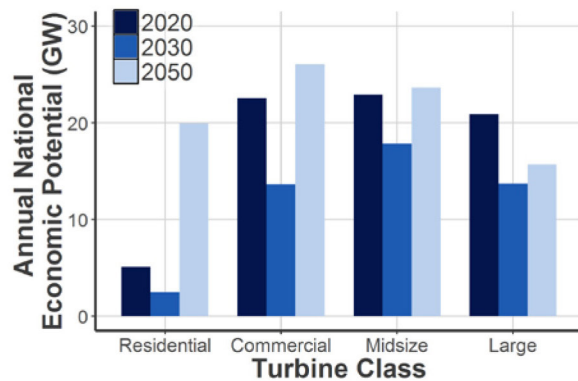
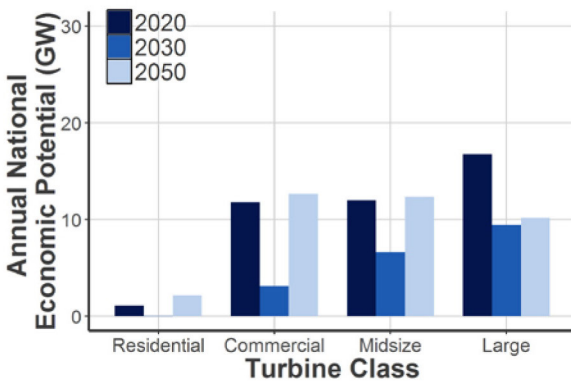


Figure 6. Economic Potential by Turbine Size Class for the Reference Scenario (left) and Combined High Scenario (right). Source: U.S. Department of Energy, *Assessing the Future of Distributed Wind*, 36-37.

### Difficulties with Renewables

As important as they are, renewable energy sources suffer from four major problems that affect their impact on the electricity system. One that has been long recognized is their variability and intermittency: the power of the wind and sun can only be accessed when they are present. A second is that, especially for solar power, peak generating times (mid-day) do not match peak demand times (mornings and evenings), creating the need for a sharp ramping up of non-solar generation for the evening peak. A third that became apparent only after the explosion of renewables is their economics — massive solar and wind installations in a region all provide power at the same time, potentially overwhelming the grid; to avoid this, substantial portions of available wind turbines and solar cells are turned off, known as curtailment, which weakens their overall economic efficiency. The fourth issue is renewables’ zero marginal operating cost, which effectively means that renewables are first in line to supply above baseload demand, driving down wholesale prices, displacing conventional coal and gas, and undermining the economics of the traditional system.<sup>13</sup>

### The Importance of Storage

These problems have affected both the market and demand for renewables and explain in part why wind, for instance, only supplied 11.8 percent of European electricity demand in 2017 even though it is the second largest potential source of electricity. In both

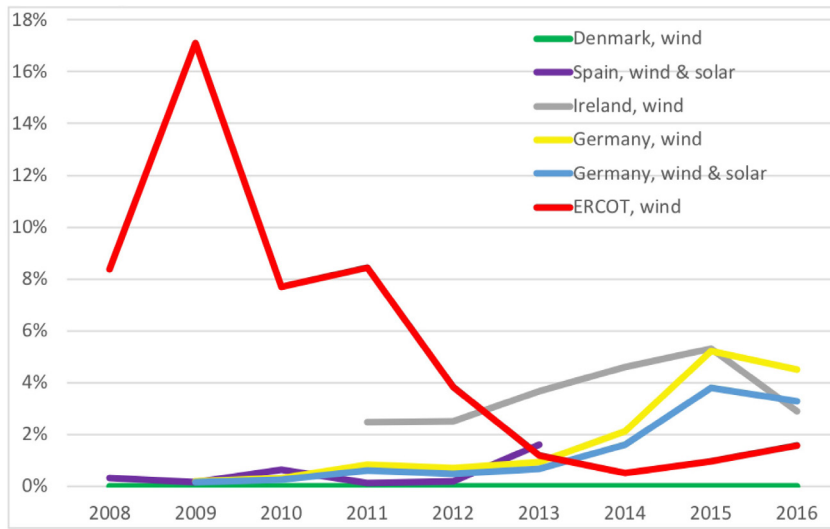
Europe and the United States, renewables have recently suffered significant amounts of curtailment as they have flooded the generating market in some areas, leading electricity companies to shut them off, such that the renewable power they could have generated is effectively thrown away.

As some of these difficulties became apparent only recently, the importance of one of the major responses to them — energy storage — is only now being broadly recognized and addressed.

Storage smooths electricity supply and demand across time. If more electricity is being generated when the sun shines or the wind blows than consumers need, storage absorbs that surplus and then can release it when the supply is down but demand exists. By offsetting the variability of renewables, storage makes them a dispatchable and reliable component of the electricity system, just like a coal- or nuclear-powered generating plant.

There are a wide range of storage technologies: large-scale hydroelectric storage as in Norway and Spain, compressed air, thermal storage, gas conversion, electro-chemical batteries (such as lithium-ion), flow batteries, flywheels, and others. Batteries in particular can serve a wide range of purposes on the electricity

<sup>13</sup> See, for example, Gerard Wynn, “Power-Industry Transition, Here and Now,” Institute for Energy Economics and Financial Analysis, February 8, 2018, which describes the “merit-based” traditional power dispatch model between baseload (around the clock), mid-merit (on-demand), and peaking (short-term balancing) generation requirements, where renewables increasingly drive the mid-merit market. See also David Roberts, “Why Wind and Solar Power are Such a Challenge for the Grids,” Vox, June 19, 2015.



Sources: Various <sup>12</sup>

Figure 7. Renewables Curtailment as a Percentage of Renewables Generation in Europe and Texas. Source: Institute for Energy Economics and Financial Analysis, Power Industry Transition, Here and Now, 15.

market; the Rocky Mountain Institute identified 13 such purposes in a 2015 study, including at the transmission, distribution, and retail levels.<sup>14</sup>

Despite these services, energy storage deployment has been underemphasized until recently in both the United States and Europe. The European Association for the Storage of Energy (EASE) conducted its first thorough study (with Delta Energy and Environment) of the sector at the end of 2017, projecting that total installed storage capacity (non-hydro) in Europe would be 2.6 gigawatts at the end of 2018.<sup>15</sup> A substantial portion of this is in the German residential market, where behind-the-meter storage at commercial and residential sites is estimated at about 385 megawatts in 2018.<sup>16</sup> In contrast, the United States had only 500 megawatts of energy storage at the end of 2016 (versus about 1.4 gigawatts for Europe at the time); in a higher estimate, the U.S. Department of Energy (DOE) Global Energy Storage

14 Garrett Fitzgerald, James Mandel, Jesse Morris, and Hervé Touati, "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Services and Value to Customers and the Grid," Rocky Mountain Institute, September 2015.

15 European Association for Storage of Energy, "European Market Monitor on Energy Storage" (Launch Webinar), [http://ease-storage.eu/wp-content/uploads/2018/01/Delta-ee\\_EASE\\_EMMES\\_Launch\\_Webinar-FINAL\\_for-distribution.pdf](http://ease-storage.eu/wp-content/uploads/2018/01/Delta-ee_EASE_EMMES_Launch_Webinar-FINAL_for-distribution.pdf), January 18, 2018. Note that Europe also has some 42 gigawatts of pumped hydro storage capacity for utilities, mainly in Norway and Spain; See EASE, "Study on Energy Storage Demand," June 2018.

16 Jason Deign, "In Germany, Storage Now Has More than Half the Number of Jobs as the Lignite Sector," Greentech Media, April 6, 2018.

Database reportedly counted 471 electrochemical energy storage projects in the United States with 1.3 gigawatts of capacity as of September 2016, the majority of which (266) had rated capacities of less than 250 kilowatts.<sup>17</sup>

Interestingly, residential battery installation beat commercial and industrial deployments in the first quarter of 2018, at 15.9 megawatts compared to 11.7 MW, and nearly beat utility-scale, at 16 MW, demonstrating that distributed home battery installation is on a rapid rise in the United States as well (see Figure 9).<sup>18</sup>

The growth in the market is due in large part to the decline in the cost of the currently preeminent lithium-ion technology for batteries, which in 2016 was \$273 per kilowatt hour, down from \$1000/kWh in 2010. This sharp decline is due in large part to the scale up in battery production, not least by Tesla, which made a huge splash in the utility market by building a 100-megawatt battery in South Australia in 90 days at the end of 2017. In fact, Tesla Powerpack batteries underlie many of the 16 largest solar with storage projects described in a May 2018 report.<sup>19</sup> Similarly, 18 megawatts of Tesla battery packs support a 32-megawatt virtual power plant facility that has just been launched at the site of an old Belgian coal mine by Centrica system flexibility provider REstore.<sup>20</sup>

Indeed, the preeminence of Tesla-like lithium-ion storage batteries — which account for about 98.8 percent of the U.S. battery storage market at the end of 2017 — could crowd out other battery technologies, much as the crystalline-silicon photovoltaic solar panel did in its industry, in part as the capacity for producing the batteries (mostly in Asia) could be more than double total demand by 2020. While this overcapacity has been a major factor behind the rapid decline in lithium-ion

17 Massachusetts Institute of Technology Energy Initiative, "The Utility of the Future," December 2016, 4.

18 Julian Spector, "Residential Batteries Almost Beat Out Utility-Scale Deployments Last Quarter," Greentech Media, June 6, 2018.

19 Tim Buckley and Kashish Shah, "Solar is Driving a Global Shift in Energy Markets," Institute for Energy Economics and Financial Analysis, May 2018, 31-39.

20 Elta Kolo, "Tesla Powerpacks Balance the European Grid in REstore's New Virtual Power Plant," Greentech Media, May 16, 2018.

BATTERIES CAN PROVIDE UP TO 13 SERVICES TO THREE STAKEHOLDER GROUPS

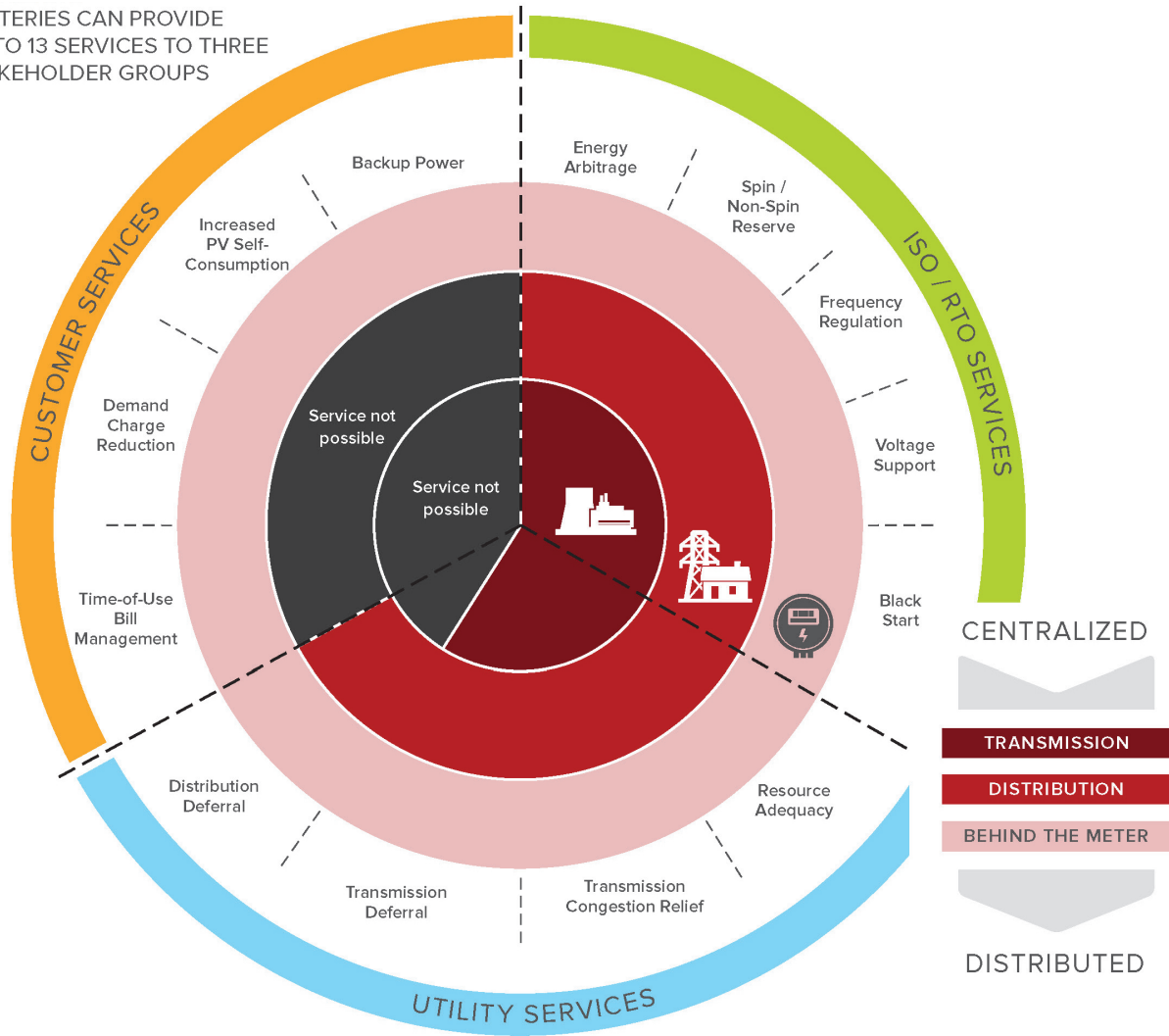


Figure 8. The Economics of Battery Energy Storage.  
Source: Fitzgerald et al., "Economics."

battery prices and thus the uptake in energy storage,<sup>21</sup> such dominance could be problematic as lithium-ion batteries are not well suited for longer-term or larger-scale storage purposes.<sup>22</sup> Fuel cells,<sup>23</sup> flow batteries,<sup>24</sup> zinc-air batteries, and even compressed air are possible alternatives for stationary, longer-term storage;<sup>25</sup> supercapacitor-based

21 Claire Curry, "Lithium-Ion Battery Costs and Market," Bloomberg New Energy Finance, July 5, 2017.

22 David Hart and William Bonvillian, "Policymakers Must Beware of Technology Lock-In for Energy Storage," The Hill, April 30, 2018. Lithium-ion battery architectures, however, vary as well; see Holgar Hesse et al., "Lithium-Ion Battery Storage for the Grid: A Review of Stationary Battery Storage System Design," Energies Review, December 2017.

23 Elisa Wood, "FuelCell Energy Wins \$3 Million Federal Grant for Long-Duration Energy Storage," Microgrid Knowledge, May 31, 2017; see also David Roberts, "This Company May have Solved One of the Hardest Problems in Clean Energy: The Hydrogen Economy May be a Thing After All," Vox, February 16, 2018.

24 Jason Deign, "Another Flow Battery Tries Residential – in Germany," Greentech Media, May 17, 2018.

25 Lisa Cohn, "Long-Term Energy Storage: What Are the Options When Lithium-Ion Falls Short?," Microgrid Knowledge, March 17, 2017.

energy storage is, like lithium-ion, shorter duration, but has a much longer life cycle.<sup>26</sup> The development of these new technologies is important for the energy transition and for consumers. Other electrolytes, for example, could improve the safety of batteries or vehicle or home use.

But whatever the technology, integrating storage and renewables into the electricity system can and will have an immense impact.<sup>27</sup> In Hawaii, California, Colorado, New York, Minnesota, and elsewhere, the combination of renewables plus storage has been demonstrated

26 Lisa Cohn, "The Microgrid Way: Going Green with Supercapacitor-Based Energy Storage," Microgrid Knowledge, April 6, 2018.

27 Peter Bronski et al., "The Economics of Grid Defection: When and Where Distributed Solar Generation Plus Storage Competes with Traditional Utility Service," May 2014.

to be a cost-effective alternative to investing in new generating capacity, often gas-powered, built to respond to peak demands. This means these gas peaker plants, as they are called, could quickly become stranded assets whose economic viability is undermined well short of their thirty-year expected lifetime.<sup>28</sup>

This is one reason why the Federal Energy Regulatory Commission (FERC) in February 2018 issued a new regulation (Order 842) requiring regional transmission organizations and independent system operators (the main forms of transmission utility in the United States) to revise tariffs and create models that integrate storage into the market, allowing them to sell not just storage but also other services into the market.<sup>29</sup> The Energy Storage Association claims the ruling, which allows for stacked services, significantly ease the path to its vision of installing 35 gigawatts of storage capacity in the U.S. by 2025.<sup>30</sup>

### The Electric Vehicle Connection

An interesting subset of the battery storage issue comes with the rise of the electric vehicle (EV), where lithium-ion batteries are used to power electric car motors. While these batteries consume electricity to power the cars, they can also be used to store energy from the grid. The International Energy Agency reported there were over 3 million EVs on the road at the end of 2017, up 57 percent over 2016; this number is expected to rise to 125 million by 2030 and could be 220 million under accommodating policies.<sup>31</sup> By 2030 EVs will comprise 44 percent of European light vehicle sales, 41 percent in China, and 34 percent in the United States.<sup>32</sup> The demand for lithium-ion batteries is accordingly expected to reach 408 gigawatt-hours

28 See, for example, Robert Walton, Report: Minnesota Storage Plus Solar Could be More Cost-Effective Than Peaking Plants After 2022, Utility Dive Brief, July 11, 2017; See also Julian Spector, "Just How Much Business Can Batteries Take From Gas Peakers," Greentech Media, May 16, 2018.

29 Lisa Cohn, "Energy Storage Gets Biggest Boost in Years. Thank You FERC," Microgrid Knowledge, February 23, 2018.

30 Energy Storage Association, "35x25: A Vision for Energy Storage," November 6, 2017. See also Ryan Hledik et al., "Stacked Benefits: Comprehensively Valuing Battery Storage in California," Brattle Group, September 2017.

31 "Number of Electric Vehicles on Roads Reaches Three Million: IEA," Reuters, May 30, 2018.

32 Colin McKerracher, "Electric Vehicles," Bloomberg New Energy Finance, May 21, 2018. See also Bloomberg New Energy Finance, "E-Buses to Surge Even Faster Than EVs as Conventional Vehicles Fade," May 21, 2018.

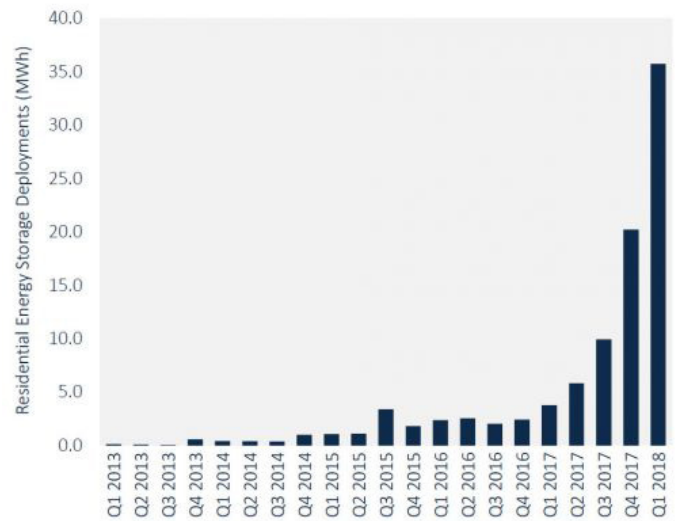


Figure 9. U.S. Quarterly Residential Energy Storage Deployments (MWh). Source: Spector, "Residential Batteries."

in 2025 and 1293 GWh in 2030 (while the stationary storage market will be 65 GWh in 2025 and 200 GWh in 2030).<sup>33 34</sup>

While EVs will of course consume electricity, they are seen here primarily as an additional distributed energy storage resource that can more than halve the curtailment of solar and wind energy because they can help absorb surpluses when renewables are generating large amounts of electricity and release them later when the sun is not shining or the wind blowing.<sup>35</sup> Indeed, a recent study demonstrates that under realistic projections, even simple, grid-integrated vehicles (V1G) could help California absorb two gigawatts of renewables electricity, thus avoiding the need to "curtail" that amount. A realistic mix of V1G and more sophisticated vehicle-to-grid (V2G) integration (where the batteries supply power back to the grid in addition to storing it) would avoid five GW of curtailment. The same scenarios would also significantly alleviate the up- and down-ramping of electricity generation to meet peak needs. In the more ambitious case, where EV batteries are available to supply electricity back to the grid when demand rises in the evening, this

33 Curry, "Lithium-Ion Battery Costs and Markets."

34 Julian Spector notes in "Mercedes Benz Exits (US) Home Battery Market," Greentech Media, April 30, 2018, that "car batteries need extremely high density capable of rapid-fire discharge, which drives the choice of certain lithium-ion chemistries, like nickel-manganese-cobalt. Stationary systems can prioritize life cycle and safety, which is why companies like Sonnen and Simpliphi tout their lithium-ferrous-phosphate chemistries."

