

The Role of Innovation in the Electric Utility Sector

Future Electric Utility Regulation
Report No. 13

April 2022

National Association of State Utility Consumer Advocates
Kevin Lee, BlueGreen Alliance
Adam Cooper, Lisa Wood, and Mike Shuster, Institute for Electric Innovation
Anne Hoskins, Christopher M. Worley, and Keyle Horton, Sunrun
Kristin Barbato, Barbara Kates-Garnick, and Max McCafferty, Build Edison

Project Manager and Technical Editor:
Lisa Schwartz, Lawrence Berkeley National Laboratory

The Role of Innovation in the Electric Utility Sector

Future Electric Utility Regulation
Report No. 13

National Association of State Utility Consumer Advocates

Kevin Lee, BlueGreen Alliance

Adam Cooper, Lisa Wood, and Mike Shuster, Institute for Electric Innovation

Anne Hoskins, Christopher M. Worley, and Keyle Horton, Sunrun

Kristin Barbato, Barbara Kates-Garnick, and Max McCafferty, Build Edison

Project Manager and Technical Editor:

Lisa Schwartz, Lawrence Berkeley National Laboratory

April 2022

About the Authors

National Association of State Utility Consumer Advocates (NASUCA)

NASUCA members are designated by the laws of their respective jurisdictions to represent the interests of utility consumers before state and federal regulators and in the courts. NASUCA's essay was developed by a subcommittee of interested members through surveys and an open call with members and was approved by the NASUCA Executive Committee.

Tim Woolf and Ben Havumaki worked with NASUCA to draft its essay for the report. Woolf is a Senior Vice President at Synapse Energy Economics with more than 35 years of experience conducting technical and economic analyses of energy and environmental issues on behalf of consumer advocates, environmental advocates, regulators, and government agencies. He served as a commissioner at the Massachusetts Department of Public Utilities from 2007–2011. Havumaki is a Senior Associate at Synapse Energy Economics.

BlueGreen Alliance (BGA)

BGA unites labor unions and environmental organizations to solve today's environmental challenges in ways that create and maintain quality jobs and build a clean, thriving, and equitable economy.

Kevin Lee is the State Energy Policy Director at BGA, responsible for developing and overseeing implementation of a multi-state plan to move state-level policies on climate change, clean energy, energy efficiency, workforce and labor standards. Prior to joining BGA, he was a Senior Staff Attorney and Program Director for the Climate and Energy Program at the Minnesota Center for Environmental Advocacy, overseeing a team of attorneys, policy analysts, and communications staff to advocate for clean energy policy before state agencies, courts, and legislatures. A graduate of Carleton College, George Washington University Law School, and the Vermont Law School, Lee also has served as faculty at the Mitchell Hamline School of Law and the University of Minnesota Law School, where he directed the Environmental and Energy Law Clinic.

Institute for Electric Innovation (IEI)

IEI focuses on advancing the adoption and application of new technologies that will strengthen and transform the power grid. IEI's members are the investor-owned electric utilities that represent about 70% of the U.S. electric power industry.

Adam Cooper is Senior Director of Research & Strategy at IEI. He publishes articles and issue briefs that assess how technology, public policy, and customer expectations are shaping an increasingly clean and innovative electric power sector. Prior to joining IEI, Cooper worked at the Center for Automotive Research and the White House Office of Management and Budget's Energy Branch, and held the title of Economist at Regional Economic Models, Inc. Cooper holds a master's in public policy from the University of Michigan and a B.A. in economics and history from Brandeis University.

Lisa Wood is Executive Director of IEI. She collaborates with a Management Committee of more than 25 electric company CEOs and a select group of technology companies and provides thought leadership on current issues and trends in the electric power industry. Under her leadership, IEI published three volumes of Key Trends Driving Change in The Electric Power Industry. As Vice President of Customer Solutions at Edison Electric Institute (EEI), Wood oversees initiatives in corporate customer sustainability solutions, military customer solutions, residential customer services and solutions, and electric transportation and collaborates with a Customer Solutions CEO Policy Committee, Executive Advisory Committee, and Customer Advisory Group. Under Wood's leadership, EEI released its first Electric Company Carbon Emissions and Electricity Mix Reporting Template for corporate customers. Prior to joining EEI, she was a principal with The Brattle Group and PHB Hagler Bailly and a Program Director at RTI International. She holds a Ph.D. in public policy and management from the Wharton School of the University of Pennsylvania, an M.A. from the University of Pennsylvania, and a B.A. from Rutgers College.

Mike Shuster is Senior Manager of Research and Partnerships at IEI. He manages a roundtable of select technology companies dedicated to advancing innovative customer solutions that support the electric power sector's transition to a cleaner, customer-centric, and flexible energy grid. Prior to joining IEI, Shuster developed industry expertise at Siemens Energy, graduating from its Engineering Leadership Development Program and leading utility integrated resource plans and city electrification programs in its advisory practice. He is a recent alumnus of the Clean Energy Leadership Institute fellowship and the Financing and Deploying Clean Energy program at the Yale Center for Business and Environment. He holds a B.S. in chemical engineering from the University of Florida.

Sunrun

Sunrun is the largest residential solar and battery storage company in the United States.

Anne Hoskins serves as Chief Policy Officer of Sunrun. She leads the company's policy and market development efforts to expand access to solar energy and storage and to modernize the electric grid, while providing industry leadership through serving on the Board of Directors of the Solar Energy Industries Association (Vice Chair) and the Interstate Renewable Energy Council. Hoskins previously served as a Commissioner on the Maryland Public Service Commission where she was a member of the NARUC Board of Directors and Chair of the NARUC International Relations Committee. Prior to joining the Maryland Commission, she led federal and state policy and advocacy for Public Service Enterprise Group, served as a Visiting Research Scholar at Princeton University, and was Senior Regulatory Counsel at Verizon Wireless. She is a graduate of Harvard Law School, the Princeton School of Public and International Affairs, and Cornell University.

Christopher M. Worley is Director of Public Policy of Sunrun, overseeing policy and government affairs in the Mountain West region. Worley serves in a leadership role on the Boards of Directors of the Arizona Solar Energy Industries Association and the Colorado Solar and Storage Association. Before joining the solar industry, he worked on energy policy at the Colorado Energy Office where he oversaw its legislative and regulatory activities. Worley worked on energy analysis at the National Renewable Energy Laboratory and earned his Ph.D. in mineral and energy economics from the Colorado School of Mines.

Keyle Horton is a recent graduate from the University of California, Berkeley with a Master in Public Policy. Specializing in climate and energy policy, she has conducted research on solar power and battery storage programs in California, local building decarbonization efforts, the potential to adopt carbon pricing policies in Colorado, and microgrids as a means of augmenting the U.S. power system.

Build Edison

Build Edison offers advisory and consulting solutions and services to enable startups to transition their technologies to commercial growth and benefit both customers and investors.

