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ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Grid Modernization

The foundation for climate change progress

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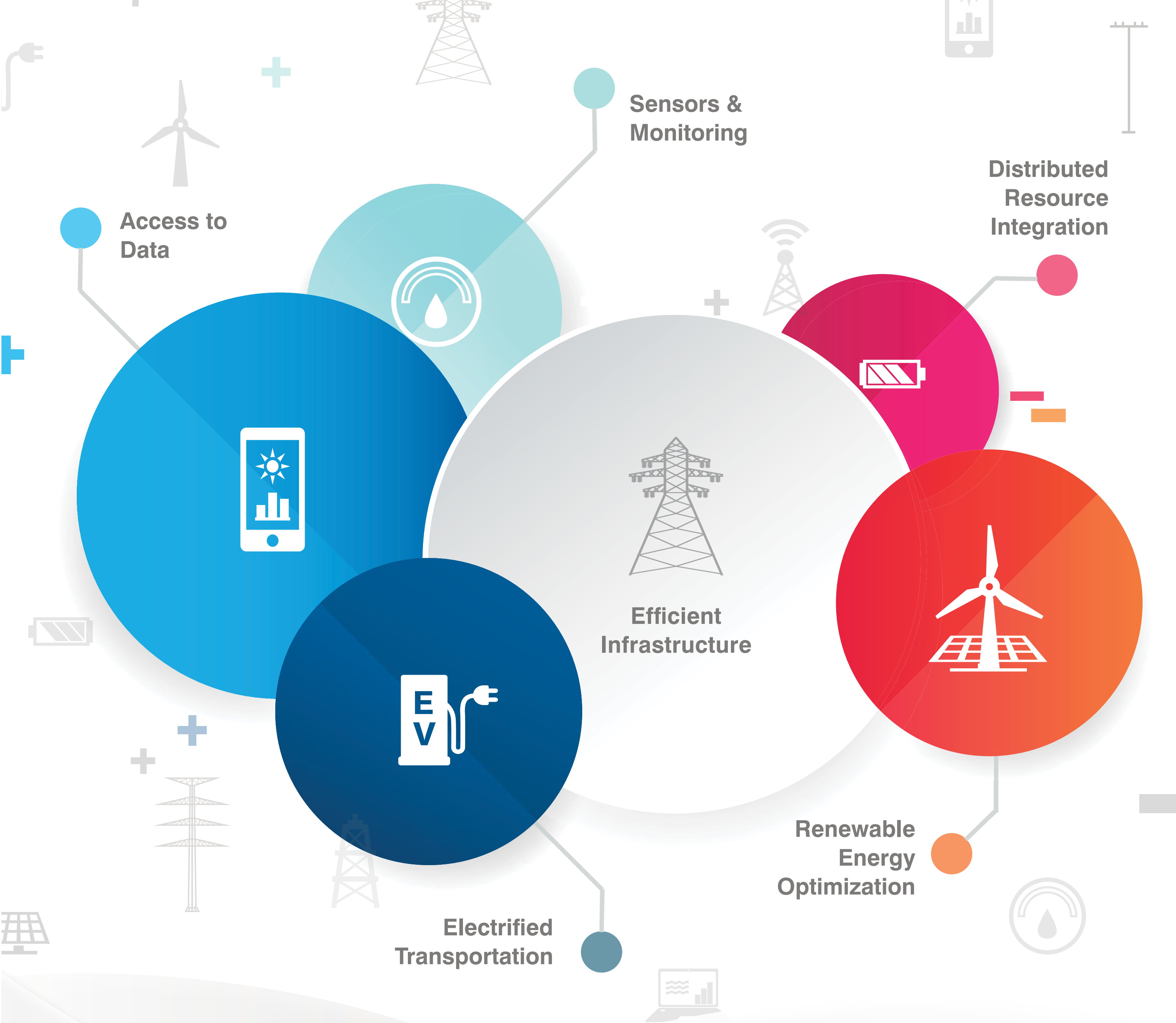
In 2017, the United States endured a series of record-breaking, extreme weather events. Communities across the West, South and the Caribbean are now rebuilding, and asking, “How can we better prepare our energy system to stand stronger in the face of these disasters?”