35 Chris Nelder, James Newcomb, and Garrett Fitzgerald, "Electric Vehicles as Distributed Energy Resources," Rocky Mountain Institute, 2016.

could supply up to seven GW per hour to the system, obviating the need to build 35,600 megawatt natural gas plants for ramping mitigation.<sup>36</sup> Integration of EVs into the management of the grid, in California and elsewhere, would significantly offset the need to invest in stationary storage; EVs can also help provide voltage regulation and support frequency and ramp rate regulation.<sup>37</sup>

The key problem for the smart integration of EVs into the grid will be the construction of the necessary charging infrastructure, discussed later in this report.

## Smart (and) Microgrids – Bringing the Disruption Together

Distributed energy production (including both conventional and renewables) and storage, if located at a residence, office building, or commercial/industrial facility, would not in and of themselves transform the electricity industry — standing alone, that self-generation represents “only” a demand reduction to the traditional producers and transmission/distribution operators (although said reduction in itself is an economic problem for traditional utility companies).

But they do not stand alone; the disruptive factor is their increasing connectivity and integration into the traditional model, whether one-way through the traditional high-voltage transmission grid, two-ways in the new, smart, medium-voltage distribution network, or increasingly in medium- and even low-voltage microgrids.

### *Regional Transmission*

Just as batteries and other storage technologies shift the consumption of essentially effervescent electricity over time, high voltage transmission lines can smooth electricity generation and consumption over space. This traditional role of transmission lines becomes, as noted, even more important with the integration of utility-scale wind and solar generation, where peak supplies can far exceed local demand, swamping the system. In Europe,

<sup>36</sup> Jonathan Coignard et al., “Clean Vehicles as an Enabler for a Clean Electricity Grid,” *Environmental Research Letters*, 13 054031, May 16, 2018.

<sup>37</sup> Lisa Cohn, “How E-Vehicles Can Support the Grid and Utilities — and Why They Don’t,” *Microgrid Knowledge*, November 13, 2017.

major transmission lines feed Danish and German wind north to Nordic hydro-storage or south to Germany’s industrial heartland to offset this.

In both Europe and the United States, one of the bigger political obstacles to such efforts has been the organization of energy regulators along (member-) state lines, where the political geography does not necessarily mesh with the broader economic logic of the energy system. The United States has tried to address this to an extent by developing a system of Regional Transmission Organizations and Independent System Operators; nine RTOs/ISOs now serve two-thirds of electricity customers in the United States and more than fifty percent of Canada’s population.<sup>38</sup> Similarly, in Europe, the European Union actively finances and otherwise helps support the creation of large-scale, interregional transmission lines. And the European Network of Transmission System Operators–Electricity (ENTSO-E) has called for broader Regional Energy Forums to promote cross-border collaboration, if not actual regulation.<sup>39</sup>

These efforts to overcome political and administrative barriers to regional energy integration are important, not least as they can help resolve one of the major adverse impacts utility-scale renewables like offshore wind have on the grid. They again center around a more traditional one-way view of the electricity sector, however, and are not further considered here.

### *Smart Grids*

As noted above, the disruption digitalization brings to the energy sector is largely to the electricity distribution networks, the medium- and low-voltage areas where residential, office and commercial/industrial customers are not just consuming self-generated electricity, but are also transmitting surplus generation to the (local) electrical system through smart grids. With this, these customers become “prosumers,” distributed energy resources (DER) capable of contributing to the

<sup>38</sup> ISO/RTO Council, “The ISO/RTO Council,” <https://isorto.org>.

<sup>39</sup> European Network of Transmission System Operators for Electricity, “Power Regions for the Energy Union: Regional Energy Forums as the Way Ahead,” Policy Paper, October 2017.

### Smart electricity meter installations (2011-2016)

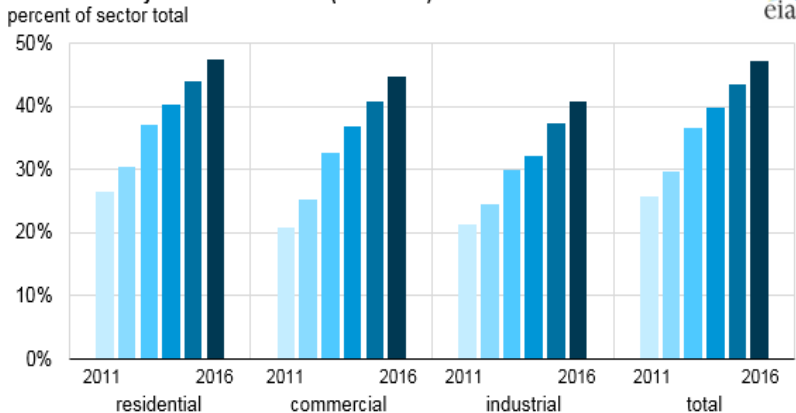


Figure 10. Smart Electricity Meter Installations, 2011-2016.  
Source: U.S. Energy Information Agency, “Nearly Half”

system as a whole — including as competitors to the traditional electricity-supplying industry, in particular the distribution system operators.

The key to this connection is smart meters. In the traditional energy paradigm, analog meters counted the one-way flow of electricity (as well as gas and water) to the customer; aggregated, this then formed the basis of periodic utility bills. Basic smart digital meters perform the same function, although they also record more granular data about the amount of electricity being consumed at any point in time and can more easily communicate this to the electricity supplier (even wirelessly). These automated meter reading devices thereby also allow more detailed bills and more sophisticated charging schemes. Time-of-use charging, for instance, is increasingly important in managing the integration of distributed energy resources into the broader electricity system. But this is largely a demand management function, explored in the next section, and in that sense less disruptive of the sector.

Here is where the promotion of distributed renewables production at the household and commercial/industrial level has made a real difference: Governments, especially in Europe and the United States, consciously promoted the installation of small-scale solar, wind, and other renewables resources to reduce greenhouse emissions. As part of these programs, they instructed utilities to buy the surplus energy that might be generated by these renewables installations, often specifying feed-in tariffs that the utilities had to pay. The main way to do this initially was for the utility itself to measure what

was coming back into the system. Increasingly, however, the prosumer wants to be in the lead. And for that, real smart meters are needed: advanced metering infrastructure (AMI) devices that can monitor both electricity consumption and supplies back to the network while doing net metering by subtracting the amount of surplus electricity generated at a site and fed back into the system from the amount consumed.

Deployment of such AMI is increasing in the United States: according to the Energy Information Agency, almost half (47 percent) of the 150 million electricity customers in the United States had AMI devices by the end of 2016, with the residential, commercial, and industrial sectors all evenly served. The 71 million deployments today are nearly double those in 2010. Naturally, the distribution of such devices in residences varies by state, but seven states and the District of Columbia have over 80 percent AMI coverage (see Figures 10, 11, and 12).<sup>40</sup>

The EU has set an ambitious goal of covering 80 percent of all Europe’s 281 million electricity customers by 2020, but this goal is unlikely to be reached. Publicly-available statistics on actual deployments of smart meters at the EU level are difficult to find, but a recent private sector report estimates that nearly 40 percent of customers had smart meters by the end of 2017, which should increase to 70 percent by 2023.<sup>41</sup> The Joint Research Center, whose interactive maps show the enabling environment for this development, shares this assessment.<sup>42</sup> Italy, which started first, has a 99 percent penetration, but these are primarily automated meter readers rather than AMI devices; ENEL reportedly plans to install 13 million second generation meters by 2020 and a further 28 million in the following decade. France and the U.K. are ramping up and expect some 10–13 million devices to be installed in the next two years, although the most recent U.K. government data shows that the 6.2 million smart meters that have been installed cover less than 25 percent of residences and small businesses. Germany, by

40 U.S. Energy Information Agency, “Nearly Half of All Electricity Customers Have Smart Meters,” <https://www.eia.gov/todayinenergy/detail.php?id=34012>, December 6, 2017.

41 Cision PR Newswire, “More Than 200 Million Households Will Have Smart Meters by 2023,” January 8, 2018.

42 European Commission Joint Research Center, “Smart Meter Deployment in the European Union,” <http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union>, updated regularly.

## A Local Energy Market for Flexibility in Cornwall

The Cornwall Local Energy Market (LEM) is a pioneer project led by Centrica's Distributed Energy & Power business and financed by the EU through the European Regional Development Fund (ERDF). To put it simply, the project is an eBay-style platform that facilitates the selling and buying of energy and flexibility on the distribution network. Along with its partners Western Power Distribution, National Grid, Imperial College London, and the University of Exeter, Centrica is testing the use of flexible demand, generation, and storage across both the domestic and business sectors.

**A VIRTUAL MARKETPLACE FOR FLEXIBILITY** The Cornwall LEM is a €22m program to explore flexible and smart energy solutions which will play an important role in supporting a secure, affordable, and lower carbon system for the Cornwall region and the U.K. Cornwall presented suitable conditions for the project. Cornwall is a region with a high level of distributed generation but with a constrained grid that generated issues for greater integration of renewable power into the grid. When the project was launched, 1.9 GW of renewables were stalled. To address this issue, the Cornwall LEM is developing a virtual marketplace that will provide participants with a platform to buy and sell energy and flexibility both at the local and national level. Centrica will be installing new generation and storage technology into Cornish businesses and homes as well as providing energy audits and grants for energy monitoring equipment. This will also allow Centrica to explore how individuals and businesses interact with the technology.

**PHYSICAL AND DIGITAL TECHNOLOGIES COMING TOGETHER** The trial is testing a variety of different technologies in both domestic and commercial environments so Centrica can learn how the local energy market platform will work in a wide range of circumstances. Businesses can offer their flexibility directly into the platform or through an aggregator, while the process of managing the flexibility in their batteries will be completely automated for homeowners. For instance, a business owner might combine existing on-site generation with a new energy storage unit and optimize their purchases from the grid utilizing time-of-use pricing, avoiding grid charges, or selling flexibility services to the local or national grid. The one hundred homes in the Cornwall trial will all be fitted with solar PV and batteries, enabling better self-consumption of PV generation and the automated dispatch of a fleet of domestic batteries for grid management services.

Centrica is building its own proprietary platform for the LEM. This platform allows market participants to bid and offer flexibility services via a centralized clearing engine. This platform thus enables the Distribution Network Operator or System Operator to procure services in an open, competitive market with multiple buyers and sellers, both over the medium term and intraday. The platform is currently undergoing beta testing and will go live in June 2018. Longer term, the platform seeks to support iOS, Android, and fully-fledged web applications with dynamic content.

far Europe's most important electricity market, has only just adopted enabling legislation that mandates smart meters only for the largest customers; some 23 percent of users are expected to have AMI by 2027.

One of the main functions performed by smart meters from the utilities' view is grid resilience — the two-way flow of signals informs utilities immediately where a fault has occurred on the grid, allowing them to send repair

crews quickly and, as discussed below, reroute electricity flows to restore power even before physical repairs are done.<sup>43</sup>

Smart meters, however, are only the beginning of the digital transformation, as in the first instance these regulate the relationship between the utility and the customer in essentially a hub and spoke system.

<sup>43</sup> Adam Cooper, "Electric Company Smart Grid Deployments: Foundation for a Smart Grid," Edison Foundation, Institute for Electric Innovation, December 2017.

But the broader connectivity enabled by digitalization is allowing newer market models to come to the fore, in particular by building platforms to aggregate the activity of, and among, prosumers. Beyond providing transparency into the system and greater customer empowerment, the new models allow much greater efficiency and resilience by bringing together and managing distributed energy resources, whether through virtual power plants, distributed energy resource management systems, microgrids, or eventually peer-to-peer trading.

### Virtual Power Plants

Utilities frequently deal with the problems associated with the integration of renewables — overload of input when the sun shines or the wind blows, and the need to ramp up production when these resources decline while evening peak demand rises — by either curtailing renewables production or turning on a fast-ramping gas turbines. A virtual power plant, in contrast, is an Advanced Distribution Management System software platform that aggregates and actively controls a range of distributed energy resources, primarily larger systems, and helps link wholesale and retail markets.<sup>44</sup> Both by balancing among generators (e.g., two large wind turbines) and calling on storage distributed through their asset base (possibly to include new installations, such as the REstore 32 megawatt battery installation mentioned earlier), they have the capacity to help utilities with demand response, peak-capacity management, frequency regulation, operational reserves, and pricing arbitrage. The efficiencies they get just by better managing existing assets suffice to substitute for a new peak generating plant — thus the name of a “virtual” power plant. Although most of those in existence are owned and operated by utilities, the application of these platforms is still relatively new, with approximately 65 percent of current capacity in the United States and another 30 percent in Europe (see Figure 13).

U.S. advanced electric utility meter adoption (2007-2016)

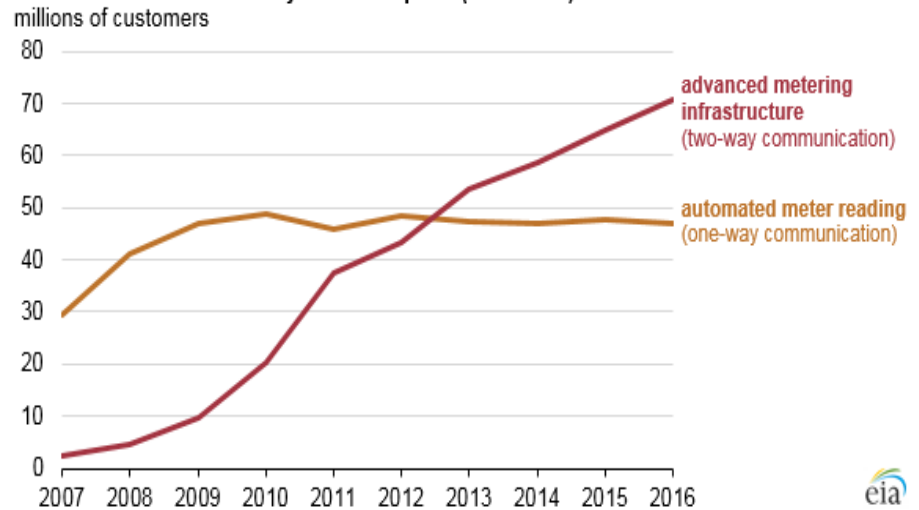


Figure 11. U.S. Advanced Electric Utility Meter Adoption, 2007-2016. Source: U.S. Energy Information Agency, “Nearly Half”

### DERMS

Distributed Energy Resource Management Systems (DERMS) are also software platforms that promote balancing in the system through aggregation but are focused on a specific location (akin to a distribution network) and can go deep into even behind-the-meter assets, such as heating and cooling equipment in an office building or a house. Indeed, as the number of smart appliances — those sending their own signals to the smart meter in the house, commercial establishment, factory, etc. — increases, the number of potential energy-generating, -using, and -storing devices that can become part of the Internet of energy system that will be part of the network will expand enormously. The DERMS take surplus power generated by many units and feed it to either where it is needed or into storage in multiple places (storage, from a stationary battery pack or plugged-in e-vehicles in the neighborhood),<sup>45</sup> and then call upon that reserve when demand rises later in the networked community. Because DERMS do not deal as much with large generating or storage distributed energy resources, they are better for voltage management, optimizing power flows, and local capacity balancing.<sup>46</sup>

44 See, for example, Navigant Research, “Virtual Power Plants,” <https://www.navigantresearch.com/wp-content/uploads/2013/03/VPP-13-Brochure.pdf>.

45 See Elisa Wood, “How Dynapower is Making Microgrids Less Complicated,” Microgrid Knowledge, June 6, 2017.

46 Energy Efficiency Markets, LLC, “Creating a 21st Century Utility Grid with DERMS and VPPs,” Microgrid Knowledge, June 11, 2018.



Residential smart meter adoption rates by state, 2016

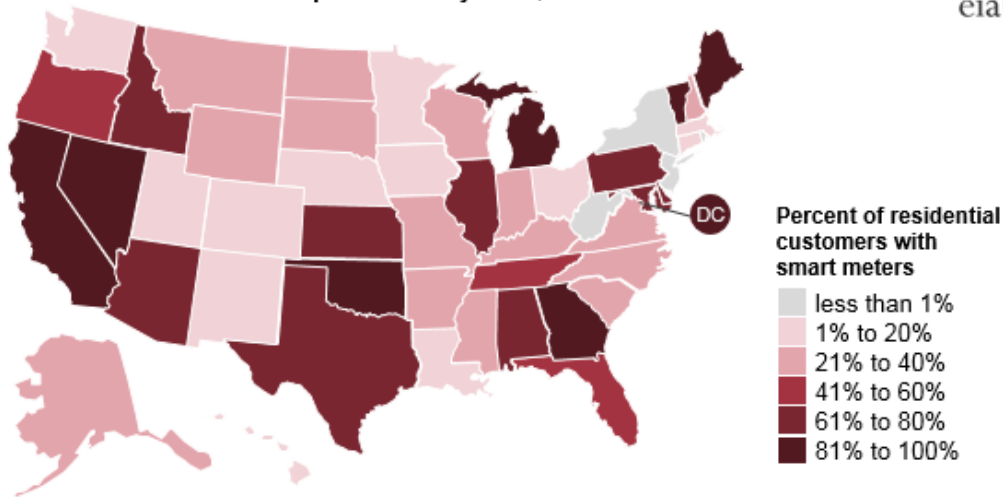


Figure 12. Residential Smart Meter Adoption Rates by State, 2016. Source: U.S. Energy Information Agency, “Nearly Half.”

**Microgrids**

A microgrid is in many ways a distributed energy resource management system — that is, a platform that uses digital technology to aggregate and manage local distributed energy resources — with the key distinction that a microgrid can operate independently of a broader grid, whether because of the site’s isolation (e.g., a smaller power source and grid on an island or other remote location), or, in the sense meant here, because it has the capacity to cut itself off from the larger grid of which it is a part (in other words, become “islanded”). This is particularly important to protect the participants in the microgrid from potential disruption should the larger grid for whatever reason encounter problems. The additional reliability a microgrid provides can also help enhance the broader resilience of the grid by making it easier to bring the grid back online after a problem.

Microgrids is something of a misnomer, as they can be of many different sizes and types. Other than the remote location model, the original concept of a microgrid was a separate generating turbine (often diesel) or plant (usually coal or gas) for a hospital, factory, airport, or other facility to both supply some of the facility’s energy needs and to be able to provide backup power in the event of an outage. In large part because of the power of digital platforms to aggregate and manage distributed energy resources, including renewables generation and storage, the model is spreading rapidly. This is especially true in the United States, where microgrids began on military bases and

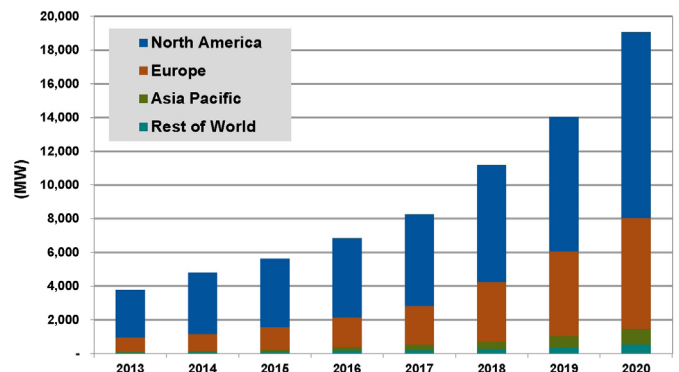
university campuses a few years ago and have expanded to commercial facilities and residential communities today.