Kristin Barbato has 25 years in energy and sustainability serving in executive roles spanning utilities, government, and energy services. Currently, she is the CEO of Build Edison, which she founded to help energy solutions get to scaled commercialization faster. She also is cofounder of Dynamo Energy Hub, a unique global network of innovative energy companies, investors, and governments in key cities to accelerate the clean energy economy. In previous roles, Barbato was Vice President of Customer Energy Solutions at the New York Power Authority and New York City's Chief Energy Management Officer, leading the long-term sustainability plan for the largest municipal energy infrastructure in the United States, with an annual budget of \$1.3 billion.

Barbara Kates-Garnick is a professor of practice at the Fletcher School of Tufts University with a focus on the energy transition. Her career in the public sector includes serving as the Undersecretary of Energy for the Commonwealth of Massachusetts and as a Commissioner of Public Utilities. She served as Vice President of Corporate Affairs at KeySpan and as a consultant to NYU-Poly (now Tandon School of Engineering), where she developed the proposal for the New York City Accelerator for Clean and Renewable Energy. With Build Edison, Kates-Garnick leverages her expertise in regulatory policy, utilities, and energy innovation to support research, policy recommendations, regulatory strategy, and program development.

Max McCafferty joined Build Edison in 2018 with a background in clean energy innovation, commercializing energy technologies, and quantitative financial analysis. Serving as Chief Operating Officer, he leverages his experience to provide Build Edison's clients with strategies to develop energy innovation programs, scale cleantech solutions, and analyze potential investment opportunities. McCafferty focuses on multiple sides of energy solutions and innovation, developing innovation programs and strategies as well as enabling energy startups to scale. He has worked with clients of all sizes, spanning early stage cleantechs, corporations, utilities, investors, and governments.

The work described in this report was funded by the U.S. Department of Energy's Grid Modernization Laboratory Consortium under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

Disclaimer

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Ernest Orlando Lawrence Berkeley National Laboratory is an equal opportunity employer.

Copyright Notice

This manuscript has been authored by an author at Lawrence Berkeley National Laboratory under Contract No. DE AC02-05CH11231 with the U.S. Department of Energy. The U.S. Government retains, and the publisher, by accepting the article for publication, acknowledges, that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this manuscript, or allow others to do so, for U.S. Government purposes.

Future Electric Utility Regulation Advisory Group

Commissioner Abigail Anthony, Rhode Island Public Utilities Commission

Michele Beck, Utah Office of Consumer Services

Janice Beecher, Institute of Public Utilities, Michigan State University

Ralph Cavanagh, Natural Resources Defense Council

Digaunto Chatterjee, Eversource

Steve Corneli, Strategies for Clean Energy Innovation

Chandra Farley, ReSolve Consulting

Commissioner Sarah Freeman, Indiana Utility Regulatory Commission

Asim Z. Haque, PJM Interconnection

Lon Huber, Duke Energy

Bob Jenks, Oregon Citizens' Utility Board

Steve Kihm, Citizens Utility Board of Wisconsin

Kerri Kirschbaum, Consolidated Edison

Kevin Lee, BlueGreen Alliance

John Lochner, New York State Energy Research & Development Authority

Jeff Lyng, Xcel Energy

Kristin Munsch, National Grid

Delia Patterson, American Public Power Association

Commissioner Tremaine Phillips, Michigan Public Service Commission

Dwayne Pickett, ComEd

Commissioner Jennifer Potter, Hawaii Public Utilities Commission

Rich Sedano, Regulatory Assistance Project

Jean Su, Center for Biological Diversity

Sally Talberg, consultant

Commissioner Letha Tawney, Oregon Public Utility Commission

Chair Ted Thomas, Arkansas Public Service Commission

Sam Whelan, Holy Cross Energy

Jordan White, GridLiance

Other reports in this series

1. *Electric Industry Structure and Regulatory Responses in a High Distributed Energy Resources Future* (November 2015)
2. *Distribution Systems in a High Distributed Energy Resources Future: Planning, Market Design, Operation and Oversight* (October 2015)
3. *Performance-Based Regulation in a High Distributed Energy Resources Future* (January 2016)
4. *Distribution System Pricing with Distributed Energy Resources* (May 2016)
5. *Recovery of Utility Fixed Costs: Utility, Consumer, Environmental and Economist Perspectives* (June 2016)
6. *The Future of Electricity Resource Planning* (September 2016)
7. *The Future of Centrally-Organized Wholesale Electricity Markets* (March 2017)
8. *Regulatory Incentives and Disincentives for Utility Investments in Grid Modernization* (May 2017)
9. *Value-Added Electricity Services: New Roles for Utilities and Third-Party Providers* (October 2017)
10. *The Future of Transportation Electrification: Utility, Competitive Market and Consumer Perspectives* (August 2018)
11. *Utility Investments in Resilience of Electricity Systems* (April 2019)
12. *Advancing Equity in Utility Regulation*

Reports and webinar slides and recordings are available at feur.lbl.gov. Additional reports are underway.

Related reports

State Performance-Based Regulation Using Multiyear Rate Plans for U.S. Electric Utilities (July 2017). <https://emp.lbl.gov/publications/state-performance-based-regulation>.

Renewable Energy Options for Large Utility Customers (June 2019). [Report PDF](#). [Webinar recording and slides](#).

All-Source Competitive Solicitations: State and Electric Utility Practices (March 2021). <https://emp.lbl.gov/publications/all-source-competitive-solicitations>.

Executive Summary

By Lisa Schwartz, Lawrence Berkeley National Laboratory

A new National Academies report evaluates energy technologies, grid operations, business practices, electricity demand, and other developments that could support beneficial evolution of the nation's power systems across a wide range of futures. According to the authors, "Creating an environment that promotes innovation will be essential if the future power system is to do an adequate job of providing service that is safe and secure, clean and sustainable, affordable and equitable, and reliable and resilient."¹

The report recognizes the importance of utility regulatory advances to speed socially beneficial innovation for investor-owned electric companies.² Among them is accelerating investigations into changes in electric industry structure, services, security, pricing, and market design to: (1) align with significant deployment of behind-the-meter technologies and other distributed energy resources (DERs) and (2) address equity issues for energy access and clean energy.³ In addition, the authors assert that "[a]chieving greater deployment of advanced electrical technologies will require states to implement regulatory reforms that allow utilities to recover the costs of larger research and development (R&D) budgets alongside other forms of regulatory approval that encourage more adoption of new technologies."⁴

Overall, state regulation can slow utility innovation, in large part because the risks for utilities may be too high relative to the rewards.⁵ In addition, consumer advocates would rather have R&D funded in ways that are not on consumer electricity bills.⁶ As a result, electric company innovations tend to be reactive to initiatives by regulators and the utility's corporate customers. In contrast to firms that put money at risk to provide solutions that customers did not even know they wanted, such as the smart phone, electric companies often are not financially motivated to change the status quo. So it is not surprising that energy utilities on average invest a low percent of net revenues in R&D compared to similarly situated industries.⁷

To achieve state targets for clean energy and reducing greenhouse gases, some public utility commissions are exploring new approaches that are intended to spur beneficial utility innovation, while minimizing risks to utility customers. Among these initiatives are regulatory and marketing flexibility for utilities,⁸

¹ National Academies of Sciences, Engineering, and Medicine (2021) at 2.