Grid modernization is essential to ensuring the energy systems that power our lives and underpin our economy are protected from future disruptive events. But beyond simply keeping the lights on, modernizing our electric grid also creates a platform to make meaningful progress on mitigating the future impacts of climate change.

Throughout the country, utilities and energy companies have an unprecedented opportunity to invest in technologies and solutions that enhance the visibility and control that operators have across the electric system. These technologies enable a range of new capabilities that improve resiliency, reduce operational costs and increase efficiency – effectively enhancing the quality of electric service. These same technologies can also empower capabilities foundational to making progress on climate.

Though grid modernization investments may meet a host of objectives, it is important that the appropriate safeguards are in place to ensure benefits are maximized and customer costs are managed. These include aligning regional policy objectives with long-range deployment plans, ensuring all benefit streams are pursued, and verifying that the results of these investments are measured against the expected outcomes once they are in place. Several states are currently leading inclusive, stakeholder processes to ensure these and other considerations are accounted for.

A modernized grid that keeps energy costs affordable and promotes economic growth is vital to our present-day society. Through its pursuit, we are making a commitment to the productivity and quality of life of future generations by helping ensure our energy remains reliably available and increasingly clean and sustainable.



A comprehensive grid modernization strategy

To facilitate a meaningful dialogue on making climate progress through grid modernization, we've organized this report around six essential capability areas. These capabilities are not completely isolated from each other – in fact, as progress is made in one of these areas, it would likely animate activities across other areas. Environmental Defense Fund believes that any comprehensive grid modernization strategy that makes meaningful progress on climate would involve the pursuit of all of these areas. Bringing together diverse stakeholders—including regulators, grid operators, government agencies, industry providers, and advocates—will ensure a methodical process and create the best opportunity to improve energy system resiliency and efficiency and drive toward a sustainable clean energy future.

Sensing and Monitoring for Enhanced System Awareness

Creating a framework for full value: reliability, resiliency, efficiency and lower carbon

With the advent of diverse cost-effective sensing and monitoring solutions, the ability to ‘see’ what’s happening across the electric grid has dramatically improved. Many of these solutions have been found more prominently across the transmission system on high voltage lines or major substations. Now, similar solutions are finding their way down into the distribution system. System operators are able to sense how equipment across the system is behaving, the status of outages, the state of power flows, and more, all in near real time.

While these new technologies can strengthen the grid and improve physical system performance, the data they gather can serve to optimize service and lower costs for consumers as well. A foundational technology of sensing and monitoring infrastructure is advanced metering. From 2010 to 2016 the percentage of meters that are ‘smart’ in the U.S. went from 8.7% to 42.8%.[1] Through these digitally connected meters, grid operators are not only able to save on operational costs, but can also get more accurate readings, better awareness of outages and other benefits that come from more granular energy use data. Advanced metering deployments can also streamline operations, improve billing and introduce other improvements that reduce costs and add functionality for energy users. Innovations that increase value to energy users like distributed energy resource integration, access to useful energy information and flexible pricing structures should also be pursued.

Today, utilities are exploring opportunities for deeper system awareness through a new generation of technology solutions. Understandably, these are often focused on critical infrastructure to avoid catastrophic failures and disruptions from events like storms. However, grid operators should work with stakeholders to review system needs, consider available solutions and define the business case to move beyond demonstrations and pilots and into scaled deployments. For example, sensors at substations can monitor the health of the assets and identify when preventative maintenance is necessary.

System planners should not be overly prescriptive on every grid modernization investment, but instead outline expected improvements and then allow discovery of the best application from an expanded portfolio of emerging options. This would also allow stakeholders to become more comfortable with how these investments align with specific policy outcomes.

Going forward, monitoring solutions will also include sophisticated analytics capabilities to derive useful, actionable information from the data flows coming from the proliferation of meters,

1: US EIA, Annual Electric Power Industry Report, 2016

Sensing and Monitoring for Enhanced System Awareness

sensors and controls. This network of monitoring functions could essentially function as the nervous system of the grid.