Navigant Research, which has been tracking microgrids since 2011, counts 1869 planned and implemented microgrid projects with renewable power generation globally as of year-end 2017, representing 20.7 gigawatts of capacity. The Asia Pacific region has the largest share,

at 8.4 gigawatts; North America is next with 7.0 GW. Europe’s share slipped to 9 percent of the total, at 1.8 GW, as a number of projects were put on hold and as a new 2.2 GW development in Saudi Arabia shifted market shares.<sup>47</sup>

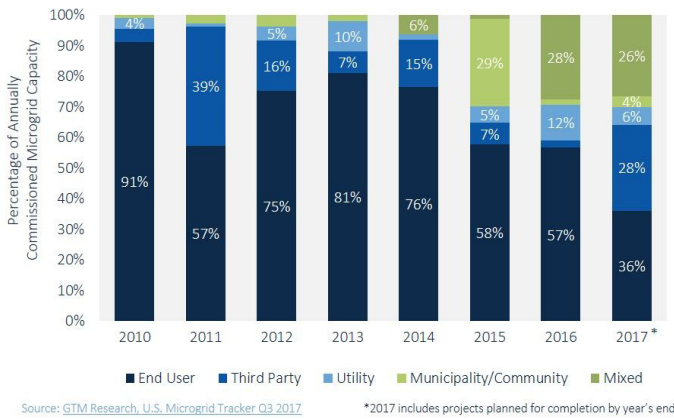
Because of the ever enlarging microgrid model, the distinction between virtual power plants (operating between the wholesale and retail levels), DERMS, and microgrids is blurring rapidly. In all three cases, the aggregation and management of distributed energy resources under a controlling platform looks, from the point of view of the broader grid, like a single point of electricity supply and demand. But while the first two

Figure 13. Total Virtual Power Plant Capacity by Region, Average Scenario, World Markets: 2013-2020. Source: Navigant Research, “Virtual Power Plants.”



<sup>47</sup> See Elisa Wood, “How Many Microgrids are There Exactly,” Microgrid Knowledge, January 31, 2018.

Annually Commissioned Microgrids Capacity by Ownership, 2010-2017



Annually Commissioned Count by Ownership, 2010-2017

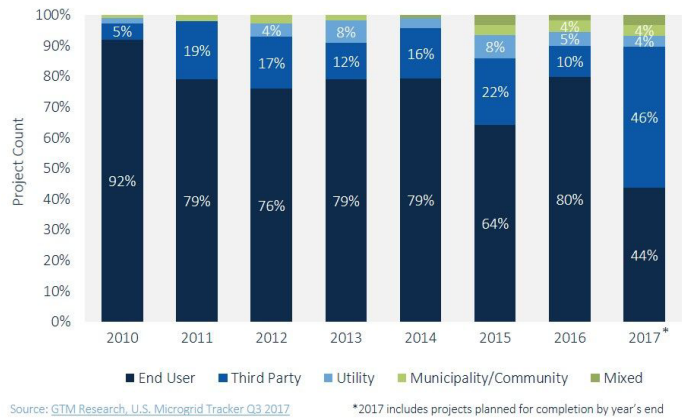


Figure 14. Annually Commissioned Microgrids Capacity by Ownership (left) and Annually Commissioned Count by Ownership (right), 2010-2017. Source: Metelista, “New Business Models.”

are associated here with transmission and distribution network operators, microgrids need not be, and frequently are not.

Further, the ownership models of microgrids — at least in the United States — are shifting. According to Greentech Media (which uses a slightly different definition of microgrid and focuses on those in operation as opposed Navigant’s inclusion of projects being built), the “end user” model (traditional back-up power, e.g., on campuses and military installations) is declining dramatically while third-party owned and operated and multi-stakeholder models (which may include utilities companies) are increasing.<sup>48</sup> These newer models provide microgrids as a service, and have increasing appeal due to the spreading of the initial capital investment among partners, as well as the reliability and resilience microgrids represent in the face of aging and exposed infrastructure and weather-induced outages. This reliability factor is also one reason that commercial and industrial demand for multi-stakeholder microgrids, which had been held back by uncertain returns, is expected to burgeon in the future.<sup>49</sup>

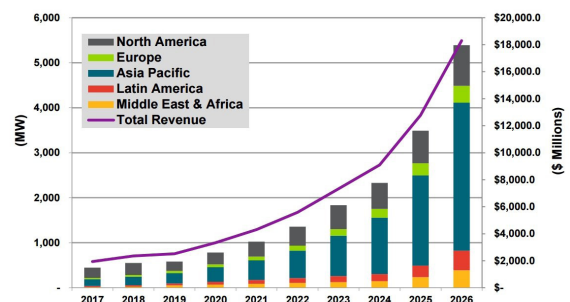
48 Colleen Metelista, “New Business Models Gain Strength with Renewed Interest in Microgrids,” Greentech Media, January 18, 2018.

49 Peter Asmus, “C&I Microgrids,” Navigant Research, Second Quarter 2017.

That said, these new microgrid arrangements usually operate with the grid and rarely go offline. In that sense they are really an embedded smart network (that is, a non-utility DERMS) where the islanding capability is arguably not needed. Indeed, a recent study of three different urban use cases for microgrids — an “eco-district” in San Diego, CA, a regional airport in France, and an industrial site in Germany — found that microgrid functionalities could be installed and operated more quickly and efficiently without the costly equipment needed to ensure smooth islanding. This is particularly true of arrangements based solely on renewables generation and storage.<sup>50</sup>

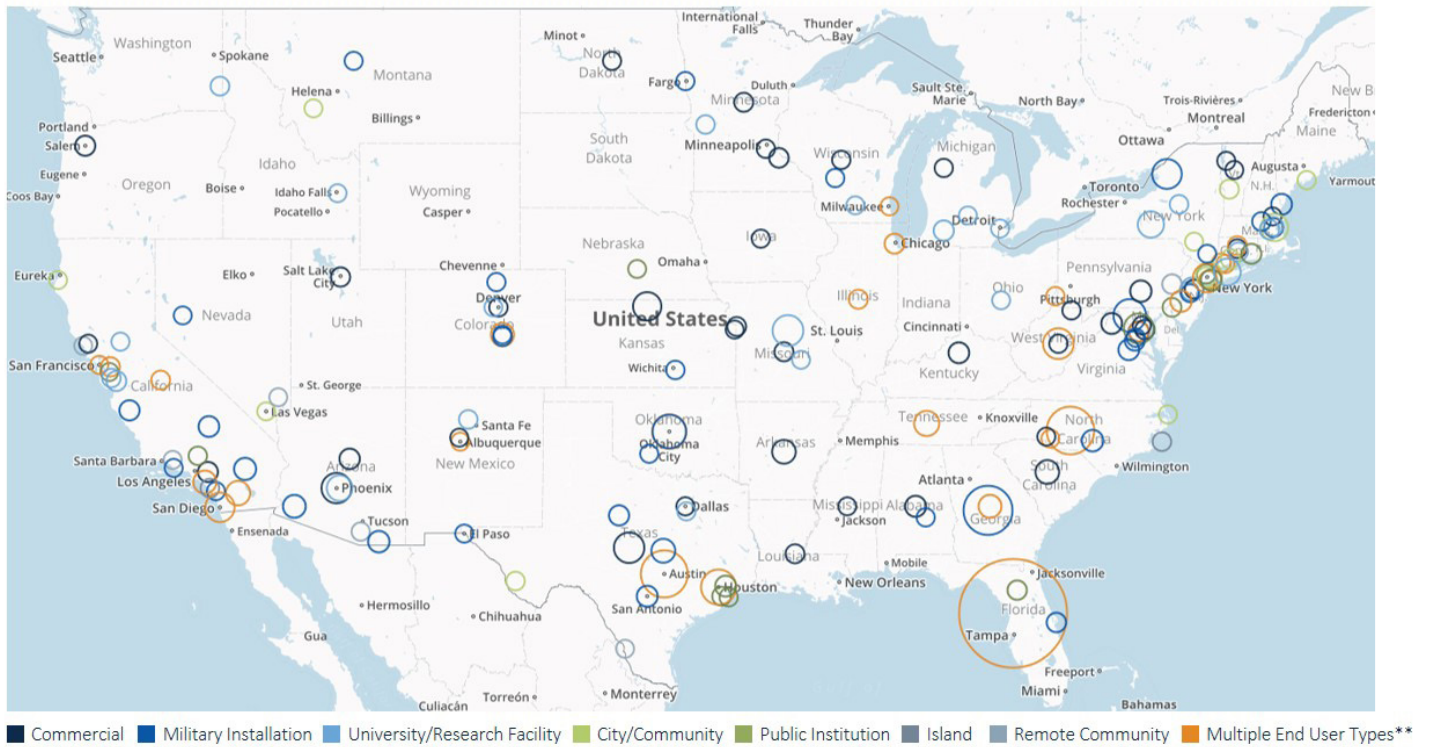
The microgrid network in the United States is leading the way in bringing together wider networks of distributed energy resources, as shown by the Greentech Media Research map (Figure 16).

Figure 15. Total C&I Microgrid Capacity and Implementation Spending by Region, World Markets, 2017-2026. Source: Asmus, “C&I Microgrids.”



50 Maeve Faure et al., “Urban Microgrids: Overview, Challenges, and Opportunities,” ENEA Consulting, February 2018.

## Map of Operational Microgrid Deployments by End-User Type Across the Continental U.S.\*



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

\* The size of the bubbles correspond with the total capacity (MW) installed in that location.

\*\* Microgrids are mapped based on city location; when multiple microgrids are in the same city they may get the multiple end user designation. In some cases for data privacy, data is given at a state or national level. In these cases, the microgrids are mapped at the center of the state.

Figure 16. Map of Operational Microgrid Deployments by End-User Type Across the Continental U.S. Source: GTM Research, U.S. Microgrid Tracker, Third Quarter 2017.

One interesting development implied by the map is that there is now a growing incidence of a set of microgrids (each able to function separately) being nested in a larger microgrid, which is where the microgrid and virtual power plant models are beginning to merge. This grid of grids concept is also arguably related to the idea that microgrids — with their single point of contact to the surrounding grid — increasingly can and will use the Federal Energy Regulatory Commission’s new rule on the participation of batteries into the grid (mentioned above) to mobilize distributed storage resources to act as a larger battery for their local utility.<sup>51</sup>

### *Transactive Energy, Peer-to-Peer Trading, and Blockchain*

In every virtual power plant, DERMS, microgrid, or embedded smart network (often organized by an aggregator), there is a software platform enabling trading of surplus energy and storage resources among hundreds or thousands of residences, businesses, and factories as it uses bidirectional energy flows to balance supply and demand among its constituent units, as well as between them collectively and the larger grid of which they are a part (assuming it is not a remote microgrid).

These transactions could be purely technical efforts to balance the system, but value is also being created between the buyers and sellers of the electricity. In most cases, the platform managing the system should be able to use dynamic pricing based on the internal balances in the system and/or in relation to the grid to which it is connected. The pricing should not just reflect the price balancing marginal supply and demand, but also the broader value to the electricity system, including

51 Elisa Wood, “Energy Storage in Wholesale Markets: Microgrids as Big Batteries?” Microgrid Knowledge, February 21, 2017.

the price of building, maintaining, and optimizing the transmission network, as well as other reliability and capacity considerations.<sup>52</sup>

More direct peer-to-peer transactive energy — that is, power directly exchanged among individual participants rather than over a platform — is still in the pilot phase. Navigant expects Australia and Germany will be the first to move to larger-scale deployment, along with states like California and New York in the United States, as in these markets regulators see the benefit of encouraging market-based returns (rather than subsidies) to promote distributed energy resources.<sup>53</sup>

But there is increasingly talk of using blockchain — which most people think of as a digital currency but is essentially a distributed ledger technology — to help record, aggregate, and monetize the thousands of transactions that might take place within the systems, better enabling peer-to-peer trading between its constituent parts. Encrypted blockchain ledgers securely and autonomously authenticate, send, execute, verify,

52 Jeff St. John, “A How-To Guide for Transactive Energy,” Greentech Media, November 30, 2013; The GridWise Architecture Council, “GridWise Transactive Energy Framework,” [https://www.gridwiseac.org/pdfs/te\\_framework\\_report\\_pnnl-22946.pdf](https://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf), January 2015.

53 Navigant Research, “Transactive Energy Markets,” <https://www.navigantresearch.com/research/transactive-energy-markets>, Second Quarter 2018.

and confirm transactions under standardized contracts between two points engaged in a transaction, allowing one participant in the electricity system to sell solar power or storage capacity to another, whether through the grid controller (as in Figure X) or directly to another participant in the system. This distributed ledger system may be permissioned — that is, closed to a defined group of participants who access the ledger — or public, and it may have a virtual coin or token attached to it, as demonstrated, for instance, by SolarCoin.

The first operational pilot of the use of blockchain technology in peer-to-peer electricity trading was in 2016 with LO3 and Siemens in the Brooklyn Microgrid, which started with three residences with solar panels selling to neighboring apartment buildings. A number of pilot projects have developed since. LO3, after securing investment by Centrica Innovations in 2017, began applying blockchain on a pilot basis to one hundred homes and one hundred businesses at the Cornwall microgrid project discussed above; in another example, Vattenfall and 22 other European power and energy trading companies formed one of the largest blockchain-enabled peer-to-peer energy trading platforms last year.<sup>54</sup> And German utility TenneT has teamed up with the firm sonnen in the first blockchain-

54 Andrew Burger, “Twenty-Three European Energy Companies to Launch Blockchain Distributed Energy Trading Trial,” Microgrid Media, June 13, 2017.

## Trading Renewable Energy on Blockchain in Hackney, London

In the London Borough of Hackney, the team of Verv executed the U.K.’s first physical peer-to-peer energy trades via blockchain technology on April 11, 2018. The trial, still in its first phase, will enable residents to benefit from local renewable energy sources and bring down energy bills, with a view to creating a fully empowered, ideally self-sustaining community.

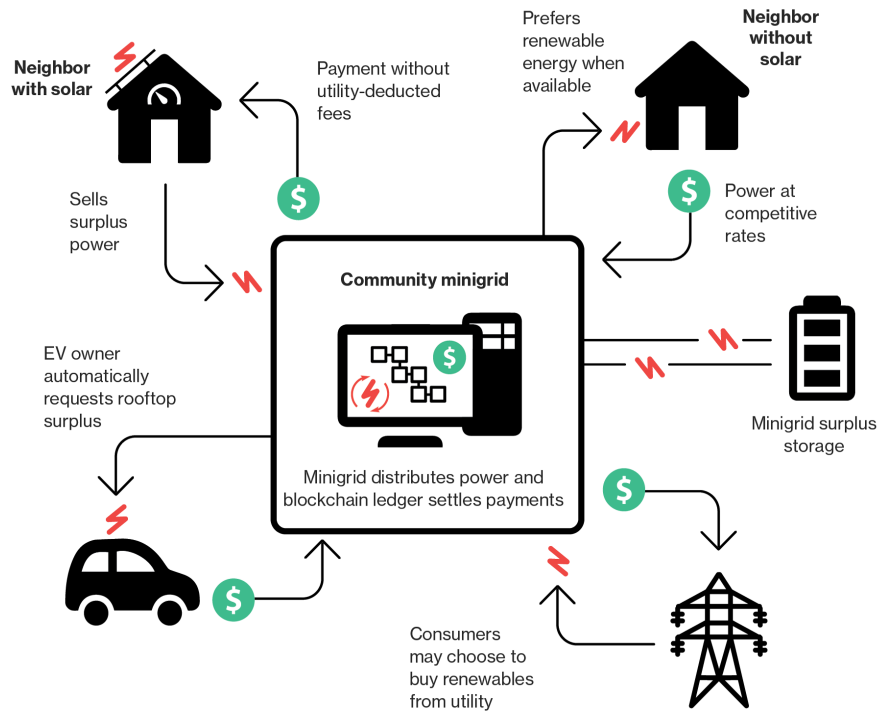
This first trade took place at the Hackney Banister House Estate, which has solar panels installed on 13 of its apartment buildings, Verv smart hubs in the residents’ flats, and Powervault batteries in communal areas. Using artificial intelligence, the Verv meters identify appliances in customers’ homes by their unique energy signatures and tells the customers how much each costs to use. The longer Verv is installed, the more insights it develops about new appliances and their behaviors, unlocking new features such as alerts if an appliance is turned on for too long or the prediction of potential faults. Customers who produce their own green energy can sell excess power directly to their neighbors via blockchain technology, turning them into prosumers. Verv’s machine-learning functionality enables it to predict the supply and demand of power, facilitating the advance trading of electricity to achieve best prices. This green power is cheaper, and prosumers receive a better payback than they would from a feed-in tariff, further incentivizing installation of renewable infrastructure and storage. Such appliance level data coupled with peer-to-peer technology could help provide improved opportunity for optimized energy usage in the home, demonstrating the power of data applications in the energy sector.

enabled experiment in Europe geared toward using the distributed home energy storage capacity in the sonnenCommunity to mitigate wind power curtailment.<sup>55</sup>

For all the recent focus, however, blockchains may not always be the best solution in the electricity market, for at least one reason: Unlike blockchain currencies, electrons move on a physical infrastructure, with all the constraints that implies.<sup>56</sup> Given the transmission system operators' responsibility for the grid, closed/permissioned block chain may also be advisable, as this limits participation only to customers in a specific area. One of the advocates of the use of blockchain in electricity, the Energy Web Foundation, agrees that currently the main market for this application may be in the trade of renewable energy certificates, which is effectively what LO3 did in the Brooklyn Microgrid.

### Community Minigrad as Central Payment and Power Control

A blockchain ledger system can be used to trade power between consumers without a utility even knowing it.



Source: Bloomberg New Energy Finance

Bloomberg

## Demand Management

Demand management — and specifically contracted demand response — has long been a tradition in the electricity sector, even in the old, one-way model: Power production and consumption must be balanced at all times, so utilities frequently needed to call on large customers to curtail consumption during times of peak demand and concluded demand response agreements with them to compensate them for doing so. Digitalization has changed this and just about everything else on the demand side of the energy equation as well.

Indeed, discussions of the digitalization of the energy sector often start with demand management, as in many ways this is where digitalization first appeared — with the introduction of (first generation) smart meters for both gas and electricity. As noted above, digital meters allowed companies to get more frequent and reliable readings of energy consumption for billing purposes, but they were

<sup>55</sup> TenneT News, "Europe's First Blockchain Project to Stabilize the Grid Launches: Tennet and sonnen Expect Results in 2018," November 2, 2017.

<sup>56</sup> Rachel Ett, "Reality Check: Blockchain Needs Proof of Concept Before Revolutionizing the Grid," Greentech Media, June 14, 2018.

Figure 17. Community Minigrad as Central Payment and Power Control. Source: Chris Martin, "How Blockchain Is Threatening to Kill the Traditional Utility," Bloomberg, April 9, 2018.

also quickly seen as a way to make consumers more conscious about energy use and provide incentives for greater energy efficiency.

And indeed, better informing consumers about their electricity bill does tend to reduce consumption. But smart meters also expand this by enabling dynamic pricing, which varies to reflect supply and demand on the grid at different points in the day, and can be a critical additional signal to motivate both demand reduction and load shifting, especially in a world of variable renewable energy generation.

Demand management happens both at the commercial/ industrial scale as well as at the residential and small business levels. The former can be and often is under formal contractual demand response terms with the supplying grid, although digitalization and larger-scale on-site generation and storage have significantly broadened the range of options and activities that can be provided to include not just load reduction but

also ramping capacity, frequency control, and other services back to the grid. On the smaller scale, demand response by individual units will tend to be in response to price signals, although microgrids and third-party aggregators can raise participation to the broader commercial scale. On both levels, as the meters, controls and other devices have become smarter and better at measuring electricity use at a granular level — water heater electricity consumption in a residence, lights or thermostat in an office building, a specific piece of equipment in a factory or warehouse — the ability to eke out even minute efficiencies by regulating energy use in these specific applications and to aggregate the cost savings in a way that can provide remuneration has grown significantly. All this is and will put downward pressures on overall demand, just as new sources of distributed supply and storage come on stream.