² City councils regulate public power utilities and boards typically regulate rural electric cooperatives. While this report does not cover these utilities, they also are piloting and deploying new technologies, implementing innovative rate designs, and engaging in new clean energy partnerships. For example, the American Public Power Association (APPA), the National Rural Electric Cooperative Association, and member utilities partner with U.S. DOE and the national labs on R&D for community solar, storage, and other low-emissions solutions. APPA's Demonstration of Energy & Efficiency Developments program provides grants and scholarships to member utilities for R&D.

³ For equity issues, also see Future Electric Utility Regulation report no. 12 by Farley et al. (2021).

⁴ National Academies of Sciences, Engineering, and Medicine (2021) at 10.

⁵ National Regulatory Research Institute (NRRI) (2016).

⁶ See, for example, NASUCA resolution 1997-01: "WHEREAS, the Electric Power Research Institute ("EPRI") is the research and development entity for the electric industry and EPRI functions as a voluntary organization whose members agree to participate and fund the research and development efforts regardless of whether the state regulatory agencies with jurisdiction over the electric utilities rates sanction flowthrough of 100% of EPRI's funding costs to electric consumers; THEREFORE BE IT RESOLVED, that the National Association of State Utility Consumer Advocates ("NASUCA") believes that in order to promote the use of competitive market forces as a tool to regulate rates for natural gas services, GRI should move in the same direction as EPRI for purposes of funding research and development..." (<https://www.nasuca.org/gas-research-institute-1997-01/>). Also see NASUCA resolution 2002-01: <https://www.nasuca.org/opposing-surcharge-for-natural-gas-research-2002-01/>.

⁷ See, for example, NRRI (2016), McKinsey & Co. (2020), and Waite (2017).

⁸ See forthcoming report by Tom Stanton, NRRI, *Achieving Benefits of Utility and Regulatory Innovation Using State Public Utility Regulatory Innovations Platforms*.

increased funding for utility demonstration projects, and performance-based ratemaking including multi-year rate plans. Another pathway some commissions are exploring is facilitating third parties to provide utility customers with innovative products and services directly.

This report provides consumer, labor, utility, third-party service provider, and clean technology consultant perspectives on innovation in the context of state regulation of utilities. A key point of departure among the authors is the role of utilities versus third-party providers in developing and providing innovative solutions. The organizations represented by the authors also are at odds over the level of spending on innovation, who bears the costs and risks, who will benefit, and who builds and maintains the electricity infrastructure that innovation requires.

The *National Association of State Utility Consumer Advocates* (NASUCA) begins the discussion by describing both opportunities and challenges for regulatory innovations in six areas to advance the transition away from fossil-fuel powered generation toward a more renewable and distributed grid: prioritization of DERs; pricing, rate design, and cost allocation; performance-based regulation; integrated planning; stranded costs; and energy equity. Without meaningful stakeholder engagement and careful design and implementation, these innovations will not necessarily offer benefits for customers and society overall. Further, innovation also raises new risks to utility customers and potentially higher utility bills for customers who cannot, or do not wish to, take advantage of new technologies. From NASUCA's perspective, "The task is to ensure that new policies and regulatory practices are well designed and strike the right balance between allowing the industry to evolve in productive directions, achieving current and new policy goals, and ensuring customer protection and equity."

Kevin Lee, BlueGreen Alliance, explains why state regulatory and utility actions to meet the climate challenge also should support strong local economies and fairness for utility workers. Specifically, he explores how utility labor decisions—pay, benefits, and staffing levels—impact outcomes for innovation in the context of community support for clean energy development and grid resiliency. According to Lee, "the same factors that drive a utility to minimize its labor costs also have produced a regulatory environment that makes it challenging for utilities to make much-needed investments in grid modernization and resiliency." Further, "[b]y enacting and implementing policies with an eye toward local impacts, including jobs, wages, and tax benefits—particularly in distressed communities—we can ensure that the massive investments required for a clean energy future will benefit communities hosting the needed electricity infrastructure, earning their support along the way."

Adam Cooper, Lisa Wood, and Mike Shuster, Institute for Electric Innovation (IEI), present case studies on U.S. investor-owned utilities that provide innovative solutions to meet the needs of their customers through partnerships with technology companies. The featured residential programs are designed to help customers manage their home energy and carbon footprints. Initiatives highlighted for the commercial market sector illustrate how utilities work directly with corporate customers to help them achieve their goals to reduce carbon emissions. IEI's essay also addresses regulatory approaches to support innovative utility services for customers in the future. These approaches include providing renewable or carbon-free energy to match hourly customer load 24/7, making carbon-free energy resources available to all customers, and improving planning for CFE resources. From IEI's perspective, "The ability to plan for and develop cost-effective and scalable carbon-free energy products and solutions is essential." However, the extent to which electric companies can satisfy this demand, and how quickly they can adopt the necessary technological innovations, depend on state regulatory approvals.

Anne Hoskins, Chris Worley, and Keyle Horton, Sunrun, instead call for a "market-based approach" for innovative technologies and services with a strong role for third-party providers willing to risk capital and compete to develop the innovations needed to meet energy, climate, and other state goals. Further, to achieve the magnitude of investment needed to meet state goals, Sunrun says customers should be encouraged to

invest in DERs and other behind-the-meter technologies, whether their motivation is economic, environmental, reliability, or resilience. According to Sunrun, “state public utility commissions should require regulated utilities to establish rate structures and program incentives that fairly compensate behind-the-meter DERs for the benefits they provide the grid. In addition, to support a decentralized energy system over the long term, utility incentives must be realigned so that onsite generation is not a source of lost revenue and lost profit.” The essay provides examples of innovative state regulatory approaches that can be replicated and adapted to promote integration of DERs, as well as innovative utility actions that facilitate modernization of electric systems. Sunrun recommends near-term regulatory actions for immediate progress as well as longer-term structural changes for the electricity sector. In Sunrun's vision of the future, utilities serve as distribution system operators, spurring innovation and integration of DERs by procuring and coordinating distributed reliability services, and coordinating and distributing power to customers and across the distribution-transmission interface.

Conversely, *Kristin Barbato, Barbara Kates-Garnick, and Max McCafferty at Build Edison*, a consulting firm for innovative clean technology companies, maintain that utilities should play the dominant investment role in the transition to a clean energy future. Utilities have access to physical grid assets and customer data. And vertically integrated utilities have generation and transmission data, as well. From the authors' perspective, “This understanding of the technical demands of the grid, as well as the demands of customers and grid assets, means that utilities are central in identifying, deploying, and scaling necessary innovative energy solutions. No third parties have the combined access, resources, expertise, and reach to achieve the same level of impact.” Further, “utility regulators have an increasing responsibility to incentivize utilities to engage with and scale innovative solutions.” The authors define a gap in the innovation adoption curve for technologies that are “often trapped in pilot after pilot with no clear path to scaled deployment.” Build Edison's recommendations to help overcome these challenges include better alignment of principles governing regulatory decision-making and principles governing utility investment decision-making, accounting for the value of innovative solutions for both current and future customers, and identifying at the design phase of pilot programs the capital needed to scale successful demonstrations.