Analytics solutions are increasingly available to solve the ‘big data’ challenge of making useful decisions based on vast amounts of information. Rich information on energy systems can be diverse, ranging from more granular forecasting of energy demand and deeper understanding of available supply to numerous aspects of the health of various grid infrastructure assets. These solutions often run in the cloud. As a result, regulators should work with utilities to manage the implied changes these solutions will bring to utilities’ capitalized infrastructure investments. Grid operators should also look to continue to examine their data needs and how they can use best-in-class solutions to make good use of these insights.

Today’s grid remains a complex system of physical devices: switches, wires, breakers, transformers and other hardware. But it is quickly becoming a digital platform as well, through software, control centers, communications and data analytics. Successful use of diverse monitoring, metering and controls solutions using networked sensors is a critical step to modernizing the grid for optimal efficiency, resiliency and flexibility while using a wide range of clean energy assets.

An Inclusive Modernization Process

Grid modernization programs can become complex undertakings, far more involved than a utility simply arriving at an agreed-upon level of expenditures across traditional investments. It introduces new capabilities into the energy system that have implications for all stakeholders connected into the grid. This is why a methodical and inclusive process to arrive at decisions for modernizing the grid is so critical. It should include:

- Agreeing on the policy objectives or purposes that would be advanced by these grids investments.
- Determining the scale and pace of deployment, recognizing that some capabilities need to be in place before others can be pursued effectively; and
- Ensuring all customer and stakeholder interests are considered, including those of low income customers, and that equitable solutions are put in place.

Many state commissions have initiated dedicated grid modernization proceedings and engagements. Some examples include Maryland’s innovative process to transform its electric grid, the Electric Reliability Council of Texas (ERCOT) process to expand transmission and harness its wind energy resources, as well as grid modernization activities in motion across Ohio, Minnesota, Illinois, Massachusetts, Hawaii and other states.

Intelligent Integration of Diverse Distributed Resources

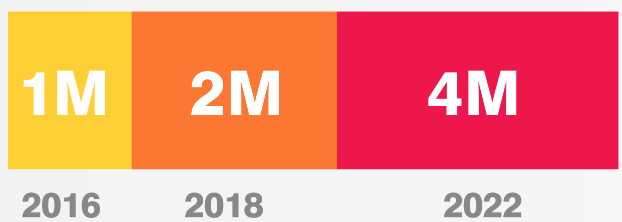
Diversity of small-scale supply resources and increasingly engaged energy users add up to a stronger, cleaner grid

Distributed energy resources at or near the point of use are coming online at a rapid pace. These resources increasingly have the potential to satisfy a significant amount of our future energy demand. And when integrated at scale, these systems could also play a larger role in providing other services essential to meeting our energy system needs.

Distributed energy resources extend beyond generating assets, such as rooftop solar systems, to encompass a growing set of generation and efficiency options: combined heat and power systems, micro-turbines turned by wind or water, energy storage through the use of batteries, demand side management solutions and microgrids where diverse distributed assets are integrated to power the needs of local facilities.

Demand side management, in particular, continues to evolve to support the needs of energy users and energy system operators alike. Communications and controls solutions are making it possible to schedule and adjust cooling, heating and other energy uses in homes and businesses, and lower consumption during times of peak demand. Intelligently managing energy use brings flexibility to the system and helps encourage the optimized use of energy during times where it is least expensive and/or when the supply has low carbon intensity.

Dedicated distributed resource management systems, enabled by a modern grid, are being used to effectively integrate a variety of energy resources. By managing distributed resources with these management systems, grid operators can visualize their aggregate operation and ensure these resources can respond appropriately based on system needs. This could serve



After reaching 1 million solar installations in 2016, the U.S. is poised to reach 2 million in 2018 and 4 million by 2022.[2]

2 SEIA, Solar Industry Data, 2017

Intelligent Integration of Diverse Distributed Resources

to benefit the owners of the assets and the overall system at large.

Utilities, regulators and stakeholders also are beginning to evaluate and prioritize the role 'non-wires alternatives' can play in deferring or eliminating the need to expand transmission, distribution and generation capacity. These alternative grid infrastructure options may include demand side programs, system efficiency, storage and other smart-grid solutions that can satisfy expected demand and requirements of the grid during peaks and other conditions. These alternatives hedge against some of the more costly capacity build outs and can blur the lines between energy supply and customer demand. This has material implications on how grid operators, regulators and others interact to make the decisions to build grid infrastructure.