### ***Residential and Small Business***

Statistically demonstrating the impact of demand management in either Europe or the United States is difficult, as consumption foregone or deferred is not measurable.<sup>57</sup> But in the United States, millions of customers who have smart meters have enrolled in time-based pricing programs that reward them for voluntarily reducing consumption when the demand for electricity is high. Similarly, in the EU, member states have adopted regulations pursuant to EU directives that allow for frequent enough readings of the smart meters to use energy efficiency dynamic pricing schemes.<sup>58</sup> This can be particularly important for those who have e-vehicles and can defer recharging to early morning hours rather than simply plugging them in at peak evening times.<sup>59</sup> This will be especially important if, as Navigant expects, annual electricity demand from e-vehicles could exceed

57 The Edison Foundation Institute for Electric Innovation reports that energy efficiency programs in the United States saved 183 terawatt hours in 2016, avoiding the generation of 136 million metric tons of carbon dioxide and saving enough to power 20 million homes for a year, but these numbers cover large-scale demand reduction contracts as well as residential energy efficiency programs. Adam Cooper, "Energy Efficiency Trends in the Electric Power Industry," Edison Foundation, December 2017.

58 Joint Research Center, Smart Electricity Systems and Interoperability, Smart Metering Deployment in the European Union, Interactive Map, <http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union>, accessed June 14, 2018.

59 Adam Cooper, "Electric Company Smart Grid Deployments: Foundation for a Smart Grid," Edison Foundation, Institute for Electric Innovation, December 2017, which also notes the numerous other consumer advantages smart meters provide, including notifications of power outages, remote connection and disconnection, budgeting options, high-use notifications, pay-as-you-go options, and decision support tools.

400 terawatt hours by 2035. Studies conducted in the U.K. in 2014 showed that just time-of-use pricing could reduce peak demand by 5–10 percent today.<sup>60</sup>

Such price-based implicit demand response, even where technically possible and legally available, may not always be actively utilized by the consumers at the residential and small business level, because consumers may prefer the status quo, do not have money to invest in a smart thermostat or other controls that automatically adjust temperature and other energy use, or do not have the interest or ability to actively manage their own consumption.

Smart digitally-enabled devices, however, can also be controlled through bidirectional smart meters, allowing the consumer to reap the demand reduction and time-shift benefits demand flexibility can provide by giving another party the ability to manage it. A new study by a major U.S. based energy policy think tank, for instance, demonstrates how a utility that can control eight major residential and commercial end-use loads can save households 10–40 percent on their bills while at the same time helping the distribution system lower peak demand net of renewables by 24 percent, reduce the magnitude of ramping up in the evening hours by 56 percent, reduce renewable curtailment by 40 percent (in a renewables rich environment), and raise the value of renewables generation by 36 percent.<sup>61</sup> (The eight applications were residential and commercial electric water heaters, electric vehicle charging, resident and commercial space heating, residential plug loads (small appliances), and residential and commercial cooling.) A 2016 study by CE Delft similarly reportedly demonstrates that by 2030 demand flexibility in European homes for only water heaters, e-vehicles, and stationary batteries could technically reach 191 gigawatts; to put that in perspective, this is three times the U.K. fossil fuel generating capacity.<sup>62</sup>

Demand flexibility services like this can be contracted with customers by the local utilities but they can also be provided by microgrid and other aggregators —

60 Low Carbon London, Residential Consumer Responsiveness to Time Varying Pricing, September 2014.

61 Cara Goldenberg et al., "Demand Flexibility: The Key to Enabling a Low-Cost, Low-Carbon Grid," Rocky Mountain Institute, February 2018.

62 See Smart Energy Demand Coalition, "Empowering Residential and SME Consumers," October 2016, 6, citing Bettina Kampman et al., "The Potential of Energy Citizens in the European Union," CE Delft, September 2016.

that is, third parties who can use a software platform that reaches in to remotely control a wide range of energy-using devices (or more generally, any on-site distributed energy resource, including generation and storage) owned by a number of customers and contract those out as a single demand response service to the local utility.

European consumers have reportedly not taken up sophisticated demand management arrangements in large numbers, in part because the financial incentives are too low, and in part because of barriers to demand aggregation, especially by third parties.<sup>63</sup> They nonetheless appear ready to accept the notion of electricity demand flexibility in response to dynamic pricing, including through third-party aggregators, but with caveats. In particular, they want consumers to be able to remain on traditional stable pricing contracts; to benefit financially from the demand flexibility they bring to the system; to be protected from price shocks, through national regulator supervision of demand flexibility providers; to have the right and ability through common standards to easily switch providers; and importantly, to ensure their privacy is protected.<sup>64</sup>

- ★ Commercially active, standardised arrangements between BRP and aggregator in place
- Commercially active
- Partial opening
- Preliminary development
- Closed
- Not assessed

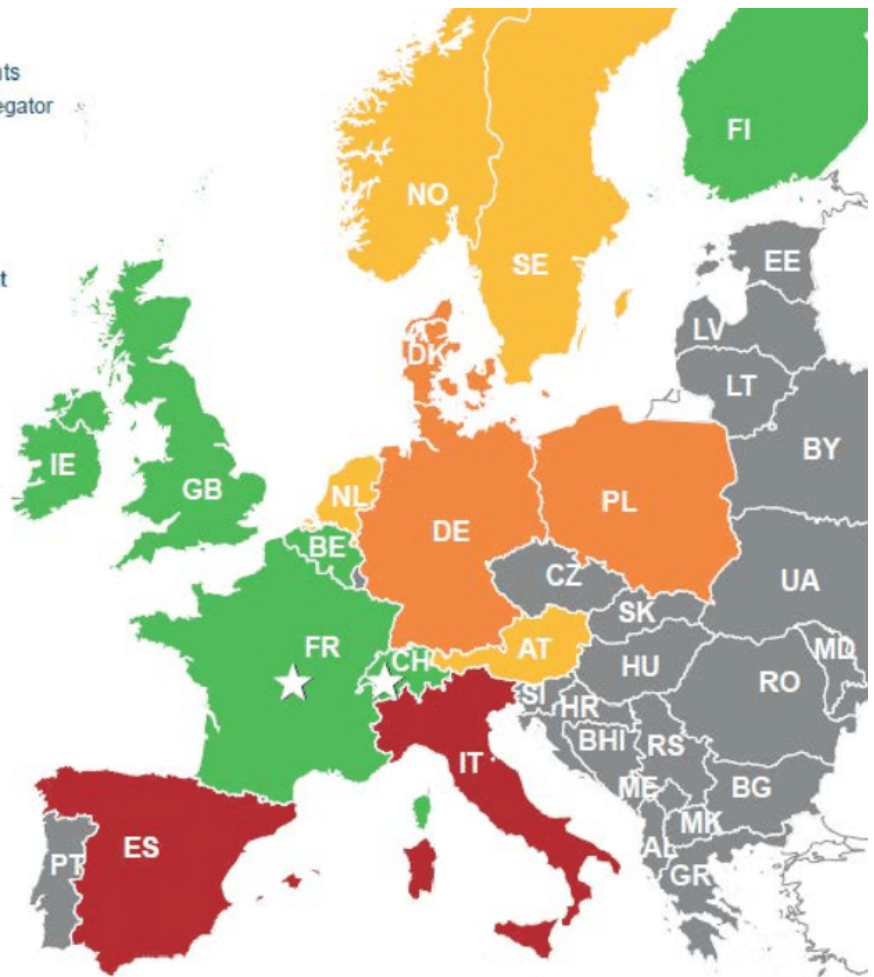


Figure 18. Map of Explicit Demand Response Development in Europe Today. Source: Smart Energy Demand Coalition, “Explicit Energy Demand Response.”

### Commercial and Industrial Demand Response

On the broader contracted demand response side, commercial and industrial customers have long invested in smart technologies to reduce their electricity bills; the benefits go straight to the bottom line. But they are increasingly also investing in larger storage units, both to provide reliability in the event of a problem in electricity provision, but also as part of a broader demand management approach they can offer to utilities.<sup>65</sup> If the unit absorbs surplus energy from the system during times of peak renewables generation, it can then shed

<sup>63</sup> Smart Energy Demand Coalition, “Empowering.”

<sup>64</sup> The European Consumer Organization (BEUC), “Making Electricity Use Smart and Flexible,” April 2017.

<sup>65</sup> See, e.g., Colin Neagle, “Unlocking the Financial Advantage of Behind-the-Meter Storage,” Microgrid Knowledge, April 5, 2018.

some of this as part of a facility's demand response contract with the utility, thereby mitigating the impact of that curtailed supply on operations. It can also take better advantage of time-of-use charging to ensure that the facility uses stored energy during times of higher prices, while calling on the grid otherwise. This also helps manage demand charges that U.S. utilities levy based on the amount of energy commercial customers use during peak demand times. These can be significant: the National Renewables Energy Laboratory estimates that nearly 5 million of the 18 million commercial customers in the United States face demand charges of over \$15/kWh, making battery storage for this purpose a good return on investment.<sup>66</sup>

Entrepreneurs are also getting into storage as a demand service. As one example, the French firm Actility contracted with Orange Telecom in France to be able to use the 8000 batteries Orange has to supply emergency backup power to provide demand response services to transmission systems operator RTE as well as distributor Enedis, a service that has been used to provide temporary added power to systems of up to 15 megawatts.<sup>67</sup>

The regulatory environment, however, must enable the use of demand response for it to contribute fully to the system. While the EU framework is improving, there appear to be both de jure and de facto barriers to full use of this instrument. The Smart Energy Demand Coalition, now known as smartEN, has been mapping this regulatory environment in Europe every two years for some time, based on the metrics of demand response access to markets, service providers access to markets, product requirements and measurement, and verification, payments and penalties. In its most recent report from April 2017 it notes progress in all 18 countries surveyed. Belgium, Finland, France, Ireland, Switzerland, and the United Kingdom get top ranks; in each, third-party aggregators have access to provide at least some services. Countries like Austria, Denmark, Germany, the Netherlands, Norway, and Sweden are open to demand response in principle; they seem to have programs that block demand side participation, and the role of various actors is unclear. (Germany

66 Seth Mullendore, "Identifying Potential Markets for Behind-the-Meter Battery Energy Storage," National Renewable Energy Laboratory, August 2017.

67 Lisa Cohn, "Distributed Energy Storage Provides Back-Up Services Via 8000 Batteries," Microgrid Knowledge, April 7, 2017.

moved from category 3 to 2 since the prior report in part as product definitions had been updated and balancing reserve markets were opened to aggregators.) Italy was credited with slowly starting to take steps needed.<sup>68</sup>

In sum, while demand reduction and management technologies, systems, and models are available at both the residential and commercial/industrial levels, their full potential remains untapped.

## Structural Disruption of Digital Transformation

Traditional utilities in Europe and the United States are under stress. Having lost some of their monopoly powers as power generation and certain distribution markets were opened to competition through actions from above, they are now facing pressures from below. The massive introduction of variable renewable energy, both utility-scale and distributed; the dramatic decline in the cost and technological quality of renewable installations; similar substantial progress in the costs and capabilities of storage; and the leaps in computing and sensing power to unite these distributed energy resources are both undermining their traditional business models and allowing new players to enter both wholesale and retail markets.

The digitalization of the energy sector per se did not cause all these new pressures; indeed, in important ways it is a tool that can mitigate them. But the economic trends digitalization is spurring will worsen the situation for many traditional energy providers; the key will be their ability to adapt.

Utilities are based on huge capital expenditures — in enormous centralized power plants, in large backup (frequently gas) power plants for peak and ramping purposes, in expensive transmission lines, and in all the substations, transformers, and wires that bring the electricity to the final customer. This equipment lasts

68 Smart Energy Demand Coalition, "Explicit Energy Demand Response in Europe: Mapping the Markets 2017," April 6, 2017. This was also the thrust of remarks by Ronnie Belmas, chief executive officer of Energyville, professor at KU Leuven, and chairman of the Smart Grids Coalition in a May 30, 2017, workshop organized for the European Parliament's Committee on Industry, Research, and Energy: European Parliament, Report Proceedings, "The Potential of Electricity Demand and Response," [http://www.europarl.europa.eu/RegData/etudes/STUD/2017/607322/IPOL\\_STU\(2017\)607322\\_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2017/607322/IPOL_STU(2017)607322_EN.pdf), 2017.



decades, and utilities naturally need long time horizons, often two to three decades, to plan new investments and upgrades. Further, as their sales prices are often regulated, their pricing is determined by the rate of return needed to ensure they have the funds to make these big investments. If they do not invest, they cannot justify rate increases. Where the utilities are investor-owned rather than public, they must ensure that they have investments to sustain these revenues.

All these factors are failing them. Indeed, there is a fear of a utility death spiral, under which distributed generation, storage, and demand reduction through efficiencies forces utilities to raise costs on a smaller customer base, leading an increasing number of customers to go offline by investing in their own generation, storage, and efficiency. Indeed, this points back to the three tipping points mentioned earlier:

- when off-grid energy reaches cost and performance parity with grid-delivered electricity;
- when electric vehicles (as distributed storage) reach price and performance parity with internal combustion engine vehicles; and
- when the cost of transporting electricity exceeds the cost of generating and storing it locally.<sup>69</sup>

On the demand side, even with the increase in applications being electrified (notably e-vehicles), demand for electricity from utilities is stagnating.<sup>70</sup> And it is likely to stay that way as the costs for the alternatives to traditional power supply decline dramatically. Utilities are accordingly being forced to revise their long-term investment forecasts. As an example: the sprawling Tennessee Valley Authority, the largest publicly-owned utility in the United States serving nine million customers in seven states, forecasted declining demand in its last long-term plan from 2015; only three years later, it has had to revise its forecasts downward even further, so that it now projects it will sell 13 percent less power in 2027 than it did in 1997.

69 EYGM Limited, "When Energy Consumers Go Off-Grid, Will Utilities Be Left in the Dark?" January 18, 2018.

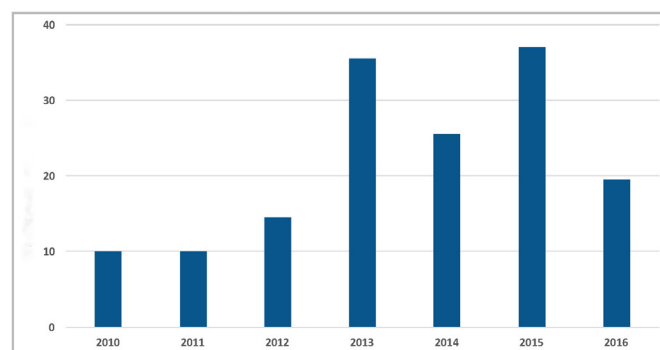
70 David Roberts, "After Rising for 100 Years, Demand for Electricity Is Flat. Utilities Are Freaking Out," *Vox*, February 27, 2018.

This decline in demand is compounded on the revenue side by the impact of renewables, which because of their low marginal cost take precedence in the electricity supply system for providing power above the baseload, thus driving down wholesale prices for electricity. This severely undermines utilities' investments in large thermal power plants.

Indeed, the IEA estimated that European utilities wrote off €150 billion in large traditional generating plants between 2010 and 2016. This magnitude of write-off forced even the most powerful utilities in Germany, RWE and E.ON, to reorganize in 2016. RWE closed 12 GW of capacity between 2012 and 2016, taking impairments of about €16 billion during that period, and placed its renewables business in a new company, Innogy. E.ON, with €24 billion in impairments, took the opposite tack and put its thermal business into Uniper.<sup>71</sup>

Further, because the prices of these new technologies and systems are falling more rapidly than expected, they are increasingly undermining the rationale for many of the long-term investments utilities make in thermal power plants. For instance, Navigant's forecasts imply that distributed generation, energy efficiency, demand response, and e-vehicles could reasonably be expected to reduce the volume of electricity going through bulk transmission (and thus centralized generation) by half by 2030.<sup>72</sup> The risk of stranded assets — which eventually become impairments — is real.<sup>73</sup>

Figure 19. Asset Write-Downs by European Utilities in Billions USD, 2010-2016. Source: International Energy Agency, as cited in Buckley and Nicholas, "Global Electricity."



Source: IEA

71 Tim Buckley and Simon Nicholas, "Global Electricity Utilities in Transition: Leaders and Laggards — 11 Case Studies," Institute for Energy Economics and Financial Analysis, October 2017.

72 Mackinnon Lawrence et al., "Energy Cloud 4.0: Capturing the Business Value through Disruptive Energy Platforms," Navigant Research, First Quarter 2018.

73 See discussion of the economics of solar plus storage earlier in the report.

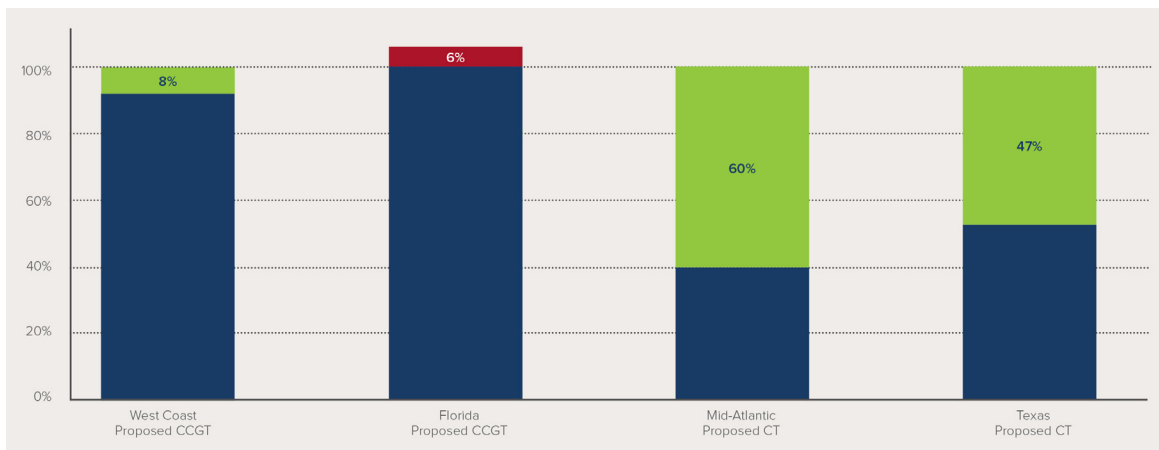


Figure 20. Net Costs of Clean Energy Portfolios Across Four Case Studies, Relative to Proposed Gas-Fired Power Plants. Source: Dyson et al., “Economics.”

In Colorado, Xcel Energy’s local subsidiary in December 2017 published a report on the 430 bids it received for 238 separate projects to fulfill its near-term energy requirements. 350 of these involved renewables, representing 100 gigawatts of capacity. According to a recent analysis of those bids, “the median bid for a wind project was \$18.10/MWh; the median for wind plus storage was \$21, just \$3 higher. The median bid for a solar PV project was \$29.50/MWh; the median bid for solar plus storage was \$36, just \$7 higher. ... Based on these bids, new wind and storage in Colorado is cheaper than energy from the state’s existing coal plants; solar plus storage is cheaper than 75 percent of the state’s coal energy.”<sup>74</sup> This underscores the importance of the decline in the cost of storage.

Similarly, a new detailed report by Rocky Mountain Institute (RMI) shows how in four specific case studies a “clean energy portfolio” including renewables generation, storage, demand response, and residential and commercial energy efficiency using existing technologies can be cheaper than gas-fired power plants, even with the low cost of natural gas in the United States today: “Thus, the \$112 billion of gas-fired power plants currently proposed or under construction, along with \$32 billion of proposed gas pipelines to serve these power plants, are already at risk of becoming stranded assets.”<sup>75</sup>

74 David Roberts, “In Colorado, a Glimpse of Renewables’ Insanely Cheap Future,” Vox, January 16, 2018.

75 Mark Dyson, Jamil Farbes, and Alexander Engel, “The Economics of Clean Energy Portfolios: How Renewable and Distributed Energy Resources Are Outcompeting and Can Strain Investment in Natural Gas-Fired Generation,” Rocky Mountain Institute, 2018.