Acknowledgments

Thanks to Michele Boyd, Kevin Lynn, and Alejandro Moreno, U.S. Department of Energy (DOE), and the following members of the Future Electric Utility Regulation Advisory Group and other experts for reviewing a draft of this report: Michele Beck, Utah Office of Consumer Services; Janice Beecher, Michigan State University Institute of Public Utilities; Peter Cappers, Lawrence Berkeley National Laboratory; Commissioner Sarah Freeman, Indiana Utility Regulatory Commission; Steve Kihm, Citizens Utility Board of Wisconsin; John Lochner and Scott Egbert, New York State Energy Research & Development Authority; Matthew McDonnell, Strategen; Commissioner Tremaine Phillips and Sarah Mullkoff, Michigan Public Service Commission; Commissioner Jennifer Potter and Layla Kilolu, Hawaii Public Utilities Commission; Rich Sedano and Ann McCabe, Regulatory Assistance Project; Tom Stanton, National Regulatory Research Institute; Sally Talberg, consultant; Chair Ted Thomas, Arkansas Public Service Commission; and Paul Zummo and Patricia Taylor, American Public Power Association.

Any remaining errors or omissions are the sole responsibility of the authors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, The Regents of the University of California, or Future Electric Utility Regulation Advisory Group members.

About the Series

The provision of electricity in the United States is undergoing significant changes for many reasons. The implications are important and merit serious attention.

The current level of discussion and debate surrounding these changes is similar in magnitude to the discussion and debate in the 1990s on the then-major issue of electric industry restructuring, both at the wholesale and retail level. The U.S. Department of Energy (DOE) played a useful role by sponsoring a series of in-depth papers on a variety of issues being discussed at that time. Topics and authors were selected to showcase diverse positions on the issues to inform the ongoing discussion and debate, without driving an outcome.

While today's issues are different, the scale of the discussion and the potential for major changes are similar. Today's discussions have largely arisen from a range of challenges and opportunities created by new and improved technologies, changing customer and societal expectations and needs, and structural changes in the electric industry. Some technologies are at the wholesale (bulk power) level, some at the retail (distribution) level, and some blur the line between the two. Some technologies are ready for deployment or are already being deployed, while the future availability of others may be uncertain. Other key factors driving current discussions include changing state and federal policies and regulations. Issues evolving or outstanding from electric industry changes of the 1990s also are part of the current discussion and debate.

Further, in recent years foreign adversaries have been developing capabilities to initiate cyber and physical attacks on our energy infrastructure, possibly inducing regional-scale outages lasting weeks or longer. In addition to making our infrastructure more resilient against such actions, we must ensure that defense-critical energy infrastructure remains functional under any conditions. We are also increasingly vulnerable to damages from severe weather or natural events, such as hurricanes, earthquakes, and wildfires, due to increasing population density and economic development in the affected areas, and the growing interdependence among our energy, water, and communications systems.

To provide future reliable and affordable electricity and to meet climate goals, power sector regulatory approaches may require reconsideration and adaptation to change. DOE is funding the Future Electric Utility Regulation series of reports, of which this is a part, to reflect the diverse viewpoints on what is needed to meet the goals. DOE hopes these reports will help better inform discussions underway and decisions by public stakeholders, including regulators policymakers, as well as industry.

The topics for these papers were chosen with the assistance of a group of recognized subject matter experts. This advisory group, which includes state regulators, utilities, stakeholders, and academia, works closely with DOE and Lawrence Berkeley National Laboratory (Berkeley Lab) to identify key issues for consideration in discussion and debate.

The views and opinions expressed in this report are solely those of the authors and do not reflect those of the United States Government, or any agency thereof, The Regents of the University of California, or Advisory Group members.

Contents

About the Authors.....	iii
Executive Summary	ix
Acknowledgments.....	xii
About the Series	xiii
1.0 Protecting Consumers in a Period of Rapid Transformation.....	1
1.1 Introduction	1
1.2 Innovations in the Electric Industry	2
1.2.1 Technological and Policy Drivers of Change.....	2
1.2.2 The Electric Utility of the Future	6
1.3 Consumer Advocacy in the Context of Innovation	8
1.3.1 Consumer Representation	8
1.3.2 Rising Costs.....	9
1.3.3 Cost Shifting.....	9
1.3.4 Energy Equity.....	9
1.3.5 Risk Shifting.....	10
1.3.6 Customer Access and Engagement	10
1.4 Innovations in Electric Utility Regulation.....	10
1.4.1 Increasing Prioritization of DERs	11
1.4.2 More Complex Cost Allocation, Rate Design, and Pricing.....	12
1.4.3 Expansion of Performance-Based Regulation.....	14
1.4.4 Enhanced Integrated Planning.....	15
1.4.5 Improved Stranded Cost Treatment	17
1.4.6 More Attention to Energy Equity.....	19
1.4.7 Increased Emphasis on Policies to Address Climate.....	21
1.5 Conclusion.....	22
2.0 A Labor Perspective on Innovation to Meet Climate Goals for the Electricity Sector	24
2.1 Introduction	24
2.2 The Economic Opportunities Inherent in a Carbon-free Electricity Grid	25
2.3 Strengthening Community Ties to Clean Energy.....	29
2.4 The Slow Decline of Utility Workforces and Consequences for Innovation	33
2.5 Strengthening Community Ties by “Relocalizing” Utility Workforces.....	37
2.6 Conclusion.....	40
3.0 U.S. Electric Companies Are Innovating to Provide the Solutions and Options that Customers Want.....	42
3.1 Introduction	42
3.2 Innovation in Providing Services and Solutions to Residential Customers	42

3.2.1	Using Technology and Data Analytics to Advance Energy Management and Clean Energy Goals	43
3.2.2	Using Technology and Data Analytics to Effectively Transition Customers onto Time-varying Rates	45
3.2.3	Using Technology and Data Analytics to Expand Rate, Billing, and Payment Options to Meet Customer Needs	46
3.2.4	Innovative Services and Solutions for Residential Customers Require Flexibility in Both Program Design and Regulatory Treatment	48
3.3	Innovations in Providing Carbon-free Energy Solutions to Corporate Customers	50
3.3.1	Examples of Carbon-Free Energy Solutions for Corporate Customers Provided by Electric Companies	51
3.3.2	Innovative Regulatory Approaches for Clean Energy Procurement Needs of the Future	55
3.4	Conclusion.....	57
4.0	Innovating the Electricity System from the Hearing Room to the Edge of the Grid	59
4.1	Introduction	59
4.1.1	Shortcomings of the Traditional Utility Business Model.....	60
4.1.2	Why Is Change Needed?	61
4.2	Case Studies in Innovation.....	63
4.2.1	Vermont: Green Mountain Power	64
4.2.2	Hawaii: Public Utilities Commission	66
4.3	A Vision for the Future	71
4.3.1	Near-Term Solutions	72
4.3.2	Long-Term Solutions	77
4.4	Conclusion.....	80
5.0	Scaling Utility Innovation: Identifying a Path to Action.....	81
5.1	Introduction	81
5.2	The Gap.....	82
5.3	Regulatory Processes.....	84
5.3.1	Utility Framework Overview	85
5.3.2	Technology Examples	87
5.3.3	Regulatory Challenges for Innovation	90
5.3.4	Proposed Changes	92
5.4	Innovation Programs	95
5.4.1	Current Energy Innovation Programs.....	96
5.4.2	Next-Generation Innovation Programs	99
5.5	Conclusion.....	100
6.0	References	102