Arriving at a value for these distributed resources can be a complex endeavor. Identifying and then monetizing these value streams can be very involved – as is the process to then convert these value streams into an effective market signal.

The valuation of distributed resources can involve the exploration of many areas including:

- How much value can any given resource bring to the system at a specific place and a specific time?
- How can solutions for distributed resources bring value to the overall system as well as their owners/site hosts?
- How can distributed solutions allow operators to make more capital efficient investments in managing the grid?

When introducing new technologies into the energy system, it's important to embrace the wide use of standards and construct pathways to encourage interoperability once the standards are implemented. These steps will help prevent issues for individuals and businesses wanting to connect their distributed assets effectively into the grid, and will also help prevent grid operators from having stranded assets in the form of solutions to integrate various distributed resources.

Diverse distributed solutions on both the supply side and the demand side can play a central role in the low carbon energy system of the future. Tying these numerous assets into systems that maximize value to their owners as well as the overall grid will be critical.

The number of smart thermostats in North America has grown 267% in the last three years surpassing 2 million in 2017.[3]

3: Navigant Research, 2017

Maximizing the Role of Renewable Energy

Flexibility from technologies and markets leads to optimization of carbon-free resources

Renewable energy has become a leading generating resource for electricity in the United States. In 2016 15% of electricity came from renewable sources.[4] This up about 50% over the last five years, mostly from large increases in wind and solar power. The clean energy boom has been driven by falling renewable energy prices, strong interest from individuals and businesses, and committed (largely sub-national) policies to help accelerate a low carbon energy future. Extending this trend, so that renewables make up significant portion of the energy mix, requires grid modernization investments and solutions at scale.

Energy stakeholders are blazing the path to a cleaner electrical grid, particularly at the local level. For some regions, the driving force is a desire to make an impact on climate and carbon management, which also results in cleaner air across communities. For others, it may be job creation and economic activity, or the reduction in electricity costs that competitive renewable energy generation sources can provide. Most regions cite some combination of all of these drivers, and more, as they aggressively pursue clean energy to power their grid.

A growing number of communities (such as Hawaii and recently St. Louis) are planning to power their grids with nearly 100% clean energy. Many communities across the country have a clean energy requirement or goal, depending in large part on their supply and technology diversity. Many will be able to access wind (onshore and off) and solar (PV and thermal). Certain regions may also tap geothermal, hydro and renewable biofuels, while others may develop marine/tidal generation. Flexible asset coordination will remain central to the reliability of energy systems with significant levels of renewable energy.

An energy system with significant levels of renewable resources will need flexible grid modernization solutions to maximize utilization of clean energy. Developing this flexibility will likely include transmission infrastructure build outs and it will include development of other solution areas. For instance, certain grid modernization applications can result in better forecasting and system modeling. With a deeper understanding of climate and weather patterns, grid operators can plan for the needs of the system. By directly tying sophisticated forecasting tools into resource planning and grid control systems, grid operators will be able to maximize the effectiveness of clean energy assets.

Another essential capability lies in developing more flexibility as to when energy is used. The key is to offer solutions that align demand for energy when clean energy resources are abundant.

4: US EIA, Electricity in the United States, 2017

Maximizing the Role of Renewable Energy

For example, tariffs for charging EVs may encourage people to charge their electric cars when the wind is blowing or the sun is shining. Under this structure consumers can pay less for their energy, and generators can expand renewable assets.

Similarly, energy storage can be used in number of ways to add flexibility in the energy system to accommodate more renewable resources.

Finally, regional markets can help bring on more renewables across large geographies. Many clean resources are variable in nature and often sited across locations that maximize their potential. Places with abundant solar, for example, could sell excess renewable power to neighboring states which may otherwise use fossil fuels. In another instance a state could import wind as the sun is setting to meet high energy demand. Creating markets that allow regions to access and trade clean energy helps make sure that resources are used to their highest potential.

Bringing a mix of clean energy to underdeveloped areas where it can be used may indeed require additional transmission and distribution infrastructure. However, all capital efficient investments should be considered. A diverse set of grid management solutions would allow communities and wider areas of the system to run on significant levels of clean energy resources.