This economic risk to long-term investments in the energy sector is increasingly encouraging (if not forcing) energy utilities to look for “non-wires alternatives” to their infrastructure investment, even though this can

directly affect their rate base. The RMI paper notes a number of projects being reconsidered in light of the changing economics in the United States.

Both examples also underscore that storage and other digitally-enabled distributed energy technologies mitigate what had been considered a vulnerability to renewables: their tendency to flood into a regional market at the same time. This would drive down wholesale prices, such that at some point adding new renewables capacity would no longer be economic. With storage and other distributed resources helping smooth out the supply of the solar or wind generation over time, the economic carrying capacity of renewables is increased.<sup>76</sup> The use of distributed resources — including, for instance, batteries, e-vehicles, and heat pumps in residences in Denmark — to manage the integration of high levels of renewables into the grid is and will become increasingly important to protect the reliability of the system as well. Indeed, a recent investigation of nine case studies demonstrates that networked distributed energy resources help systems with high penetrations of renewables to be as and sometimes even more reliable — in terms of outages, congestion, and curtailment — than normal grids.<sup>77</sup>

This is where the importance of digital platforms plays an increasingly important role and where new players are increasingly entering the market. As distributed resources in the system are bundled, they create an even more powerful balancing tool — as noted in

76 See, for example, David Roberts, “The Economic Limitations of Wind and Solar,” Vox, June 24, 2015.

77 Gerard Wynn, “Power Industry Transition, Here and Now: Wind and Solar Won’t Break the Grid — Nine Case Studies,” Institute for Energy Economics and Financial Analysis, February 2018. The case studies include Denmark, Ireland, Germany, Spain, Texas, and California, where renewables penetration ranges from 15–53 percent.

the discussion of microgrids as batteries above. This despite the fact the nearly two-thirds of utility executives surveyed by Accenture in mid-2017 felt that small-scale distributed generation would stress their networks and create reliability problems through backflow of power into distribution substations and voltage issues.<sup>78</sup>

In its new white paper on the “Energy Cloud 4.0,” Navigant underscores these opportunities to “capture business value through disruptive energy platforms.” The rise of distributed energy resources is pushing the value of the electricity system toward retail markets and consumers, including significant commercial and industrial customers, who are less concerned about the firm they buy from than the value they receive. This provides “fertile ground for customer-centric, cash-rich, and digitally savvy companies to capitalize on emerging technology and customer ecosystems.”<sup>79</sup> Those that have already entered the fray are neatly summed up in Figure 21.

The Navigant report, which is essentially an advisory signal to traditional utilities, highlights that these opportunities for value-added services are in the areas of integration of distributed energy resources, connecting the transportation sector (e-vehicles) to the grid, connecting commercial buildings to the grid, building an Internet of energy (that is, connecting all the smart devices in residences and elsewhere to the grid), transactive energy (ensure everything on the grid can trade with each other), smart cities, and the neural grid.

The implications of bringing together distributed energy resources into “local energy communities” (whether as a community microgrid or some variant thereof) are particularly difficult for Distribution System Operators, as these carve territory and customers out of what had been the DSOs’ monopoly domain, effectively become mini (and potentially unregulated) DSOs in their own right.

78 Accenture Consulting, “Power Surge Ahead: How Distribution Utilities Can Get Smart with Distributed Generation,” June 2017.

79 Lawrence, “Energy Cloud 4.0.”

Not surprisingly, DSOs are deeply concerned, as they believe they can provide these functions themselves. (And indeed, many examples exist of DSOs becoming active managers of distributed energy resources, such as Scottish Power’s Accelerating Renewables Connection project, which integrated one hundred megawatts of distributed energy into a localized grid.)<sup>80</sup> They believe these up-starts should be subject to all the rights and obligations they as regulated entities face, including regulatory oversight, prohibition on owning generating assets, and substantial contributions toward the cost of maintaining the larger grid of which they are a part.<sup>81</sup>

Many electricity utilities recognize this and are diving into the world of distributed energy rather than trying to resist the trends. To some extent, this is related to individual utilities’ willingness to move into renewables. Some utilities shifted quickly as they saw that the way renewables drive down wholesale prices because of their ability to supply above baseload electricity at zero marginal cost would undermine their fleet of traditional generating plants (ENEL in Italy, NextEra Energy in the United States); others resisted the write-offs but are now moving belatedly into renewables

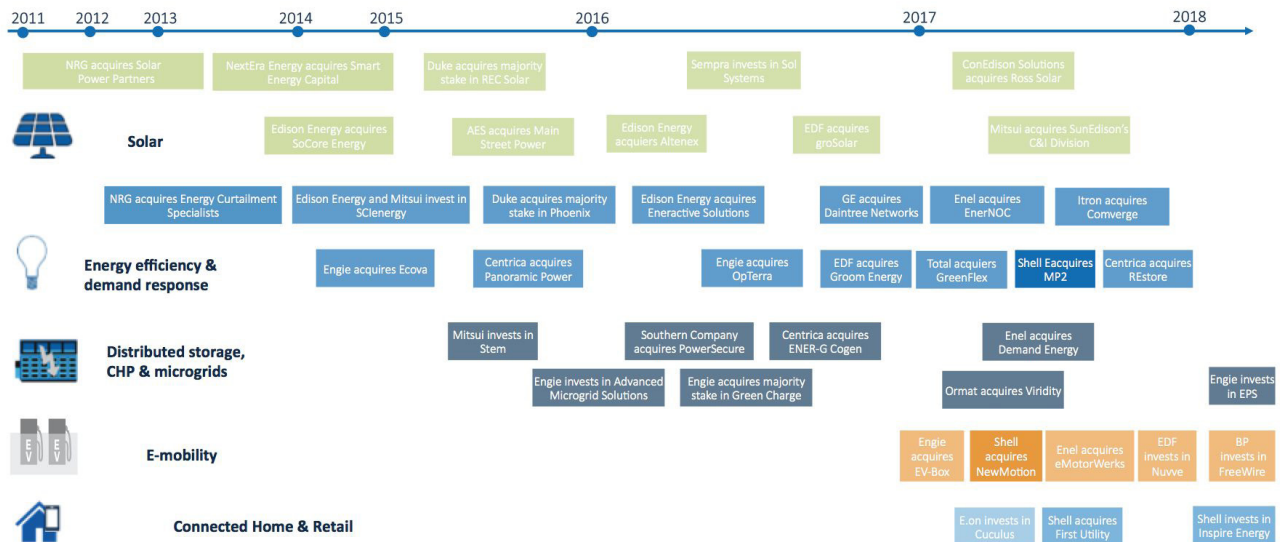


Figure 21. Retail Disruption in the Energy Cloud.  
Source: Lawrence, “Energy Cloud 4.0.”

80 Eurelectric, “Transformational Perspective: Data as a Critical Element for the Energy Transmission,” November 2017. Most cases cited, however, relate to using data for grid maintenance.

81 See European Distribution System Operators for Smart Grids, “Position Paper on Local Energy Communities,” September 2017.

## Energy Giants Are Investing in Customer Energy Management



February 2018

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Figure 22. Energy Giants Are Investing in Customer Energy Management. Source: Pyper, "Meet Inspire."

generation (Engie in France, E.ON and RWE in Germany); while still others (NRG in the United States, which backed out of its earlier renewables move) remain dedicated to traditional power sources.<sup>82</sup>

Those that made the shift to renewables also tend to be those investing in transitioning toward being an energy services provider as well as an electricity provider. Utilities can build on their existing customer base and their intimate knowledge of the grid but converting the existing company to a new one can be difficult. As such, many are moving through acquisitions (see Figure 22).<sup>83</sup>

(Indeed, those smaller utilities that have invested in renewables, smart meters, and energy services, such as the Dutch utility Eneco, are themselves good candidates for acquisition.)<sup>84</sup>

<sup>82</sup> Tim Buckley and Simon Nicholas, *Global Electricity Utilities in Transition: Leaders and Laggards – 11 Case Studies*, Institute for Energy Economics and Financial Analysis, October 2017.

<sup>83</sup> Julia Pyper, "Meet Inspire: A Shell-Backed Company with a Unique Smart Energy Subscription," *Greentech Media*, March 5, 2018.

<sup>84</sup> Sylvia Pfeifer, Andrew Ward, and Tobias Buck, "Winds of Change Blow Through Europe's Energy Sector," *Financial Times*, June 12, 2018.

Others, such as National Grid in New York or a number of the Nordic transmission system operators, are testing a different distributed system platform business model: one where they provide the inventory of distributed energy assets and the basic platform, on which third parties can reach out to customers and provide services to them.<sup>85</sup>

In every case, however, one of the major issues utilities must contend with is that they are regulated businesses and in some jurisdictions in both the United States and Europe can be prohibited from providing certain energy services. In California, for example, the Public Utilities Commission had to overturn a 2011 regulation that prohibited utilities from owning e-vehicle charging infrastructure in order to encourage these companies to become part of the solution. Similarly, Arizona had to explicitly allow its electricity company to install and operate solar panels in private residences in part to bring lower-income homes that might not otherwise be served into the renewables age. In Massachusetts, California, and Oregon, mandates on the utilities to build out storage capacity were coupled with significant flexibility in how those mandates could be met, including in installing behind-the-meter

<sup>85</sup> Elisa Wood, "DSP Isn't Just Any Old Energy Acronym. National Grid Shows Why in Buffalo," *Microgrid Knowledge*, June 29, 2018.

batteries in homes.<sup>86</sup> The U.S. electric industry has stressed that its members should be allowed to engage in providing energy services, requiring a distinction between regulated pricing and other revenues, a level playing field with third parties, and ensuring users of energy services pay the full cost of them.<sup>87</sup> Similarly, in Europe, the Council of European Energy Regulators in a June 2018 report acknowledged that a number of regulatory changes would be needed both to enable utilities to provide services to customers, and to protect those customers, across a range of retail applications — smart home energy management, self-generation, electricity storage, e-vehicle charging stations, and blockchain use in the energy market.<sup>88</sup> In both areas, utility companies that are forced to base prices on the amount of energy supplied (volumetric pricing, even if dynamic) makes it virtually impossible to charge for specific services or even update internal information systems to make them able to provide services, either directly or working with a third party.<sup>89</sup>

Utilities are utilities precisely because they serve a social purpose of providing safe and reliable electricity to the public. But the new digitalized world of energy has grown well beyond their traditional, regulated model of producing in centralized plants and feeding consumers. Indeed, in some ways, in both Europe and the United States, we are returning to the even older model of individual consumers producing electricity for themselves and their neighbors. But in today's world, the connectivity that digitalization brings allows us to better balance this load at the microscale, with networks of networks interacting with one another through platforms at different levels. Totally new players are entering into that market; utilities can as well.

86 Jonathan Blansfield and Lisa Wood, "The Role of Electric Companies in Providing Distributed Energy Resources and Other Energy Services," Edison Foundation Institute for Electric Innovation, February 2018.

87 Blansfield and Wood, "Role of Electric Companies."

88 Council of European Energy Regulators, "CEER Report on Smart Technology Development," C17-RMF-101-04, June 5, 2018.

89 See the European Distribution System Operators for Smart Grids, "Response to the Council of European Energy Regulators Consultation on Incentive Schemes for DSOs, Including Innovation," May 2017, which stresses that the current cost recovery approach to pricing discourages innovation; they recommend a separate funding line for costs related to pilots and other innovative schemes (as in the U.K.), inclusion of assets financed by EU and other subsidies for smart grids innovation in their regulated asset base so they can earn returns on these (not allowed in 14 of 17 member states), and ensuring that all users of the grid pay (including prosumers) for associated operation and maintenance costs.

This system, while still nascent, is rising to cover the gaps that are beginning to develop as traditional utilities struggle with declining demand and distributed new supplies. It will not be an easy transition, but it will be part of moving our societies to a cleaner energy world.

## Forces Driving Transformation

A number of factors drive digitalization on both sides of the Atlantic. For industry, digitalization can be a key part of ensuring competitiveness. Digitalization can empower customers, advance innovation, and allow companies to become more resilient to changes in the energy mix in their areas of operation. For policymakers, digitalization provides a mechanism to integrate renewable energy sources into the grid, help meet climate change goals, and improve resilience in case of extreme weather events or cyberattacks. Furthermore, policies that encourage digitalization can lead to greater energy security and a reduced reliance on imported energy sources.

The roles of these economic and political factors are different in the United States and Europe. In the United States, resilience, competitiveness, and innovation in the energy sector are especially strong motivators. In the European Union, climate change policies, renewable energy targets, and emissions reduction goals are especially important factors driving the digitalization of the energy sector.

### *Commercial Drivers*

Embracing digitalization allows policymakers and business leaders to stay on the cutting edge of innovation and remain competitive. For the energy industry, this is crucial. The transformation of the energy sector is blurring the lines between traditional energy companies, technology companies, and the automotive sector. Many drivers for industry are commercial in their nature. Some are related to remaining competitive vis-à-vis new entrants in the energy field, while other drivers are internal to the energy industry, such as a desire to develop better ties to consumers. From a technological standpoint, improving efficiency in existing energy systems is crucial for utilities to survive this transformation. These drivers will be explored in greater depth below.

If cars become batteries, and smart phones and other devices help manage energy usage, the role of the utility could diminish. Rather than buying power and energy services from traditional power companies, customers could be inclined to shift to tech or large retailers for their energy services. Capgemini has called the entrance of “Google, Amazon, Apple, Walmart, and other corporate giants” into the energy field as a top disruptive trend for utilities in 2018.<sup>90</sup> This prediction is based on the massive investments these companies are making into renewable energy for their own use, which sets up the potential for them to become alternative electricity suppliers to consumers as well.

But new competitors can change the market without even selling electricity. Professor Dieter Helm of the University of Oxford argues that smart meters would allow new companies with “focused strategies on particular segments of the market” to “increasingly break the links with generation” and “bring in a host of businesses from the outside — from the broadband and broadcasting companies, to the consumer providers, through to the car companies.” Helm named Apple, Google, BMW, BT, and Amazon as possible new competitors.<sup>91</sup>

Given this environment, utilities are developing digital energy services to become more attractive to consumers. This has forced the energy industry to change their approach to consumers, from viewing them as simple rate payers to essential partners in their business. When consumers can generate their own electricity, sell it to the grid, or selectively use or not use power to provide a service to the utility, they become an active player in the digital energy economy.

Utilities’ digitalization strategies are also driven by the potential for cost reduction. The first part of this report addressed the efficiency gains that digital technologies can provide. Lowering the costs for electricity generation and for balancing the grid is especially important in the context of widespread disruptions in utility business

90 Perry Stoneman, “Top Five Energy and Utilities Trends for 2018: The Impact of RenTechs Will Play a Role in Disrupting the Long-Standing Business Models of the Energy Market,” Capgemini, <https://www.capgemini.com/2018/02/top-energy-and-utilities-trends-2018/>, February 2, 2018.

91 Dieter Helm, “Why Smart Meters Matter,” Smart Energy GB, November 11, 2015.

structures. Efficiency gains that come from storage, electric vehicles, and other new technologies are strong motivators for companies to pursue digitalization.

It is important to note that customer-focused and competitiveness motivations are not important for the private sector alone. The European Commission is seeking to make its policies more consumer-centric and is therefore encouraging digitalization in the energy sector. The Commission’s Clean Energy for All Europeans package is motivated by the desire to give a “fair deal to consumers.” Just as industry sees the importance of building robust relationships with customers, policymakers also want to facilitate greater agency for their citizens. The Commission’s communications on its electricity market reforms emphasize that “consumers are at the center of the energy union” and specifically name smart meters and dynamic pricing (two digitally enabled components of new energy systems) as changes that “will make it easier for households and businesses to become more involved in the energy system, to better control their energy consumption, and [to] respond to price signals.”<sup>92</sup>

Finally, advancing digitalization promotes competitiveness in the global space. Policymakers in Europe are eager to promote digitalization, new electricity market design, and efficiency to be more competitive geopolitically.

The European Commission references President Juncker’s political priority “for the European Union to become the world number one in renewables” in its policy communications.<sup>93</sup> Leadership in renewables can translate not only into a diplomatic victory for the EU in the context of the Paris Agreement, but also into leadership roles for European industry in markets around the world.

“**The energy industry has changed its approach to consumers, viewing them as essential business partners.**”

92 European Commission, “Providing a Fair Deal for Consumers,” Fact Sheet, Brussels, [http://europa.eu/rapid/press-release\\_MEMO-16-3961\\_en.htm](http://europa.eu/rapid/press-release_MEMO-16-3961_en.htm), November 30, 2016.

93 European Commission, “Europe Leads the Global Clean Energy Transition: Commission Welcomes Ambitious Agreement on Further Renewable Energy Development in the EU,” Strasbourg, [http://europa.eu/rapid/press-release\\_STATEMENT-18-4155\\_en.htm](http://europa.eu/rapid/press-release_STATEMENT-18-4155_en.htm), June 14, 2018.

## Policy Drivers

A key question that policymakers on both sides of the Atlantic are seeking to answer is “digitalization — to what end?” While utilities, distribution and transmission system operators, tech companies, and automotive companies can identify growth and efficiency benefits from the digital transformation in the energy sector, policymakers seek to craft policy that not only promotes innovation and economic growth but also achieves broader societal interests. Other motivations for pursuing digitalization include achieving greater progress in mitigating climate change, building resilience in energy systems, and promoting energy security and energy independence. Climate change is not only a driver for policymakers, but also a key priority for industry on both sides of the Atlantic.

## Climate Change

Climate change is an important driver for policymakers and business leaders across the world. Digitalization can help integrate renewables into the energy grid and reduce emissions. For example, digital technologies can shift energy usage away from peak periods to times when more power is available. This reduces the need for additional fossil fuel power plants to add electricity to the grid thereby reducing emissions while it also moves demand to times when renewable energy is more plentiful. Wind energy, for instance, is often available overnight. The ability to move household energy use such as running dishwashers and washing machines to overnight hours is valuable for improving energy efficiency, but these shifts are especially meaningful when applied to electric vehicles. When digital technologies enable electric vehicles to be charged when solar or wind power is plentiful, emissions are avoided not only in the power sector but also in the transportation space.

Globally, digitalization can have a large impact on emissions. The World Economic Forum and Accenture found that, “in the electricity sector, if smart asset planning and management, and energy storage integration were universal, [...] up to 8.8 billion metric tons of CO<sub>2</sub> emissions could be saved by 2025.”<sup>94</sup>

<sup>94</sup> World Economic Forum and Accenture, “World Economic Forum White Paper: Digital Transformation of Industries: Societal Implications,” January 2016.

It is important to note that digitalization does not guarantee emissions reductions. The IEA’s Digitalization and Energy report warned policymakers that “digitalization’s impact may not always align with environmental protection.” Emissions could also increase. Self-driving cars could increase overall travel, digital technologies could decrease the price of coal generation, and connected devices themselves will consume energy.<sup>95</sup> Still, the potential for positive climate change outcomes, if adequate planning is put in place, is a strong driver of digitalization.

In the European Union, integrating renewables and reducing greenhouse gas emissions is a political imperative. By 2020, the EU must meet binding targets to reduce greenhouse gas (GHG) emissions by 20 percent from 1990 levels, obtain 20 percent of its energy from renewable sources, and improve energy efficiency by 20 percent. These targets will rise by 2030. The European Commission had suggested targets in 2014 to double GHG emissions reductions to 40 percent and increase renewables and energy efficiency to 27 percent.<sup>96</sup> But in 2018, the European Parliament and member states have gone further to set a new binding target for renewables of 32 percent<sup>97</sup> and an energy efficiency target of 32.5 percent.<sup>98</sup> The greenhouse gas emissions target has not yet been adjusted to account for the implications of the other changes, but EU Climate and Energy Commissioner Miguel Arias Cañete has said that “both the new targets would de facto mean that the European Union would be in a position to [...] increase our emission reduction target from the current 40 percent to slightly over 45 percent by 2030.”<sup>99</sup>

The European Commission has linked its ability to meet its climate goals to its progress in digitalizing the energy sector. Roberto Viola, director general of DG

<sup>95</sup> International Energy Agency, “Digitalization,” 149.