Figures

Figure 1. EIA Projections of U.S. Generation by Resource for 2050.....	3
Figure 2. Declining Costs of Solar PV Installations	4
Figure 3. Cumulative Capacity Additions of Wind, Solar, and Battery Storage in a Modeled 90% Clean Electricity Grid by 2035	26
Figure 4. Cumulative Transmission Capacity Additions by 2050 in a Modeled Net-Zero Scenario.....	26
Figure 5. Change in Average Annual Power Outage Minutes per Utility Customer, 2013–2015, Compared to the 2018–2020 Three-Year Average.....	28
Figure 6. Employment for Utilities: Electric Power Generation, Transmission, and Distribution (NAICS 2211) in the United States.....	33
Figure 7. Types of Smart Thermostats in the APS Cool Rewards Program	43
Figure 8. Example of Energy Use Visualization Using the DTE Insight App.....	44
Figure 9. How Customers Earn Bill Credits During Peak Time Events	46
Figure 10. Georgia Power Rate Options	47
Figure 11. Comparison of U.S. Electric Company Energy Efficiency Program Savings and Renewable Energy Generation (2020).....	49
Figure 12. Solar Power Plant Under Construction.....	52
Figure 13. Heat Map Showing Gaps in Google’s Carbon-Free Energy Supply	53
Figure 14. Clean Energy Optimization Pilot Participants	54
Figure 15. U.S. Carbon-free Electricity Generated, by Source (2020)	57
Figure 16. State Renewable and Clean Energy Goals.....	81
Figure 17. Valleys of Death for Energy Technologies	83
Figure 18. Timelines for Approval and Completion of Utility Grid Modernization Projects.....	84
Figure 19. Implementation time frame for new technology deployment.....	90

Tables

Table 1. Potential Opportunities and Challenges - Increasing Prioritization of DERs	12
Table 2. Potential Opportunities and Challenges - Pricing, Rate Design, and Cost Allocation.....	13
Table 3. Potential Opportunities and Challenges - Performance-Based Regulation.....	15
Table 4. Potential Opportunities and Challenges - Integrated Planning	17
Table 5. Potential Opportunities and Challenges - Stranded Costs.....	19
Table 6. Potential Opportunities and Challenges - Equity	21
Table 7. Potential Opportunities and Challenges - Decarbonization	22

1.0 Protecting Consumers in a Period of Rapid Transformation

By National Association of State Utility Consumer Advocates⁹

1.1 Introduction

Major developments affecting the electricity grid will continue to drive its transformation. This essay summarizes the views of consumer advocates on expected changes in the U.S. electricity sector and ways that innovation will both drive and respond to these changes. To formulate this work, the National Association of State Utility Consumer Advocates (NASUCA)¹⁰ asked its members about their expectations for how the electricity sector will change over the next 10 to 20 years, views on the potential benefits of innovation and prospective challenges, and perspectives on how all these developments will impact the roles of consumer advocates in the electricity sector.

The essay chronicles recent advances in technology and policies, then centers the discussion on regulatory innovations. Innovations are often framed as developments that promise to advance key policy aims and offer overall benefits for customers and society. But innovations do not necessarily lead to positive outcomes. This essay addresses both potential upsides and downsides of selected innovations.

Consumer advocates and other stakeholders should be mindful of both the opportunities and the challenges associated with innovations in the electricity sector. New policies and regulatory practices should be well designed and strike the right balance between enabling the electricity sector to evolve in productive directions, achieving current and new state goals, and ensuring customer protection and equity.

Consumer advocates and other stakeholders should be mindful of both the opportunities and the challenges associated with innovations in the electricity sector.

Achieving this balance is especially daunting given that innovations often come from the electric industry or market developments. Consumer advocates often are not well-positioned to anticipate innovations; they are more likely to react to them than to predict and plan for them. Further, consumer advocates generally do not expect a complete redesign of electric utility regulation over the next 20 years.

This essay distills input and comments from many NASUCA members. Contributors provided differing perspectives regarding the types and pace of technological and regulatory changes that will likely affect

⁹ Tim Woolf and Ben Havumaki, Synapse Energy Economics, provided technical assistance in drafting this essay.

¹⁰ NASUCA is a nonprofit, voluntary organization of 59 consumer advocate offices in 44 states and the District of Columbia, Barbados, Puerto Rico, and Jamaica. NASUCA members are designated by the laws of their respective jurisdictions to represent the interests of utility consumers before state and federal regulators and in the courts. Members operate independently from state utility commissions as advocates primarily for residential consumers. Some members may additionally represent small business consumers, and others may represent all utility consumers in their respective state. Some NASUCA member offices are separately established consumer advocate organizations while others are divisions of larger state agencies (e.g., the Attorney General's office). NASUCA members typically represent customers served by investor-owned utilities, not those served by utility cooperatives or public power authorities. NASUCA's associate and affiliate members also serve utility consumers but are not created by state law or do not have statewide authority.

the electric utility industry over the next 20 years. Many of the issues contemplated are a function of state policies that are outside of the purview of most public utility commissions. Therefore, prospective changes discussed here may or may not occur in any individual state. What is expected and encouraged in one state in the way of technological and regulatory changes may not be expected, and may even be discouraged, in another state.¹¹

The essay is organized as follows:

- Innovations in the electric industry
 - Technological and policy drivers of change
 - The electric utility of the future
- Consumer advocacy in the context of innovation
- Innovations in electric utility regulation
 - Increasing prioritization of distributed energy resources (DERs)
 - Pricing, rate design, and cost allocation
 - Expansion of performance-based regulation¹²
 - Integrated planning
 - Stranded cost treatment
 - Energy equity

1.2 Innovations in the Electric Industry

1.2.1 Technological and Policy Drivers of Change

The last 30 years have seen significant technological changes on the electric grid. The grid is increasingly interconnected and dynamic, and the growing adoption of renewable resources, DERs,¹³ and grid modernization technologies have had impacts on transmission and distribution networks, the relationship between customers and utilities, and ultimately, the regulation of a monopoly sector that is becoming increasingly decentralized.

Meanwhile, policy changes have unfolded alongside these technical developments. Policy shifts at both the state and federal levels have helped to catalyze the transition away from fossil-fuel powered generation and toward a more renewable and distributed grid.¹⁴ Overall, changes in technology and policy operate symbiotically, with grid advances driving changes in policy, and the grid evolving with new policies.