Metrics Build Confidence in Grid Modernization

How can regulators and energy stakeholders ensure the benefits of diverse grid modernization investments if they aren't measured? By developing metrics closely tied to desired policy outcomes and increased system functionality, we can track the progress of grid upgrades.

Metrics can also provide the information that would allow decision-makers to course-correct certain aspects of the design and implementation of these investments. Providing consistent and transparent information about progress allows customers, policy makers and other stakeholders to feel comfortable with investments that have been made and have greater confidence in future investment decisions.

Some of these metric areas can include:

- Frequency and duration of outages;
- Level of greenhouse gas emissions from energy sector;
- Number of customers with access to actionable data;
- Amount of demand side resources being used; and
- Time to connect customer generation to the grid

States including Illinois, New York and Indiana have already employed such metrics and some are considering tying grid operator compensation to their success.

Electrification of Transportation Systems

Zero-emissions vehicles drive new opportunities for utilities while significantly decarbonizing transportation

For the first time since the late 1970s, the electric power sector carbon emissions have fallen below those of the transportation sector.[5] To drive carbon and other emissions even lower, the U.S. must intensify its focus on electrifying transportation systems and ensuring they are powered with clean energy. In addition to making significant progress on climate, electrified transportation can create new markets for products and services that catalyze economic growth and jobs.

Of the more than 260 million registered commuter vehicles in the United States only about 0.2% are electric vehicles.[5] The share is quickly growing however. Bloomberg New Energy Finance estimates that electric vehicles will make up 54% of all new light-duty vehicle sales in the U.S. by 2040, and add as much as 5% to global electricity consumption.[7] At the same time, fleets, buses, and trucking also show potential in becoming increasingly electrified.

This rapid electrified transportation growth can strengthen grid operator business models as a result of the increased revenues that come from serving millions of electric vehicles. Moreover, enabling the infrastructure to charge and manage electric vehicles presents a significant business opportunity for grid operators and other providers.

The clearest path for aligning the rapid growth of electrified transportation and a carbon-free future lies in smart charging. Electricity rates should encourage charging at times that optimize the use of abundant clean energy – be it in the afternoon when the sun is shining or evenings when wind turbines are spinning. If vehicles are charged at peak demand times, such as mid-morning or early evening in some regions, grid operators may need to rely on fossil fuel-burning peaking plants. Rates that encourage use of available renewables not only benefit customers with low-cost power for their vehicles, but also help grid operators and other clean energy providers maximize value from investments in clean energy projects.

Electric vehicle charging rates (“tariffs”) can indeed be simple at the outset. These tariffs may evolve to create pricing signals that dynamically communicate system needs to optimize time of charging and increase the value that electric vehicles provide through various grid services, similar to existing smart thermostat pricing and automated demand management programs.

Regulators should consider how best to deploy the charging infrastructure needed to accommodate this transition. They may

5: US EIA, Today in Energy blog, 2017 6: US Dept. of Transportation and IHS Markit, 2016 7: BNEF, Electric Vehicle Outlook 2017, 2017

Electrification of Transportation Systems

look to help facilitate diverse sources of capital, examine the role of third-party provider services, and ensure interoperability of infrastructure for open access to resources by all. To date, regulators from California to Kansas have taken a deliberate approach to defining utility roles in the needed electric vehicle infrastructure. However, as the trend for electrified transportation continues, regulators and other stakeholders should look for a clearer understanding of how charging and other infrastructure investments by utilities and other parties benefit ratepayers and maximize customer value.

Regulators and other stakeholders should help utilities embrace the diverse roles they could be playing in the acceleration of EV charging, including:

- As potential owners of EV infrastructure, selling electricity to people using charging stations, and capitalizing investment assets;
- As marketers to help customers understand the needs and value for smart charging and how electrified transportation is a good proposition;
- As partners with infrastructure providers to share in revenue generated from EV service solutions; and
- As a regulated entity, ensuring equal access to and benefits from electrified transportation for all income groups in their service areas.

In these ways, regulators and stakeholders can align the emerging needs of customers with the underlying business case changes needed to make the electric vehicle transition work for everyone. However, it is clear that in order to reach the low-carbon, electrified transportation future, regulators must be open to allowing grid operators to quickly respond to this market opportunity while helping EV owners use available clean resources.