<sup>96</sup> European Commission, “EU 2020 Climate and Energy Package,” [https://ec.europa.eu/clima/policies/strategies/2020\\_en](https://ec.europa.eu/clima/policies/strategies/2020_en); European Commission, “EU 2030 Climate and Energy Framework,” [https://ec.europa.eu/clima/policies/strategies/2030\\_en](https://ec.europa.eu/clima/policies/strategies/2030_en).

<sup>97</sup> European Commission, “Europe Leads the Global Clean Energy Transition: Commission Welcomes Ambitious Agreement on Further Renewable Energy Development in the EU,” Strasbourg, [http://europa.eu/rapid/press-release\\_STATEMENT-18-4155\\_en.htm](http://europa.eu/rapid/press-release_STATEMENT-18-4155_en.htm), June 14, 2018.

<sup>98</sup> European Commission, “Energy Efficiency First: Commission Welcomes Agreement on Energy Efficiency,” Statement, Brussels, [http://europa.eu/rapid/press-release\\_STATEMENT-18-3997\\_en.htm](http://europa.eu/rapid/press-release_STATEMENT-18-3997_en.htm), June 19, 2018.

<sup>99</sup> Ewa Krukowska, “EU Can Toughen Its Emissions-Cut Target Under Paris Climate Deal,” Bloomberg, <https://www.bloomberg.com/news/articles/2018-06-20/eu-can-toughen-its-emissions-cut-target-under-paris-climate-deal>, June 20, 2018.

Connect, and Dominique Ristori, director general at DG Energy at the European Commission, have argued that to meet “commitments in the context of the UN Paris Agreement on Climate Change, the EU needs to rethink the way it produces and consumes energy. [...] The transition to a smart, secure and sustainable energy system energy transition [...] requires first and foremost bridging energy and digital economy.”<sup>100</sup> The IEA has found that in the EU, digitalization can help better integrate solar and wind power and avoid 240 million tons of CO2 emissions cumulatively till 2040.<sup>101</sup>

In June 2018 the European Commission proposed infrastructure funding for the 2021–2027 budget that better integrates the transport, energy, and digital sectors and promotes digitalization and decarbonization. For Maroš Šefčovič, the European Commission’s vice president for energy union, the purpose for improving synergies between these sectors is to “maximize the impact of the energy transition.”<sup>102</sup>

In the United States, while greenhouse gas emissions reduction is no longer a formal policy goal of the federal government, digitalization can help achieve local- and state-level climate change goals. After President Trump indicated his intention to withdraw from the Paris Agreement on climate change, city- and state-level governments continued their commitments to reduce emissions. Last year over 250 mayors in the U.S. Conference of Mayors pledged to move their cities to 100 percent renewable energy by 2035 and to support electric mobility and energy efficiency.<sup>103</sup> The mayors proposed changes to tax law and infrastructure investments to incentivize a more digital energy system that includes microgrids, distributed generation, and storage systems and called for the U.S. federal government to restore federal challenge grants for smart grids.<sup>104</sup>

100 Robert Viola and Dominique Ristori, “Digitizing the Energy Sector: An Opportunity for Europe,” European Commission, <https://ec.europa.eu/digital-single-market/en/blog/digitising-energy-sector-opportunity-europe>, August 2, 2017.

101 International Energy Agency, “Digitalization,” 149.

102 European Commission, “EU Budget: Commission Proposes Increased Funding to Invest in Connecting Europeans with High-Performance Infrastructure,” Press Release, June 6, 2018.

103 United Nations Framework Convention on Climate Change, “More than 250 U.S. Mayors Aim at 100 Percent Renewable Energy by 2035,” June 28, 2017.

104 Sara Durr, “U.S. Conference of Mayors Adopts Recommended National Energy Infrastructure Actions — ‘The New Bedford Principles,’” The United States Conference of Mayors, Washington, DC, <https://www.usmayors.org/2017/09/15/u-s-conference-of-mayors-adopts-recommended-national-energy-infrastructure-actions-the-new-bedford-principles/>, September 15, 2017.

A recent study by the NewClimate Institute found that if U.S. cities, states, and companies fulfilled their existing commitments to limit emissions, the United States would achieve half of the emissions reduction commitments the previous Obama administration set forth in the Paris Agreement.<sup>105</sup>

Industry is also motivated by climate change and sustainability goals. For some businesses, such as Tesla, contributing to the creation of sustainable distributed energy systems is a part of the company’s mission.<sup>106</sup> Many companies outside of the energy, digital, and automotive space also stand to benefit from supporting a digitized energy system. Walmart, for example, is at the vanguard of U.S. retailers, investing heavily in U.S. solar power and leading in the adoption of microgrid solutions.<sup>107</sup> Although some of this commitment comes from general support for climate change action, as shown by the company’s involvement in the “We Are Still In” declaration,<sup>108</sup> its interest in digitalization and renewable energy is also tied to the resilience such systems provide.

## *Resilience*

Businesses, utilities, customers, and policymakers all see the benefit of a reliable and resilient energy system. In the United States, due both to the aging/congested electric power infrastructure and the tendency to have distribution wires above ground, extreme storms and fires have left large areas in the dark. As such, the U.S. government reported in 2013 that the United States had experienced 679 instances of widespread power outage due to weather-related events between 2003 and 2012, and that the annual average cost of these outages was \$18–33 billion.<sup>109</sup> (Another estimate suggests the

105 Takeshi Kuramochi, Niklas Höhne, Sebastian Sterl, Katharina Lütkehermöller, and Jean-Charles Seghers, “States, Cities, and Businesses Leading the Way: A First Look at Decentralized Climate Commitments in the United States,” New Climate Institute and The Climate Group, September 2017.

106 Gregory Unruh and David Kiron, “Digital Transformation on Purpose,” MIT Sloan Management Review, November 6, 2017.

107 Jeff St. John, “Walmart, Advanced Microgrid Solutions to Turn Big-Box Stores into Hybrid Electric Buildings,” Greentech Media, April 11, 2017.

108 For more information on their signatories, please see “We Are Still In,” <https://www.wearestillin.com>.

109 Council of Economic Advisors, “Economic Benefits of Increasing Electric Grid Resilience to Weather Outages,” Executive Office of the President, [https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report\\_FINAL.pdf](https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf), August 2013.



costs could be higher, from \$25–75 billion annually.)<sup>110</sup> In 2016 the average electricity consumer was without power for 250 minutes (138 minutes of which were due to major events, usually weather-related), and experienced 1.3 outages.<sup>111</sup> The need to redesign energy systems to be more resilient is an especially strong driving force behind the digitalization of the energy system, especially the installation of smart meters and establishment of microgrids.

During Hurricane Irma, for instance, the Florida Light and Power Company (FLP) used smart meters to gather data on the nature, extent, and location of damage to the grid in its service area in the midst of the storm. Thanks to this technology, FLP managed to restore power to one million customers before Irma had even exited the service area, in part by redirecting electricity through alternative pathways. The remainder of their customers had power restored in a matter of days. CenterPoint Energy<sup>112</sup> in Houston had a similar story during Hurricane Harvey. Their smart meters and data analytics enabled repair teams to be deployed to the most critical areas when an outage occurred. Thanks to the intelligent grid switching devices CenterPoint had in use, almost 41 million outage minutes were avoided during Hurricane Harvey. The value of smart meters in natural disasters is so great that the U.S. Department of Energy decided to invest \$50 million in the research and development of distributed energy and grid intelligence in September 2017 in the wake of the hurricanes.

An energy system that includes microgrids and storage can help communities recover faster from outages. LO3's Brooklyn Microgrid project, featured earlier in this report, could redirect electricity in the case of a blackout on the main grid to essential services such as hospitals, fire stations, and community centers where power is needed the most. But the emphasis on reliability and resilience is perhaps the major driver behind the push

110 Richard Campbell, "Weather-Related Power Outages and Electric System Resiliency," Congressional Research Service, <https://fas.org/sgp/crs/misc/R42696.pdf>, August 28, 2012.

111 U.S. Energy Information Administration, "Average Frequency and Duration of Electric Distribution Outages Vary by States," <https://www.eia.gov/todayinenergy/detail.php?id=35652>, April 5, 2018.

112 See Jeff St. John, How CenterPoint's Integrated Smart Grid Is Paying Off, Greentech Media, April 16, 2015, for a good story on the resilience rationale behind CenterPoint's smart grid and foreshadowing the success with Harvey.

toward microgrids in the United States discussed earlier, precisely because the ability to disconnect from the grid allows the islanded area to weather storm-induced damage better.

Resilience is also a driver for the digital transformation of the energy sector in the EU as well. Given the increasing unpredictability of weather events because of climate change, the European Commission's Joint Research Center recommended in late 2017 that the EU move away from its present model of "hardening system assets" (such as reinforcing the physical infrastructure of the grid, equipment, and buildings) to a model of "building resilience." Referencing the example of New York State's response to Hurricane Sandy, JRC scientists recommended approaches that could split a large network into microgrids and the use of "smart grid technologies [to] allow power grid operators to automate the process of detecting an outage and reconfiguring the grid to reroute power to the affected area through available circuits."<sup>113</sup> In effect, the JRC recommended the increasing digitalization of the EU's electricity system.

“ **The need to redesign energy systems to be more resilient is a strong driving force behind digitalization.** ”

### ***Energy Security and Independence***

Digitalization can strengthen energy security on both sides of the Atlantic. For policymakers, this serves as a motivator for promoting digital technologies in the energy sector. Digitalization can help secure energy systems against interruptions by improving efficiency, reducing the need for imported fuels, improving maintenance of infrastructure, and creating islands that operate during larger outages. These measures allow a region to be more protected against fuel supply interruptions, cyberattacks, and less dependent on

113 Georgios Marios Karagiannis, Stamatios Chondrogiannis, Elisabeth Krausmann, and Zehra Irem Turksezer, "Power Grid Recovery After Natural Hazard Impact," Joint Research Center Science for Policy Report, EUR 28844 EN, doi:10.2760/87402, European Commission, Luxembourg, <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC108842/jrc108842kjna28844enn.pdf>, 2017, 42.

energy suppliers. Digitalization can also have a negative effect on security by increasing the risk of cyberattacks, discussed in the section on cybersecurity further below.

Digitalization improves energy efficiency and enables the development of energy storage technologies. Not only is this commercially and environmentally beneficial, as discussed above, but it also provides energy security benefits. In the European Commission's Clean Energy for All Europeans legislative package from November 2016, efforts to improve energy efficiency are promoted as "one of the most cost-effective ways to ensure energy security."<sup>114</sup> The legislative package represents a massive effort by the European Commission to adapt to the digital economy and put forth a more consumer-centric vision for the EU's electricity market. Tying energy efficiency to energy security in this context is very significant.

Energy savings could translate into a reduction in imported fuels if electricity is generated through natural gas or oil, especially in the EU. Saving energy and using more domestic energy sources means less dependence on foreign energy suppliers. Because digital technologies allow for the better integration of variable renewable energy sources into the power grid, they also help shift the energy mix toward domestic sources.

Given the concern in the United States over imported oil, the potential value of digitalization and electrification in the mobility sector is significant. Shifting more cars to electric fuels and automating transformation could reduce oil imports and transfer value to domestic power producers. A study for the U.S. Department of Energy found that in some cases, automated vehicles could reduce fuel consumption by up to ninety percent (or alternatively, increase it three times over, wherein lies the challenge for policymakers).<sup>115</sup>

In the European Union, policies to electrify transport are pursued with the aim of ending dependence on oil. The European Commission's communication on the

<sup>114</sup> European Commission, "Putting Energy Efficiency First: Consuming Better, Getting Cleaner," Fact Sheet, Brussels, [http://europa.eu/rapid/press-release\\_MEMO-16-3986\\_en.htm](http://europa.eu/rapid/press-release_MEMO-16-3986_en.htm), November 30, 2016.

<sup>115</sup> International Energy Agency, "Digitalization," 36.

energy union promotes the electrification of transport and the integration of mobility into the electricity grid because it "is important to break oil dependency."<sup>116</sup>

When energy security is taken to include protection from technical outages, digitalization can also provide key support. Advanced sensors and real-time data analytics can help predict mechanical failures in energy systems.<sup>117</sup>

Finally, distributed energy systems make energy systems more resilient not only to weather events but also to attacks, which is an important factor for the defense sector. The U.S. military uses microgrids to ensure greater resilience. At present, these microgrids typically are built around diesel or gas-fired generators. But the military will be integrating more renewables as a part of targets to achieve one gigawatt of renewables into the Army, Navy, and Air Force.<sup>118</sup> The U.S. Navy is already partnering with UniTechnologies on a solar and storage microgrid on a base in California.<sup>119</sup>

## Digital Transformation Policy Issues

The disruption brought by the digitalization of the energy sector raises numerous issues for politicians and policymakers on both sides of the Atlantic. Chief among these are of course those directly related to the energy sector itself: ensuring sufficient and reliable supply, including the successful integration of renewables, while at the same time promoting resilience in the face of grid failures as well as natural and cyberthreats.

But there are other issues that are more directly related to the digitalization aspect itself. Some of these issues, which were the focus of the four multi-stakeholder workshops GMF ran for this project, include:

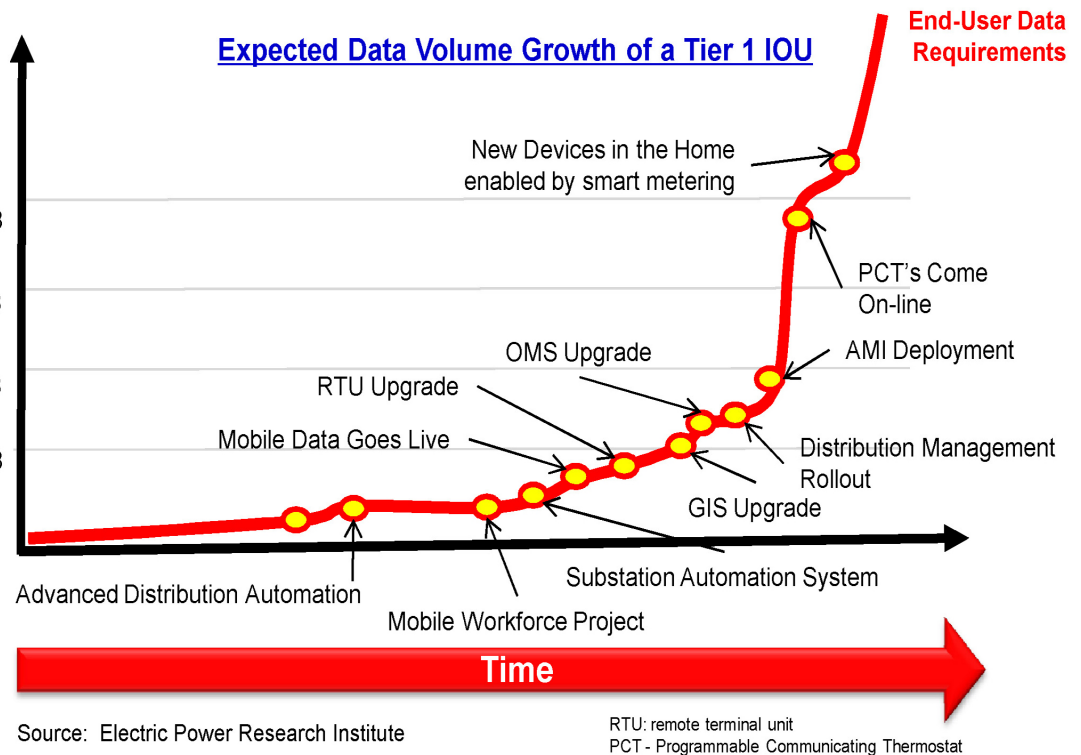
<sup>116</sup> European Commission, "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy," Communication, /\* COM/2015/080 final \*/, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52015DC0080>.

<sup>117</sup> International Energy Agency, "Digitalization," 152.

<sup>118</sup> Jeff St. John, "How Military Microgrids Could Save the Country — On Energy Costs," Greentech Media, January 17, 2017.

<sup>119</sup> Julian Spector, "From Solar to Second-Life Batteries: Why the Navy Leads the U.S. Government in Clean Energy Deployment," Greentech Media, October 21, 2016.

- determining who “owns” the petabytes of data being generated by everything from smart devices in the home to a windmill on a farm and regulating who gets to use that data and how;
- managing the privacy concerns that arise when smart meters can literally read the lifestyle of the residents of a house;



- understanding that infrastructure for the grid is no longer just wires, but also the stuff of the digital world, including everything from sensors to 5G to spectrum allocation; and
- addressing new cybersecurity vulnerabilities to the grid brought by this new sprawling digital face.

### **Business Model Disruption: Who Owns Access to Data**

As noted in the beginning of this report, the energy sector has always been highly digitalized, with sensors and controls in the system generating vast amounts of data that were fed into and analyzed by high-capacity computers and then acted upon to keep the system in balance. For decades, this did not present an issue. The vast majority of the data was operational, and within the clear remit of the power, transmission, and distribution system operators. Other data was simply about usage and settlement — often read once a month or less and figured into the bill between the customer and the utility.

This has changed dramatically. At every point in the system, literally everything that uses or produces electricity is becoming a node generating reams of data. At the wholesale/operational level, the transmission system operator needs to observe and often control things

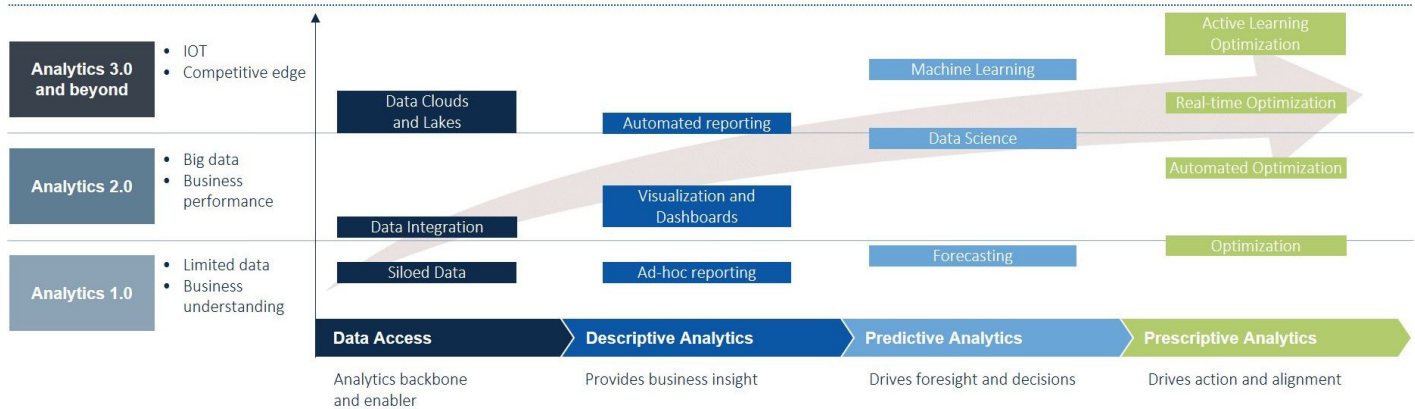
Figure 23. Expected Data Volume Growth of a Tier 1 IOU. Source: Guangyi Liu, “Big Data in Smart Grid,” China Electric Power Research Institute, Semantic Scholar, <https://pdfs.semanticscholar.org/presentation/d3b0/e05fb9fac4cd2d6e385c968e45795dc65e02.pdf>.

like wind turbines that may be owned by others; the producer of a transformer in a utility substation may be getting real-time data on how the equipment is operating to be able to predict and address possible faults. Companies like Panoramic Power are placing wireless sensors on equipment at thousands of industrial facilities to collect and analyze data about energy use. In these large-scale business-to-business data sharing transactions, access to and use of data will be (more) easily covered by detailed contractual arrangements, not least to ensure business confidentiality.

At the customer level, however, things get more complicated. A smart building generates up to 250 gigabytes of data a day; a single household smart meter recording at 15-minute intervals captures an estimated 400 megabytes of data a year, which would mean exabytes of data in the United States given current smart meter deployment;<sup>120</sup> an estimated 680 million smart meters globally may have produced 280 petabytes

<sup>120</sup> Pat Kennedy, “Six Big Data Challenges for the Power Industry,” Utility Dive, May 17, 2018.