Overall, changes in technology and policy operate symbiotically, with grid advances driving changes in policy, and the grid evolving with new policies.

¹¹ This essay does not represent a NASUCA position or the position of any particular NASUCA member. Each individual NASUCA member reserves the right to take positions or advance views that are consistent or inconsistent with this document.

¹² See Section 1.4.3.

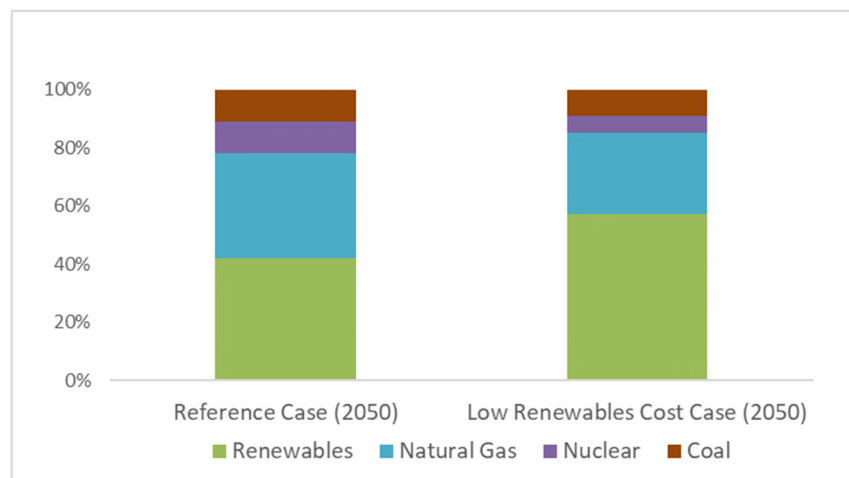
¹³ The term *DER* typically refers to a broad category of customer-sited equipment, ranging from distributed generation and energy storage to electric vehicles, smart appliance technologies, and energy efficiency and demand response.

¹⁴ The close connection between competition, market innovation, and renewable energy supply has a long history in the United States that arguably began with the passage of the federal Public Utility Regulatory Policy Act (PURPA) in 1978. This law opened the door to non-utility-owned renewable supply and combined heat and power and ensured that utilities purchase all eligible energy and capacity supplied at an avoided cost rate. The federal Energy Policy Act of 1992, which provided for Federal Energy Regulatory Commission oversight of retail wheeling, also proved to be a key spur to both competition and renewable resources in retail electric supply.

1.2.1.1 Technological Developments

All segments of the grid—generation, transmission, and distribution—are expected to continue to evolve over the next two decades. On the generation side, the biggest development in the recent past has been the growing role of renewable energy. This trend is expected to continue. In its Reference case, the Energy Information Administration (EIA) projects that renewable resources will account for about 42% of total U.S. generation by 2050.¹⁵ EIA’s Low Renewables Cost case projects higher penetration totals by mid-century.¹⁶ Figure 1 presents EIA projections for the Reference and the Low Renewables Cost cases.

Figure 1. EIA Projections of U.S. Generation by Resource for 2050



Source: EIA (2021b).

Most of the current renewable energy output comes from utility-scale installations. These installations are expected to continue to provide the lion’s share of renewable generation in the coming years.

With respect to distributed generation, the story has been dominated by distributed solar. There are now more than 3 million residential solar installations in the United States, and growth remains swift, with an estimated 20% increase in total residential systems between 2020 and 2021.^{17, 18} Community solar installations are also on the rise. Though just a handful of states account for the estimated 3 gigawatts of total installed capacity of community solar, several other states have enacted supportive measures, and the total number of community facilities is expected to expand significantly.^{19, 20, 21}

¹⁵ EIA (2021a), Reference case, Table 8. The Reference case generally assumes that current laws and regulations that affect the energy sector, including laws that have end dates, remain unchanged throughout the projection period.

¹⁶ EIA (2021). The Low Renewables Cost case examines capital cost sensitivities for renewable electric power generating technologies. See Table 8.

¹⁷ EIA. Table ES1.A. Total Electric Power Industry Summary Statistics, 2021 and 2020. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_es1a.

¹⁸ Including small industrial and commercial photovoltaic arrays in the total raises the number of distributed systems in the United States to more than 5 million.

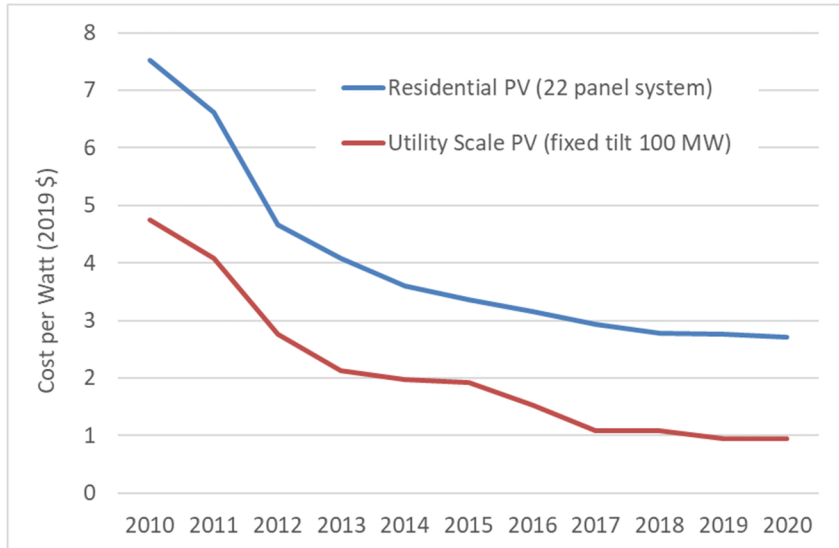
¹⁹ See the National Renewable Energy Laboratory’s (NREL) Community Solar webpage at <https://www.nrel.gov/state-local-tribal/community-solar.html>. Per NREL, community solar is “a distributed solar energy deployment model that allows customers to buy or lease part of a larger, off-site shared” PV system.

²⁰ Fekete (2020).

²¹ The growth in renewable resources in general, and for distributed resources in particular, has not been evenly experienced across the country. Alongside differences in natural endowments of sun and wind are legal and regulatory distinctions that have

Figure 2 illustrates cost declines in two types of solar photovoltaic (PV) technologies that have helped to spur the growth in this resource.

Figure 2. Declining Costs of Solar PV Installations



Source: Adapted from Ramasamy et al. (2021).

The increase in utility-scale wind and solar and DERs expands the need for complementary technologies to help optimize the increasingly complex generation portfolio. Wind and solar are variable energy sources, presenting challenges for planning and operating the system to maintain reliability and power quality.