Additionally, electrification is expanding in areas beyond transportation. Electrifying heating and a number of other areas of energy use have become increasingly powered by electricity rather than other fuel sources. These developments increase the need for grid modernization progress. as new applications are powered by clean sources and efficient solutions.

Electric vehicles' potential climate benefits could increase dramatically over time, from over

125 MILLION TONS CO2/YEAR IN 2030

1.5 BILLION TONS CO2/YEAR IN 2050[8]

8 ICCT, global climate change mitigation potential from a transition to electric vehicles, 2015

Access to Actionable Energy Data

Helping consumers make smart decisions that benefit themselves and the shared electric grid

Most customers receive information on their energy use once a month in a utility bill, and this comes to them some time after they've consumed it. Given the delay and lack of detail involved with data provided at this level, this process does not empower customers to manage their energy use. Emerging data access standards enabled by grid modernization radically change this dynamic by providing customers with meaningful, current and actionable information to take control of their energy use.

With the arrival of new energy options and services including rooftop solar, smart thermostats, and building automation systems, some consumers and businesses aren't willing to just take a passive role when it comes to their energy use. According to the Smart Energy Consumer Collaborative, consumers are highly interested in participating in real-time reporting of electricity outages (66%), energy use information (65%) and participation certain pricing programs (59%).[9]

Vast amounts of data from grid modernization investments can be collected from smart meters, connected thermostats and other sources. New applications then turn that data into actionable information for energy users in an easy-to-understand and easy-to-engage format. This information provided by utilities or other third parties equips people and businesses with the tools they need to decide how to manage their energy and power their lives in the ways most rewarding to them.

Utilities and various third-party providers have the opportunity to strike the right balance of getting deep information to those that want it, and providing simpler options to others who prefer less-involved energy interactions. Whatever their level of engagement, energy consumers want more than just lower costs. Their interests could include:

- Increased communications for outages and restoration;
- Options for accessing clean energy;
- Signing up for demand management programs;
- Extra resiliency solutions to keep the power on;
- Helping support community-based projects;
- Seeing where their energy comes from; and
- Comparing their usage to neighbors or others in similar living situations.

Even if some customers choose not to actively participate in energy management programs, grid operators can leverage key system information—and aggregate the collective actions by users—to achieve system benefits including peak management, stabilizing generation including the ramping of renewables, and delaying or entirely avoiding costly infrastructure builds. These

9: SCGG, Consumer Pulse and Market Segmentation Study, 2017

Access to Actionable Energy Data

grid efficiency benefits come back to all energy users in the form of the lower rates.

Because not all customers are alike, utilities and third-party providers should develop a deep understanding of individualized customer preferences and act on that knowledge with a range of offerings. Customized engagement will improve customer satisfaction and maximize energy related outcomes. One leading best practice in this area is ensuring that grid operators who may have invested in foundational technologies (such as smart meters) use their position as a platform for other innovators to provide value to customers. The Department of Energy's Green Button Initiative, and in particular its "Connect My Data" capability, provides guidance on how utilities can provide open access metering data so that third parties can more effectively bring energy management solutions to interested customers.

In creating additional energy information services, each utility and third-party provider should also follow leading practices in data privacy and security. Customers need to be assured that their information will be secure and used only for purposes they agree to. Consumer advocates and regulators can help set the guidelines to leverage the vast data about energy systems securely, fairly and efficiently. Using this actionable information, energy users can become more active participants in their own energy management and in aggregate help system operators run the grid more effectively,

Harnessing Hidden Efficiency: Voltage Optimization

Voltage optimization is a practice that allows for greater visibility and control of the grid and has the potential to decrease how much electricity we consume by about 2-3% nationally,[10] with commensurate reductions in greenhouse gas emissions equivalent to taking approximately 15 million fossil fuel burning cars off the road.[11]

This practice involves the use of advanced control technologies to "right-size" voltage levels delivered to electric customers. This can reduce how much energy people use, lowering costs for customers and the amount of air pollution produced through electricity generation, without requiring customers to take any action or sacrifice service quality. This practice can also help in integrating more renewable energy.