## Evolutionary Analytics Journey



Source: GTM Research

Figure 24. Evolutionary Analytics Journey.  
Source: Chen, "U.S. Utilities."

of data in 2017.<sup>121</sup> These estimates are old and can be expected to increase exponentially as on-site generation continues its upward trend and as smart thermostats, appliances, and plugs become even more widespread, as shown in Figure 23.

All this data first goes to the retailer/distributor who is responsible for supplying and billing the customer and who may have installed the smart meter. And not unreasonably, many distributors argue that they own the data the meter collects, although they understand they need to supply it as well to the customer on demand and in deregulated markets may need to allow the customer to transfer it to another supplier. The volumes of data are far greater than needed for net metering, time-of-use, and other sophisticated dynamic billing practices. As suppliers are almost always under a legal requirement to keep billing data for up to ten years, data storage presents a serious problem, although it is increasingly outsourced to large-scale cloud providers. The troves of data, however, would be underutilized in a simple billing function.

As intimated previously, the number of uses for this data is expanding enormously to include granular customer or third-party control over distributed energy resources in the factory, office, or household for demand reduction/management purposes. And it is specifically in this area that third parties are increasingly playing,

often bringing machine/deep learning (a simpler form of artificial intelligence) behind their platform to mine and bring value to this big energy data.

Energy usage information, it should be noted, does not need to only go to and through the smart meter. The suppliers of smart devices that help create the connected home, whether thermostats, water boilers, or other devices, want access to (and may even think they own) this data — and the data of other devices they may help smarten — to provide customers information and control over these devices. This data can also be directly uploaded to platforms through wireless routers and used to provide customers with information that allows them to reduce or optimize energy use, to develop a budget and get alerts for overuse, or to alert them to possible problems with home devices.

Further, third parties such as aggregators want to be able to get data through the smart meter to provide services which allow customers to get financial rewards from their distributed energy resources for participating in demand management programs and the like. (Increasingly, in addition to networking the electric devices in a house, third-party providers are bundling a suite of other residential services related to the home, including alarms and even healthcare; while not directly related to the customer's energy data, it does increase customer interest in working with the provider.) Here, the issue of ownership of raw meter data is more nuanced. On the one hand, public policy issues would arise where the distribution system operators/retailers insist that they will not provide the data they own to any third party or only to a favored few. (Among others, the customer might rightly object that the data belongs to him/her). On the other, a third-party service provider

<sup>121</sup> Daniel Castro, Data Generation in the Energy Sector, Information Technology and Innovation Foundation, Presentation to GMF Workshop, July 2017.

(which could also be utility-facing) may argue that the data as used in its analytics belongs to it, but the real issue here is access.

In Europe, data management practices vary among countries, with some opting for a centralized approach, such as EDSN in the Netherlands under which the transmission system operator collects data from the distribution system operators/retailers and makes it available under specified terms (including data protection) to all third parties on a neutral basis. A variant might be the Integrated Information System (IIS) in Italy, where the DSOs continue to collect data but the IIS is a separate neutral body to manage sharing it with others. The other approach is more decentralized, with data residing generally with the DSO, such as EDIFACT in Germany. In either event, the data holder (the meter data management agency) is expected to ensure that consumers stay in control of their data (that is, consent is required for processing), to be neutral and non-discriminatory in providing access to the data, to ensure its quality and adhere to a number of other principles.<sup>122</sup>

That these ownership/access issues can be tough is underscored in two U.S. states that are frontrunners in renewable energy and digitalization: Texas, which has had a centralized Smart Meter Texas program run by the regional system operator ERCOT since 2009, needed to make major changes to its program through a settlement agreement reached in February 2018 in order to facilitate effective third-party access to the data, while California's Public Utility Commission made a key decision on this only in July 2016.<sup>123</sup>

For many over-the-top service providers, the ability to access and to use the data that is available is the key issue. Both the United States and Europe are trying to facilitate this. In the United States, the Green Button program is a voluntary, industry-led initiative encouraged and overseen by the Department of Energy, established in 2015, under which the 50+ participating utilities will provide customers with smart meter usage data in a standardized format for them to provide to third parties; this has now been expanded with the ConnectMyData functionality to

<sup>122</sup> Eurelectric, *The Power Sector Goes Digital — Next Generation Data Management for Energy Consumers*, [https://www3.eurelectric.org/media/278067/joint\\_retail\\_dso\\_data\\_report\\_final\\_11may\\_as-2016-030-0258-01-e.pdf](https://www3.eurelectric.org/media/278067/joint_retail_dso_data_report_final_11may_as-2016-030-0258-01-e.pdf), May 2016.

<sup>123</sup> Jeff St. John, "Texas Makes a Big Step in Improving Access to Smart Meter Data," Greentech Media, February 6, 2018.

allow the 60 million covered customers to share the data automatically with third-party providers should they desire. (The Green Button guidelines were reportedly helpful in resolving the Texas issue mentioned above.) In the EU, Flexiciency is a large-scale demonstration project to implement the same sort of thing. Specifically, Flexiciency is a consortium based on four major DSOs that have extensive smart meter rollout; they work with electricity retailers, aggregators, and others to show that novel retail services can be fostered with standardized data and actions. DSOs make metering data available on a real-time basis to the third-party service providers, based on consumer consent.

Ultimately, non-discriminatory access to the data in the system is arguably more important than ownership; further, concepts like data sharing and renting will likely develop in a collaborative way — as long as it is under a watchful eye. But there will be a race to see who gets the most value out of the data; Greentech Media estimates that U.S. utilities alone will spend \$20 billion over the next four years on customer data analytics, encompassing the steps in Figure 24.<sup>124</sup>

### ***Protecting Privacy or Protecting the Planet***

As indicated above, one of the most sensitive issues surrounding access to and use of data is that of privacy, the protection of personally identifiable information. This is particularly relevant at the household level. While one could argue that for multiple-person households, energy usage could not be attributed to any one individual, it would at the very least be complicated to have different rules about the use of data based on single- or multiple-person households, and in any event the personally identifiable information of the head of household on the utility bill is enough to create issues. As a member of DG Justice said in a private conversation, all residential energy usage information should be considered personally identifiable information and subject to the EU's General Data Protection Regulation (GDPR), regardless of size household size.

In the pre-digitalized energy world, knowing how much electricity a household consumed was a relatively simple issue — a monthly reading of aggregate energy usage of a home or apartment provided virtually no information

<sup>124</sup> Olivia Chen, "U.S. Utilities to Spend \$20 Billion on Customers' Analytics Through 2024," Greentech Media, November 8, 2017.

at all beyond possibly the profligacy of the resident(s). The granularity of the data even a first-generation smart meter can capture on energy usage during a day, however, provides considerably more insight and could lead to an invasion of privacy.<sup>125</sup>

With more smart appliances entering homes (including water heaters, washing machines, heating and cooling systems, TVs, lights, and others that might be smartened through a smart plug), the information that is accessible through the smart meter becomes even more intrusive, to the extent that it is reportedly possible to determine what TV shows are being watched.

Concerns about possible misuse of these insights has generated considerable anxiety among customers and privacy advocates<sup>126</sup> and has delayed the rollout of smart meters in parts of the United States and many countries in Europe. Even where the smart meter is utility-installed and -owned for its own purposes of being better able to predict and manage load requirements, many customers want both to control the extent of access and use of the data and to access it themselves. And while accepting that utilities must have access to usage for billing purposes, they certainly want to be able to control data access by third parties.

In both Europe and the United States, systems are in place to achieve these objectives, although they differ substantially. In Europe, the GDPR puts the user in many ways in complete control; indeed, a customer must give explicit consent for the collection and use of any personally identifiable information about him or her, and as noted above this applies essentially to all information about energy usage. In the United States, the U.S. Department of Energy in 2015 published a Smart Grid Data Protection Voluntary Code of Conduct, which covers such issues as consumer notice, choice and consent, consumer data access, data integrity, and security which, while voluntary, would also be overseen and enforced by the Federal Trade Commission. And the aforementioned Green Button program allowing data access can only work if the consumer actively permits it.

<sup>125</sup> Image taken from Dennis Gündüz et al., "Privacy in Smart Metering Systems," Presentation at IEEE WIFS, <https://www.esat.kuleuven.be/cosic/publications/talk-306.pdf>, November 16, 2015.

<sup>126</sup> See, for example, K.T. Weaver, "Smart" Meters Generate a 'Gold Mine of Data' for Utilities," Smart Grid Awareness, December 31, 2015.

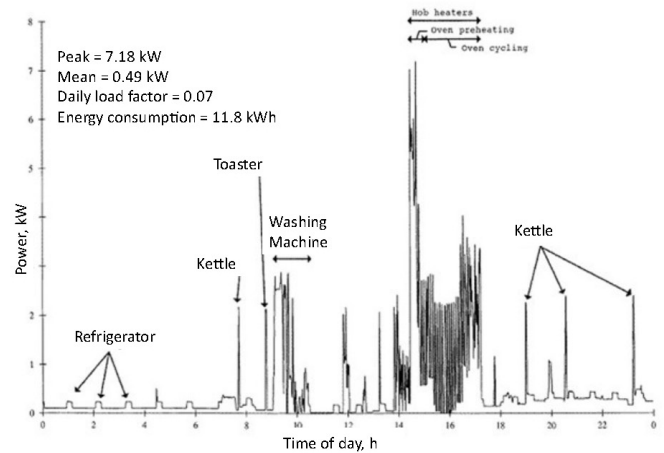


Figure 25. Personal Energy Footprint of Smart Monitoring Systems. Source: Gündüz et al., "Privacy."

The requirements for explicit consent, however, create a certain tension with the broader social goal of reducing energy usage and greenhouse gas emissions, which is, after all, one of the major drivers of the digitalization of the energy sector. As described extensively above, the ability to call on distributed energy resources including residential water heaters, heating and cooling systems, e-vehicle batteries, and plug loads can be important for integrating renewables into the system, managing demand loads, and reducing unnecessary energy consumption through efficient use. To the extent that customers do not opt-in, these resources will not be available.

Building trust in the privacy protections for energy use data by having strong legal protections and educating consumers about the environmental (as well as economic) benefits of participating in smart energy programs is obviously critical to getting this right. Utilities will need to manage their use of data taking household consumers fully into account. But at the same time, there is clearly an important public purpose at stake as well. Policymakers should consider, especially as renewables penetration increases, whether that public purpose is sufficiently important to justify an exception to the opt-in rule, an exception even allowed for by the GDPR.

## *Financing Necessary Infrastructure*

Conventional power plants, high-voltage power transmission lines, and substations and transformers on distribution networks are built to last decades. But in both the United States and Europe a large part of the electricity network was built in the 1960–1980s, and those plants are aging fast. In both areas, governments and industry have called for trillions of dollars and euros to replace the aging stock, even as they choose, for various reasons, to mothball nuclear power plants important to the baseload. But while these calls recognize that renewables and distributed energy resources have taken pressure off the need to invest in replacing many of these assets, there is growing evidence that they have underestimated that effect. Further, the silos that often exist between the energy and telecommunications sectors sometimes obscure the fact that the digitalization of the electricity sector makes it dependent 5G and spectrum allocation infrastructure as well as new transformers and transmission lines. As such, business constraints affecting investment in telecom infrastructure are also of concern here.

The electricity grid of the United States is an engineering wonder: Some 19,000 individual power generators at 7000 power plants produce 3.8 terawatt-hours of electricity that are delivered over 640,000 miles of high-voltage transmission line and 6.3 million miles of distribution lines to 160 million industrial, commercial, and residential customers.<sup>127</sup> At least half of this system is nearing the end of its useful life: by one estimate, the current depreciated value of the system is \$1.5–2 trillion, and it would take \$5 trillion to replace it.<sup>128</sup>

One of the most detailed reviews of the U.S. electrical system, the 2011 Failure to Act report by the American Society of Civil Engineers, estimated that based on then-current investment trends versus the estimated needs, the United States would face an investment shortfall of \$732 billion through 2040. This, ASCE argued, could cost the U.S. economy a cumulative \$2 trillion in lost real GDP between 2020 and 2040.<sup>129</sup>

127 U.S. Department of Energy, “Quadrennial Energy Review 2015: Electricity,” April 2015.

128 Joshua Rhodes, “The Old, Creaky, Dirty U.S. Electrical Grid Would Take \$5 Trillion to Replace: Where Should Infrastructure Investment Go?”, *The Conversation*, March 16, 2017.

129 American Society of Civil Engineers, “Failure to Act: The Economic Impact of Current Investment Trends in Electricity Infrastructure,” 2011.

Fortunately, the problem should not be as bad as ASCE estimated — as noted earlier, electricity demand growth has been nearly stagnant over the past decade due to efficiency gains and other factors, and U.S. infrastructure spending has picked up considerably since then, reaching some \$21 billion in 2016 according to the U.S. Department of Energy.

Interestingly, despite that, the ASCE in its 2017 Annual Infrastructure Report Card gave the electricity grid a score of D+, in large part due to the 3571 outages Americans experienced, averaging 49 minutes.<sup>130</sup>

The numbers, both in terms of overall investment needed and the shortfall, are similar in the European Union, although the focus is on the investment needed specifically to achieve the EU’s climate change goals. After surveying a range of studies, including by the European Commission, the OECD/IEA, and others, a recent report for the European Parliament notes that the EU will need €95–145 billion of annual investment between 2021–2050 (so €2.7– 4.2 trillion) to upgrade its power generation, transmission, and distribution systems, depending on the scenario. During the same period, the shortfalls in investment against current trends (the same approach ASCE used in its report card) could range anywhere from €116–580 billion in power generation (mainly renewables) and from €145 billion to €1.3 trillion in transmission, storage, and demand flexibility.<sup>131</sup>

Van Neffel et al.’s research is particularly interesting as it considers the role of storage and demand-side response, including the residential sector, in its calculations, as well as the decommissioning of a substantial fleet of thermal power plants. Both are important in the transition to substantial emissions reductions, as shown in Figures 26 and 27.

Whether or not the EU or the United States can fully decarbonize and move to 100 percent renewables, the decline in prices and improvements in quality

130 American Society of Civil Engineers, “Infrastructure Report Card 2017,” <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Energy-Final.pdf>, 2017.

131 Luc Van Neffel et al., “European Energy Industry Investments,” European Parliament, Economic and Scientific Policy Department, January 2017, which surveys in particular the European Commission’s Energy Roadmap 2050 (2011), its EU Reference Scenario (2016), the OECD/IEA World Energy Investment Outlook (2014), the European Climate Foundation’s Roadmap 2050 (2010), and Power Perspectives 2030 (2012).

of storage as well as the burgeoning of distributed energy resources are playing a major role in electricity infrastructure investment decisions today.

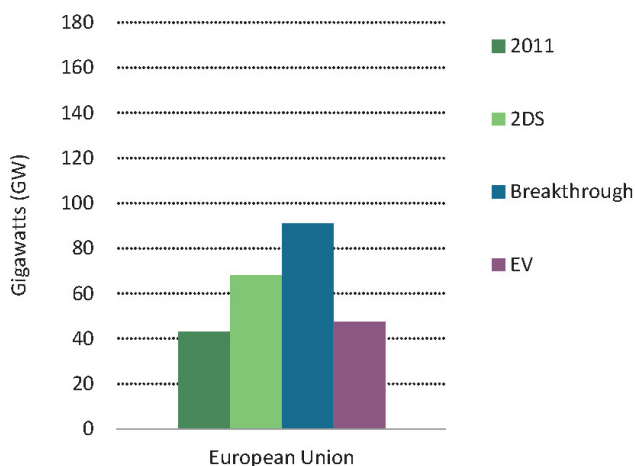
As noted earlier in this report, utilities are increasingly being asked to search for non-wires alternatives to investment in major generating plant as well as in transmission and distribution functions.

These non-wires alternatives will increasingly depend upon accessing a wide range of different, smaller-scale assets distributed throughout communities. Those assets — in terms of residential storage (including e-vehicles), demand response and reduction, as well as largely renewable power generation — can become significant players if bundled together under a platform guided by significant computing power and presented to those managing the grid as a single unit, with or without islanding capability.

Distributed energy resources are not, of course, a silver bullet. As discussed above, a critical ingredient to absorbing a localized oversupply of renewables is high-capacity transmission lines that can shift it to other markets; this is one reason why the EU remains focused on interconnectors between member states, including high-voltage direct current lines.<sup>132</sup> Further,

132 See, for example, Towards a Sustainable and Integrated Europe: Report of the Commission Expert Group on Electricity Interconnection Targets, European Commission, October 2017, and Joseph Dutton and Jonathan Gaventa, Innovation in EU Electricity Grids: Linking Research and Innovation to Deployment Instruments, E3G, May 2018.

Figure 26. Electricity Storage Capacity for Daily Electricity Storage in 2011 and 2050 for ETP 2014 Scenarios. Source: International Energy Agency, “2014 Tech Road Map.”



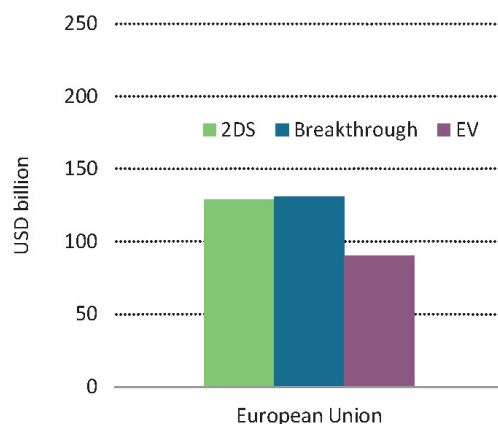
the amount of storage that might be needed (absent the use of nuclear power as a baseload provider) to make renewables dispatchable so that they can cover longer-term reductions in renewables supply due to seasonal variations and thereby help reach a 100 percent renewable target is enormous. The United States, for instance, would need storage covering anywhere from 8–16 weeks of energy consumption. Currently, all ten of the pumped-hydro facilities in the US could provide 43 minutes; adding all currently installed batteries in the United States brings the total to just over an hour.<sup>133</sup> And yet at the same time, largely due to concerns over the reliability of the aging electrical system, residential battery installations are soaring and some three-quarters of commercial and industrial facility managers recently surveyed indicated they intend to install both batteries and on-site generation in response, so achieving the necessary storage amount may be difficult, but not necessarily impossible.<sup>134</sup>

The impact these forms of distributed energy resources can have on overall grid investment and infrastructure needs is not yet fully explored, but its potential is recognized. The move toward building these assets is burgeoning in the United States, as it may soon do in Europe if the regulatory environment becomes more accommodating.

133 David Roberts, “Is 100 Percent Renewable Energy Realistic? Here’s What We Know,” Vox, February 7, 2018.

134 Jeff St. John, “DistribuTech 2018: Microgrids, Underground Networks, and Keeping the Lights On,” Greentech Media, January 23, 2018.

Figure 27. Corresponding Investment Needs, 2010-2050. Source: International Energy Agency, “2014 Tech Road Map.”





But for these systems to work, they need a different infrastructure: that of the telecommunications network. This is not generally appreciated in discussions of energy infrastructure investment (it is not, for instance, mentioned in any of the reports just cited on the electricity infrastructure needs). Nor is the need for a functioning electricity grid as such the main focus of the telecommunications industry or its regulators.<sup>135</sup>

The fifth generation of wireless technology (5G), for instance, will prove critically important as it dramatically enhances the speed of wireless communication (from theoretical maximums of 1 gigabyte per second in today's 4G world to 10 gigabytes per second in 5G), which in turn is necessary since load-balancing operations on the grid (e.g., between a DSO and a virtual power plant) need to be virtually instantaneous. 5G (as well as the next generation of the Internet protocol, IPv6) is also critical to bring ever larger numbers of electric devices into the Internet of things (IOT). As 5G operates at extremely high frequencies (3–300 gigahertz), it is relatively low range and requires line-of-sight connections, meaning a fully functioning 5G network requires hundreds of thousands of microcells in lieu of today's current cell towers as well as fixed wireless antennas on buildings that are connected to picocells inside. In addition, fiber optic cable infrastructure will be needed to provide the backbone for all of this.<sup>136</sup>

In this sense, even though many utility companies have dedicated private networks (and want to make sure they are allocated the spectrum they need), the telecom companies responsible for all this investment are also part of the energy ecosystem. And they can see that digitalization and the decentralization it fosters is beginning to introduce electricity utilities to the often-difficult evolution they went through. This is especially true, from their point of view, as “over the top” service providers (Internet service providers like Google and others) benefit from the infrastructure they created and continue to invest in, but do not need to invest in themselves. To the telecommunications companies, these over the top platforms are free riders and often seem to get an inordinate share of the profits from the new services they enable. As discussed earlier, utilities see the possibility that they will be held responsible for investing

<sup>135</sup> Jasmin Melvin, “U.S. Energy Infrastructure Investments Must Extend to Utilities’ Telecom Networks,” Platts, March 14, 2018.