Energy storage and grid modernization technologies can help meet these needs.²² For example, both utility-scale and distributed energy storage may be used to balance variable renewable energy and provide a cleaner alternative to traditional fossil-fuel “peaker” generating units. There also is a fast-growing trend toward “hybrid” power plants—storage plus wind, solar, or natural gas.²³ Meanwhile, grid modernization technologies, mostly situated at the distribution level, promise to help keep the increasingly complex grid running smoothly—providing operators with greater visibility, automating key functions, and ultimately allowing for the integration of higher levels of renewable resources. The scope and scale of energy storage and grid modernization technologies is expected to increase in coming years.

The increase in utility-scale wind and solar and DERs expands the need for complementary technologies to help optimize the increasingly complex generation portfolio.

made some states more attractive for renewable energy development. In any case, as the economics of renewable generation relative to traditional fossil-fuel generation continue to improve, its profile across all states is expected to continue to grow.

²² A range of other new grid technologies may appear at scale in coming years. These include small modular nuclear units as well as hydrogen production and distribution technologies. The future viability of these new resources rests on continued technological advances but changing grid dynamics may create new niches for novel technologies that would not have been viable for the grid of the past.

²³ Bolinger et al. (2021).

Grid modernization is a broad term that includes a variety of technologies, from distribution management systems and outage management systems to Volt-VAR optimization and advanced metering infrastructure (AMI).²⁴ Grid modernization technologies may provide reliability, resilience, and safety benefits, reduce line losses and energy theft, and facilitate time-sensitive pricing that can smooth and shift peak electricity demand and reduce the need for new investment in capacity across the electricity system. Advances in grid modernization technologies will continue to have spillover impacts. For example, storage technology improvements are among the factors driving the rising adoption of electric vehicles (EVs), and other grid modernization technologies may enable cost-effective utilization of EVs for a variety of grid services.

Meanwhile, the bulk power system also is evolving. New long-distance direct current lines are being installed to ferry energy from remote renewable installations to the grid, and thereby to load centers. Elsewhere, DERs are avoiding the need for some investments in distribution and transmission systems,²⁵ as DERs reduce peak demand and can obviate existing and future anticipated congestion issues.

1.2.1.2 Statutory and Policy Developments

Policy changes at both the state and federal levels continue to impact the grid. These developments create new opportunities for technological innovation and may also change the economics and overall viability of certain technologies.

Driven by concerns about climate and the importance of decarbonizing the electricity sector, as well as interest in in-state economic development and fuel sources, a majority of states today have adopted renewable portfolio standards (RPS).²⁶ States also are broadening their focus to target reductions in carbon emissions across all sectors of the economy. This trend toward economy-wide decarbonization, coupled with increasingly ambitious RPS goals in some jurisdictions and corporate climate commitments, is likely to mean a continued acceleration in the integration of renewable energy.²⁷

Policies also have been enacted to address potential adverse outcomes related to renewable energy trends. For example, some states that adopted net energy metering for distributed generation have passed new laws to revise the compensation framework.^{28,29} The motivations underlying these changes vary, ranging from concerns about cost shifting and inequity of compensation at the retail rate to interest in more mature and efficient markets and utility programs to facilitate more complete leveraging of DER benefits for grid services.

Many states have taken steps to investigate, promote, and develop standards for modernization of distribution systems.³⁰ Again, the motivations are varied. Some states are promoting grid modernization for reliability and resilience. Others also view grid modernization through the lens of decarbonization, as an aid to integrating higher levels of variable renewable energy. Conversely, some states are implementing more rigorous standards and limitations to prevent unwarranted spending in the name of

²⁴ Grid modernization is broad and inconsistently defined—one state’s version of grid modernization may differ greatly from another’s version. See North Carolina Clean Energy Technology Center (2021).

²⁵ See, e.g., California Public Utilities Commission Decision 20-04-010, issued on April 24, 2020. Also see Frick et al. (2021).

²⁶ National Conference of State Legislatures (2021).

²⁷ EIA (2021b).

²⁸ Barbose (2017).

²⁹ North Carolina Clean Energy Technology Center (2021b).

³⁰ National Conference of State Legislatures (2019).

grid modernization.³¹ Ultimately, some version of distribution system modernization is likely inevitable in all states as more advanced technologies such as advanced meters supplant legacy analog ones.

The federal government has provided some incentives to promote decarbonization. For example, the federal government has supported EVs with tax incentives for more than a decade. The Plug-in Electric Drive Vehicle Credit is still buoying EV sales overall but will phase out once manufacturers reach 200,000 in total fleet sales.³² While it is not yet clear whether the federal government will follow the lead of some other nations and a few states in phasing out gasoline and diesel vehicle sales over time, automakers could play a major role in influencing the direction of future policy by embracing and promoting EVs.

Finally, at all levels of government, new concerns will be met with new policy responses. Lawmakers' focus will likely include decarbonization, cybersecurity, customer data privacy, resilience, wholesale electricity market designs, customer equity, economic development and new economic opportunities associated with energy-related industry, and appropriate roles for utilities. The answers issuing from state houses and Congress will likely include new laws aimed at protecting both customers and the grid.

Lawmakers' focus will likely include decarbonization, cybersecurity, customer data privacy, resilience, wholesale electricity market designs, customer equity, economic development and new economic opportunities associated with energy-related industry, and appropriate roles for utilities.

1.2.2 The Electric Utility of the Future

In the face of technological and policy trends, electric utilities will likely continue to evolve over the next 20 years. While the focus of investor-owned utilities on maximizing profits is unlikely to change, the ways that companies serve their customers and generate revenues—and critically, their commitments in the context of regulatory structures—are not expected to remain static.

The major developments in the electricity sector that are expected to impact utilities over the coming 20 years fall into four categories, discussed below:

1. Changes in the way customers consume electricity
2. Changes in the way utilities price electricity
3. Changes in the way utilities construct and operate their grids
4. Changes in markets and market structure

1.2.2.1 Changes in the Way Customers Consume Electricity

While distributed generation, energy efficiency, demand response, and grid modernization may act to reduce energy consumption, utility retail sales are not assured to fall. Customer adoption of EVs and the substitution of electricity for direct use of fuels (natural gas, oil, propane, wood) across a variety of end

³¹ Some states have developed standards to promote distribution system modernization, including requirements for regulated utilities to file grid modernization plans and distribution system plans for review. Standards include justification for proposed utility investments. See Woolf (2021).

³² Internal Revenue Service (2021).

uses will have countervailing impacts. In addition, retail pricing structures and consumer preferences will have significant influence over peak demand patterns. Meanwhile, the peak demand hour is also expected to shift in some jurisdictions as a result of the growing share of distributed solar generation. Other regulatory policies, like revenue decoupling,³³ will influence whether and how changes in overall retail sales and peak demand will impact utility bottom lines.

1.2.2.2 Changes in the Way Utilities Price Electricity

Enabled by new technologies such as AMI and spurred by regulatory imperatives, the utility of the future is likely to offer a wider variety of rates. Fewer utilities are likely to offer just a single standard rate for residential customers. The most likely development in rates is the increasing adoption of time-varying pricing structures, including real-time pricing, critical peak pricing, peak time rebates, value of DER pricing, and more. Some utilities might promote increased use of demand charges, minimum bills, or subscription charges to provide them with revenue stability.³⁴

Changes in cost allocation are also expected, potentially resulting in the creation of additional customer classes and subclasses. The impetus for this may come either from the utility or state regulator, both enabled and necessitated by technological advances. Further disaggregation of prices by service component (unbundling) is expected as well.