Utilities can deploy this tool in just a few years and these extensive benefits persist year over year. That's why utilities such as Duke and Xcel Energy are pursuing broad or system-wide deployments of this practice across select territories.

10: PNNL, Evaluation of Conservation Voltage Reduction on a National Level, July, 2010

11: Based on US EIA electricity sales estimates and EPA Greenhouse Gas Equivalency Calculator

Efficient Transmission and Distribution Management


Source: Avista

Smarter, cleaner use of new and existing infrastructure

With the diversity of technology solutions now available, utilities are able to not only rebuild our aging infrastructure and meet future demand, but also to proactively invest in analytics and controls that increase the utilization of equipment we already have. These solutions can boost energy system efficiency, cost-effectiveness, and reliability, while improving the quality of electric service in a sustainable manner.

The grid has been designed with considerable redundancies in order to ensure that throughout various dynamic conditions, from outages to overloads, reliable electric service could be provided to all customers. For instance, the grid has been built to accommodate the highest level of electricity demand, even though we may only experience this level of use for a few hours in a year. A modernized grid can act as a platform that allows various resources to meet demand (peak or otherwise) more cost-effectively. These capital efficient investments in energy infrastructure help ensure that customers save money and pay a more appropriate level for the systems and solutions that reliably tie them into the grid.

For example, allowing redispatch when certain transmission paths are restricted sends a signal to power providers regarding transmission capacity. This request for changes in power generation levels may be more cost-effective than additional transmission build-outs, and helps to increase the utilization of existing infrastructure.[12]

Other capabilities enabled by grid modernization investments can improve the overall quality of electric service. Voltage optimization, for instance, uses sensors for greater visibility into grid operations to allow operators to match system voltage more precisely with the electricity needs of customers. This cost-effective, proven application can improve service, save customers money and defer the need for new generation, transmission and distribution.

Efficient infrastructure management does not entirely replace the need for new infrastructure. EEI reports that its investor-owned utility members boosted transmission infrastructure investments from around $10B a year in 2010 to around $20B in 2015, a level which likely only increases.[13] The nation's energy infrastructure is aging, and making investments in transmission resources to improve reliability and resiliency and to integrate renewable energy is critical. In doing so, however, regulators, consumer advocates and others must evaluate all technically reliable solutions to accommodate system needs, and incentives should be in place for grid operators to select resource

12: NREL, Effective Grid Utilization: A Technical Assessment and Application Guide, 2012

13: EEI, Transmission Projects at a Glance, 2016

Efficient Transmission and Distribution Management


Source: Avista

efficient options that align with state and regional goals.

Improved infrastructure management will rely as much on new digital infrastructure as new poles, wires, substations and transformers. Enhanced networks, systems and processes are necessary for distribution systems to coordinate a myriad of generation and demand side resources, deliver variable clean energy resources to load centers, optimize dynamic pricing structures, provide the backbone for distribution system operators to integrate into energy markets, and more.

Efficiently managed transmission and distribution infrastructure indeed leads to desired outcomes, such as a reduction in losses of energy between generation and consumption, better power quality, smart planning and right-sized investments. Most importantly, it's a cornerstone to developing a modern grid. This efficient system helps ensure that renewable energy generation is optimized and reaches customers. It accommodates the increasing electrification of transportation systems. It increases levels of awareness across the system so that service issues can be minimized and diverse objectives can be met. It ensures that all customers have access to actionable data and that grid operators are able to aggregate distributed resources and manage them in an effective manner, as has been the case with central generation sources for decades.

We are asking more of our electric infrastructure now and very likely will have even higher demands of going forward. Effectively modernizing our grid so that it can continually respond to diverse requirements sets the foundation to progress local, regional and national climate-related objectives - not only for for our energy system but for our society overall.

Moving Forward

We hope the core capabilities described here serve as a useful guide for those working to make meaningful progress on climate change in their regions. The 'right' combination of grid modernization steps and investments will look different for each region, but core elements in each of these categories can make meaningful progress everywhere. We plan to go deeper and release more details on each capability area in subsequent white papers.

EDF looks forward to working with all stakeholders, including state regulators, utilities, consumer advocate groups and others to make meaningful progress on climate with grid modernization. If you have questions about how your organization can best pursue grid modernization topics in your community please contact:

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