<sup>136</sup> CB Insights Research Report, “What is 5G: Understanding the Next-Gen Wireless System Set to Enable Our Connected Future,” CB Insights, June 5, 2018.

in the safety and reliability of the power system, while companies that come into the market just to offer energy services reap the profits. And, like the telecoms before them, utilities are responding either by trying to make it more difficult for the upstart competitors, by trying to make sure that the third parties pay for infrastructure services (the net neutrality debate in the Internet world), or by seeing if they can join them.<sup>137</sup>

But whatever the relevance of the previous experience of the telecommunications companies, the fact is that the success of digitalization in energy will depend on investments in the infrastructure of both the energy and telecom sectors.

### *Cyber Vulnerabilities of Connected Digital Energy Space*

Rapid innovation and digitalization in the energy sector brings benefits to consumers, industry, and society by creating more responsive, efficient, and resilient energy systems. Resilience in particular is key to the transatlantic security agenda, as discussed earlier. But resilience is only half of the story linking digitalization and security. While microgrids can help communities protect themselves against weather-related outages and physical attacks, digitalization makes communities on both sides of the Atlantic more susceptible to cyberattacks.

Intelligence communities in Europe and the United States have been open about the new risks they foresee in the energy sector, and attacks have already occurred around the world, with significant outages seen in Ukraine. Policymakers, industry, and consumers on both sides of the Atlantic will need to prioritize cybersecurity as they undertake the digital transition in the energy sector. Significant efforts have been made to assess and improve security in large infrastructure, such as power plants and major grids, but more work will need to be done to protect consumers as their use of the IOT grows.

<sup>137</sup> See, for example, Blansfield and Wood, “Role of Electric Companies”; European Distribution System Operators’ Association for Smart Grids, “EDSO Response to CEER Consultation on Incentive Schemes for Regulating DSOs, Including for Innovation,” May 12, 2017.

EU and U.S. officials have warned against the new risks of digitalizing energy systems. A 2017 U.S. Department of Energy study linked technological advancements and increased threats:

There are key trends that are increasing the risk of significant cyber incidents. On the one hand, utilities and grid operators are adopting new technologies that leverage ever-expanding amounts of data and automated control capabilities to manage the grid more efficiently and reliably. On the other hand, cyber threat actors are becoming more knowledgeable about how to exploit various aspects of the grid infrastructure, including pathways through these new technologies, to achieve their malicious objectives.<sup>138</sup>

Industrial control systems that use new network and communications technologies are facing new vulnerabilities to cyberattacks due to the very same technologies that are allowing them to adapt to the future: automation, two-way flows, and centralized controls.<sup>139</sup>

The EU is similarly aware of the risks digitalization poses to cybersecurity. A report for the European Parliament's Committee on Industry, Research, and Energy (ITRE) found that the increased presence of networked devices in the energy distribution system requires more coordinated strategies by the EU to counter the risk of cyber incidents. Like in the United States, the transformation of the energy sector and the effect of digitalization in Europe is very significant: "The range of potential attacks (or 'threat vectors') is multiplied, both by the growing sophistication of cyberattackers and by the increasing number of accessible targets within the smart energy ecosystem of devices."<sup>140</sup>

138 U.S. Department of Energy, "Section 2(e): Assessment of Electricity Disruption Incident Response Capabilities" in Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure, [https://www.energy.gov/sites/prod/files/2018/05/f51/EO13800\\_percent20electricity\\_percent20subsector\\_percent20report.pdf](https://www.energy.gov/sites/prod/files/2018/05/f51/EO13800_percent20electricity_percent20subsector_percent20report.pdf), August 9, 2017, v.

139 U.S. Department of Energy, "Section 2(e)," 3.

140 David Healey, Sacha Meckler, Usen Antia, and Edward Cottle, "Cybersecurity Strategy for the Energy Sector," Directorate General for Internal Policies, Policy Department A: Economic and Scientific Policy, European Parliament, IP/A/ITRE/2016-04, [http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587333/IPOL\\_STU\(2016\)587333\\_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587333/IPOL_STU(2016)587333_EN.pdf), October 2016, 7.

Energy services have already been disrupted by cyberattacks. Some of these disruptions have resulted from wider cyberoperations, such as the large WannaCry ransomware attack that disrupted computer systems around the world in May 2017. Other incidents target energy infrastructure in particular. The best examples of energy-focused attacks took place in Ukraine in 2015 and 2016.

On December 23, 2015, cyberattacks resulted in approximately 225,000 customers losing power in various regions of Ukraine. Ukrainian government officials attributed the attack to Russia.<sup>141</sup> The attacks were very sophisticated. The variety of tools the attackers used included:

... spear phishing emails, variants of the BlackEnergy 3 malware, and the manipulation of Microsoft Office documents that contained the malware to gain a foothold into the Information Technology (IT) networks of the electricity companies. They demonstrated the capability to gain a foothold and harvest credentials and information to gain access to the ICS network. Additionally, the attackers showed expertise, not only in network connected infrastructure, such as Uninterruptable Power Supplies (UPSs), but also in operating the ICSs through their supervisory control system.<sup>142</sup>

The Ukrainian electricity system was targeted by another attack a year later in December 2016. The Industroyer attack illustrated the growing capabilities of attackers. Malware allowed "attackers to view, block, control or destroy grid control equipment such as circuit breakers. Its design suggests expert knowledge of several standardized industrial communication protocols widely used to control infrastructure — not only electricity grids — throughout Europe, Asia, and the Middle East."<sup>143</sup>

As the Industroyer attack indicated, attackers have developed the tools to target energy infrastructure across the transatlantic community. Recent disclosures

141 Robert M. Lee, Michael J. Assante, and Tim Conway, "TLP: White Analysis of the Cyberattack on the Ukrainian Power Grid Defense Use Case," SANS and E-ISAC, [https://ics.sans.org/media/E-ISAC\\_SANS\\_Ukraine\\_DUC\\_5.pdf](https://ics.sans.org/media/E-ISAC_SANS_Ukraine_DUC_5.pdf), March 18, 2016, iv.

142 Lee et al., "TLP," 1.

143 International Energy Agency, "Digitalization," 125.

have indicated that cyberattacks have been attempted in the United States and the EU, but as yet, the effect has not been as significant as in the case of Ukraine.

The U.S. National Security Agency has witnessed attempts to intrude into critical infrastructure by actors who could “take down control systems that operate U.S. power grids, water systems, and other critical infrastructure.”<sup>144</sup> In March 2018 the U.S. Department of Homeland Security and FBI issued an alert that “Russian government cyber actors” had “targeted small commercial facilities’ networks where they staged malware, conducted spear phishing, and gained remote access into energy sector networks. After obtaining access, the Russian government cyber actors conducted network reconnaissance, moved laterally, and collected information pertaining to Industrial Control Systems (ICS).”<sup>145</sup>

In Germany, an attack called Berserk Bear in June 2018 saw hackers try to penetrate German energy and electricity companies. The attacks did not result in outages because only office networks were disrupted. The BfV domestic intelligence agency has said that “Russia was probably behind” the attack.<sup>146</sup>

Both the United States and the EU are pursuing policies to protect the cybersecurity of the energy system, but the two sides of the Atlantic have taken different approaches. According to an IFRI comparative study, the U.S. is ahead of the EU on developing “precise and detailed norms for cybersecurity in the electricity sector,” while the EU has done more work on data privacy and protection, “cybersecurity for low carbon technologies, as well as the protection of electricity distribution.”<sup>147</sup> The U.S. government has federal powers that can

mandate secure practices across for all electrical utilities and has very precise rules for management controls, training of personnel, physical security of the grid, and recovery.<sup>148</sup>

Individual member state regulations across the EU are inconsistent. In particular, there are different approaches to security in the energy system between eastern and western EU member states: “Eastern and Western Europe may not be implementing the same systems and therefore the same security policies and will likely require a specific process and period for harmonization across these regions.”<sup>149</sup>

The primary policies underpinning the European cybersecurity approach are the GDPR discussed above and the Network and Information Security (NIS) Directive. Neither policy is written specifically for the energy sector; both are part of the EU’s wider approach to data protection and cybersecurity. The NIS Directive became effective in May 2018 and requires essential services such as energy comply with security measures and inform their national governments of cybersecurity breaches. The United Kingdom was the first country to set the level of fines for failure to report breaches at up to £17 million, or €19 million.<sup>150</sup> The NIS Directive also will enable better cooperation between member states on cybersecurity.

But unlike the United States where climate change legislation did not specifically address cybersecurity, the EU’s Winter Package does address cybersecurity in its proposals for “Clean Energy for All Europeans.” It foresees that new low carbon technologies identify cyber vulnerabilities and would anticipate the creation of network codes or technical rules for cybersecurity for renewable energy.<sup>151</sup> The EU’s system therefore has very technical provisions tied to new technologies and large overarching policies. The ambition is noteworthy, but this piecemeal structure does not yet have the rigor of the U.S. guidelines.

144 U.S. Department of Energy, “Section 2(e),” v.

145 U.S. Computer Emergency Readiness Team, “Russian Government Cyberactivity Targeting Energy and Other Critical Infrastructure Sectors,” Alert (TA18-074A), <https://www.us-cert.gov/ncas/alerts/TA18-074A>, March 15, 2018.

146 “German Intelligence Sees Russia behind Hack of Energy Firms: Media Report,” Reuters, <https://www.reuters.com/article/us-germany-cyber-russia/german-intelligence-sees-russia-behind-hack-of-energy-firms-media-report-idUSKBN1JG2X2>, June 20, 2018.

147 Arnault Barichella, “Cybersecurity in the Energy Sector: A Comparative Analysis Between Europe and the United States,” IFRI Center for Energy, [https://www.ifri.org/sites/default/files/atoms/files/barichella\\_cybersecurity\\_energy\\_sector\\_2018.pdf](https://www.ifri.org/sites/default/files/atoms/files/barichella_cybersecurity_energy_sector_2018.pdf), February 2018, 42.

148 Barichella, “Cybersecurity,” 15.

149 Healey et al., “Cybersecurity,” 7.

150 Euractiv, “First EU Cybersecurity Law Takes Effect — with New Fines for Misbehaving Companies,” <https://www.euractiv.com/section/cybersecurity/news/first-eu-cybersecurity-law-brings-fines-for-companies-that-fail-to-report-hacks/>, May 9, 2018.

151 Barichella, “Cybersecurity,” 33.

The guidelines set by U.S. and EU policymakers prioritize big industry and critical infrastructure. An equally important area of vulnerability is the consumer. Individual homes and small communities can become targets in and of themselves, becoming vulnerable to hacks and interference. Policymakers have been primarily focused on the need to protect large systems rather than the individual.

Consumer IOT devices are a key element increasing vulnerability. The approach to consumers should be different from the approach to massive infrastructure and should be regulated with the threat of fines and imposition of mandatory disclosures. As consumers on both sides of the Atlantic use smart meters, purchase and use IOT devices, and use peer-to-peer technologies, they need to be aware of their own vulnerabilities. Education and public awareness campaigns to reach these new, active consumers are especially important. Cybersecurity starts with good user cyber hygiene.

For utilities that roll out smart technologies on the population scale, it will be important to judge whether the smart device is smart enough to be secure. The ability to update and patch systems, while expensive, is critical. Policymakers can consider minimum standards for all devices that interact with the energy system.

## Policy Recommendations

Digitalization is bringing change — sometimes wrenching change — to the energy sector. It speeds the shift to electrification. It helps integrate renewables. It provides the platform for the dramatic increase in distributed energy resources seen in Europe and the United States today. And it spurs new business models, both in terms of the architecture of the grid and the companies that can supply the services the grid and its customers will need.

As with so many aspects of the digital revolution, these changes are coming quickly, perhaps all too quickly for an industry comfortable with thirty-year time horizons. Digital transformation causes disruptions, even as it creates new and important opportunities for our societies, both in strengthening the reliability and resilience of our grids and in helping attain even highly ambitious climate change goals.

In the end, politicians, policymakers and industry need to welcome and facilitate this creative disruption. But they also need to be alert to, and try to mitigate, the downsides that will inevitably accompany it.

### *Accept Digitalization — It Will Not Go Away*

The disruption and dislocation brought by change are difficult. Those who are or think they may be harmed by them will highlight the potential costs of change. Utility regulators and those they oversee will be understandably cautious, given the enormous responsibility they have for the reliability of the grid and the tradition of maintaining sufficient back-up capacity to ensure this. There will be natural concerns about energy sources that may not provide baseload, new players who do not share the same mandate, and new technologies and approaches that are based on invisible things like wireless rather than tangible, wired networks.

But the Internet of everything is coming, and with it the Internet of energy. Every electrical device in every factory, office building, and residence will eventually become a node connected to an AI-enabled platform that will drive efficiency and the demand for electricity down. And many more customers will become competitors, generating their own supply and sending surpluses back to the system, simply because digital technologies allow it and declining costs of the technologies bring profit (both monetary and in reliability) from both the consumption and supply sides. The accelerating trend toward the digital transformation of the energy sector is there; it will not go away.

### *Keep It in Perspective*

But even as that first recommendation sounds hyped, one of the report's main purposes was also to underscore that while energy sector renewables integration and digitalization have progressed, they are still relatively small players in what is after all an enormous system. The trend is important, and the pace of change is accelerating, but it is often from a small base. Policies related to this need to keep that in perspective. But it is also worth bearing in mind that the zero marginal cost of renewables and the rapid declines in technologies like storage have allowed them to have an enormous impact

on wholesale prices and on decisions over billions of dollars of investment, even as they remain relatively small players on the market.

### ***Facilitate Integration of New Models and Platforms***

The first two points underscore the third: even though change is still coming, the likely endpoint of a substantially decentralized energy system is certain. We of course cannot know precisely what the contours of the system will be in 2050 (for instance), but politicians, policymakers, the private sector, and the public can and should anticipate that endpoint and let it guide them.

This implies, above all else, willingness to allow new ways of organizing distributed energy resources to enter the market. It is obvious that the traditional centralized model is no longer sufficient; new models, essentially platforms for providing energy services, will be needed. And all players, including utilities, should be allowed to experiment with them. Many will have the main mission of connecting and getting aggregated value from hundreds of digitized devices. Many may fail. But a decentralized system should be resilient enough to manage this. The European Commission's new electricity market design proposals to ensure open space for new models already go in the right direction.

The creation and integration of new model platforms will entail the entry of new market players into the energy sector. Thus far, policymakers have been regulating energy markets with traditional energy actors in mind. Looking forward, policymakers should expand their understanding of the energy system to include new actors, including but not limited to tech, telecommunications, and automotive companies. This is especially relevant for competition policy.

### ***Support Markets, Not Subsidies***

In both the United States and in Europe, the desiderata to reduce greenhouse gas emissions led to decisions to subsidize the introduction of renewables — until it became apparent that the system couldn't digest them. The subsidies helped drive up volumes and thus drive down costs, and that is a good thing — but perhaps too much of a good thing. The new distributed energy resources — including e-vehicles and batteries — and

the digital technologies that underpin them have their own economic and commercial rationale; they should be allowed to find their own way. Supporting research is one thing, subsidizing commercialization another.

But this also applies to prices in the electricity market. Both in Europe and in the United States, often regulated pricing structures suggest implicit subsidies (not least to voters), some of which directly militate against investments in the non-wires alternatives that distributed energy resources can provide. Explicit and implicit barriers to non-wires alternatives should be changed. Similarly, practices like dynamic pricing may have some unfortunate consequences in that higher price timing will also affect lower-income households, but rather than avoiding the tool altogether, it might be better to help cushion the blow where necessary.

### ***Smart Digitalization for Climate Change Wins***

The digitalization of the energy sector can have a large impact on reducing greenhouse house emissions if the appropriate policies and planning are put into place. By itself, digitalization does not guarantee a greener outcome, but digital technologies can facilitate more efficiency within existing fossil fuel-based energy systems and can allow for more renewables to be integrated into the grid. These benefits are real and arguably override possible concerns about problems energy sector digitalization might bring.

Cities, regions, the EU, and U.S. state and federal governments should encourage systems-based approaches to redesigning energy grids so that distributed energy systems are integrated to help achieve decarbonization. Such systems should promote balanced energy use and work with battery and electric mobility developers to use new their technologies in a way that promotes community benefits rather than individual benefits — in this sense, smart charging for e-vehicles is more important than rapid charging facilities.

In the EU, where meeting new energy efficiency targets will require sustained ambition over the next decade, policymakers and industry should work with citizens to illustrate how digital efficiency solutions such as demand response systems can help meet climate change

goals. This is especially true in communities where privacy-driven concerns have discounted the value of such technologies.

### ***Emphasize Both Resilience and Reliability***

As important as climate change considerations are, especially in Europe, they are only one factor that should drive the digitalization of the energy sector — reliability and resilience are critical too. Microgrids can provide communities with greater resilience against outages caused by extreme weather, technical disruption, or cyberattacks on large infrastructure.

When developing microgrids, industry and policymakers should make sure that resilience to outages also means resilience to climate change. It is possible to build resilience to extreme events with diesel generator-fueled microgrids. But such traditional fuel grids will not deliver the efficiency gains that renewable and storage-based systems would provide. While more complex to set up initially, the policy imperatives and cost reduction in the renewable and storage markets make these solutions more desirable.

It may be the greater U.S. interest in reliability and resilience that is helping speed the introduction of microgrids and other connected approaches to energy management in the United States with clear benefits for the climate as well.

### ***Stay Focused on Cybersecurity***

Rather than focusing attention primarily on the risk of cyberattacks against large energy infrastructure, policymakers and industry should prioritize developing security in the many small entry points into the digital energy system. This will require a focus on setting and implementing minimum cybersecurity standards for IOT devices (such as smart thermostats or washing machines), electric vehicles and EV charging stations, and smarter traditional energy devices such as meters.

Devices that are linked to the energy network of a community must be patchable. Industry should consider its responsibility in marketing and installing smarter rather than “dumber” smart devices, even though this will entail higher costs especially when rollout occurs on a population-wide scale as in the

case of smart meters. The reputational risks for not providing adequate security should motivate industry toward greater cybersecurity ambition.

Lastly, consumers need to be taught to be responsible for their cybersecurity and the security of their communities. Public and private sector informational campaigns that encourage good cyber hygiene should accompany the rollout of IOT energy devices and should complement the development of digital energy systems.

## **Conclusion**

When electricity first began systemically expanding into the economies and societies of the United States and Europe, it was decentralized. To foster rapid electrification and industrialization, our governments encouraged consolidation and encouraged vertically integrated monopolies. These served their purpose well.

But the times they are a-changin'. Competition was injected into the system both upstream and down-; large-scale deployment of renewables intensified it upstream, while small-scale solar and other distributed energy resources did so underneath. Digitalization is now accelerating both by accentuating efficiencies through connectedness.

The irony is that in some ways this is returning us to the past: the energy system of tomorrow will be both more decentralized and more connected than it is today.

This will bring many benefits to both the European and American economies, and that is a good thing. But it will also enhance our security, both by helping integrate the renewables we need to tackle climate change and by helping wean us from foreign hydrocarbons. The energy security aspect of the digital transformation is yet another critical reason that politicians and policymakers on both sides of the Atlantic should both consciously embrace and encourage the creative destruction the digital transformation of the energy sector brings.



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