1.2.2.3 Changes in the Way Utilities Plan, Construct, and Operate Their Grids

While the impact of new technologies will vary across service territories, the broad trend is toward decentralization of utility service. Even in service territories less transformed by renewable energy resources, the impact of centrally organized wholesale electricity markets and planning requirements that compel utilities to consider procurement of energy and capacity from third parties will continue to chip away at the old, centralized model—including in states that have retained vertically integrated utility structures. In areas experiencing more rapid growth in distributed generation, this trend will continue to transform the relationship between utility and customers.

Requirements to employ benefit-cost analysis, consider non-wires alternatives for traditional distribution and transmission upgrades, and more rigorously consider demand-side resources will further transform utilities' practices for long-term planning. New regulatory structures that depart from the traditional cost-of-service model, such as performance-based regulation,³⁵ are already being adopted in some jurisdictions and will further influence utility planning and decision-making.

1.2.2.4 Changes in Markets and Market Structures

The creation and growth of new markets will continue to transform how utilities do business. New wholesale energy and capacity market structures will likely enable increased competition and provision of power from independent generators. New provisions requiring utilities to support DERs will likely enable

³³ Decoupling is a modification to traditional rate-setting practices. It breaks the link between the amount of energy sold and the revenue collected by the utility by setting a predetermined allowed revenue requirement, or revenue requirement formula, and reconciling the actual revenues collected to match those that are allowed.

³⁴ Demand charges involve charging a customer for a portion of their electricity on the basis of their highest hourly demand on the electricity system during specified periods. Minimum bills create a floor on a customer's bill to ensure that they provide a minimum amount of revenue to the utility regardless of energy consumption. Subscription charges involve charging a customer a flat fee for monthly service, usually with some limitation on use, to prevent excessive consumption.

³⁵ See Section 1.4.3.

increased competition and provision of services from third-party vendors of DERs.³⁶ The roles of monopoly utility providers and competitive third-party providers are not yet well-defined and still need to be determined.

Utilities may also develop new revenue streams—for example, by leveraging customer data gleaned through new grid technologies.

Finally, the trend toward increasing consolidation of utilities is expected to continue. It is not clear how increasing consolidation will affect utility innovation in the future. In general, increasing consolidation can make it more difficult for consumer advocates to address local issues as utility management becomes increasingly removed from the local utility and its customers' needs.

1.3 Consumer Advocacy in the Context of Innovation

Innovation offers potential benefits to customers, but it may introduce new risks. Consumer advocates' roles will need to evolve over time to ensure that significant innovations are promoted and adopted in ways that benefit all customers. Consumer advocates might need to explicitly examine the role of innovation over time and how best to respond to innovation to ensure net benefits to customers. Many of consumer advocates' key objectives and interests of the past will continue into the future, but some may require increased attention, and additional objectives and interests may evolve over time. Some of these areas of concern include customer representation, rising costs, cost shifting, energy equity, risk shifting, and customer access and engagement.

1.3.1 Consumer Representation

As the electricity industry becomes increasingly complex—with new technologies, advanced integrated planning practices, new and more detailed pricing options, new third-party vendors of products and services, and increasing mandates to address climate—the demands on consumer advocates will only increase. Consumer advocates will need increased funding, resources, and expertise to adequately address these new complexities.

Consumer advocates may engage more in a wider variety of arenas. As competitive wholesale markets and interstate transactions expand and become more complex, consumer advocates will need greater representation at, and interaction with, independent system operators (ISOs), regional transmission organizations (RTOs), and the Federal Energy Regulatory Commission (FERC). In addition, as third-party vendors play a larger role in providing electricity products and services, consumer advocates will need to increase their attention to these markets, perhaps having to advocate in forums beyond regulatory commissions (e.g., legislative forums, on boards of relevant organizations, with consumer protection agencies, and in civil courts). Finally, as legislators, commissions, and consumer advocates place greater emphasis on energy equity, it will become increasingly important to find ways to ensure better representation of vulnerable or disadvantaged customers.

The consumer advocate's position is already challenged by utilities' greater access to resources and information. This challenge is expected to grow with the increasing scope of consumer advocacy and mounting complexity of issues requiring consumer advocate attention.

³⁶ For example, FERC Order 2222 attempts to enable DERs to compete on a level playing field in the organized capacity, energy, and ancillary services markets run by regional grid operators. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf.

1.3.2 Rising Costs

Some of the proposed investments in innovative technologies and in support of emerging goals may increase utility system costs without offering commensurate, direct utility system benefits, raising new challenges for consumer advocates. Concerns about cost-effectiveness may be raised by proposals for utility investments in grid modernization, resilience (including cybersecurity measures), EV charging infrastructure, and measures to meet climate goals, among other things. Whether these new investments will ultimately reduce costs will depend on a range of factors, including jurisdictional standards for cost-benefit tests, associated policy imperatives, and particular grid needs. In any case, investments in new and innovative infrastructure and programs will likely require careful review from consumer advocates and other intervenors to ensure that increased costs are justified by the benefits.

1.3.3 Cost Shifting

As electricity technologies become increasingly distributed and accessible to customers, it will be more important to ensure that costs are properly allocated across and within customer classes to avoid undue or unreasonable cost shifting. Consumer advocates will need to pay careful attention to properly defining benefits and ensuring that customers who receive the benefits of innovations pay the costs for them. The current challenge of trying to prevent unreasonable cost shifting from distributed solar technologies is likely to be just the tip of the iceberg relative to the cost shifting challenges that will exist in 20 years.

Consumer advocates will need to pay careful attention to properly defining benefits and ensuring that customers who receive the benefits of innovations pay the costs for them.

To date, the costs of innovations in the electricity sector (e.g., some DER programs, grid modernization investments, and actions to address environmental mandates) have often been recovered by socializing them across all customers. Consumer advocates and others might need to find more creative, accurate, and equitable ways to recover these costs from customers.

1.3.4 Energy Equity

While consumer advocates have always worked to protect vulnerable and disadvantaged customers, more recently, social and environmental equity and justice concerns have come to the forefront. A concerted effort is underway to incorporate those concepts more fully into the policy-making and decision-making structure for energy issues. As the electricity sector becomes more complex, so too will the challenges of ensuring energy equity.³⁷ For example, one of the key goals of consumer advocates for many years has been to ensure that utility costs are properly allocated among customer classes. With increasing energy equity goals, it might be more appropriate to expand this goal and any necessary statutory frameworks to include cost allocation among subclasses of customers, such as subclasses that include only vulnerable or disadvantaged customers. Other strategies to achieve fairness and equity could include efforts to carefully manage rate impacts and ensure that investments in innovative technologies are prudent and deliver anticipated benefits.

³⁷ See Farley et al. (2021).

1.3.5 Risk Shifting

As the electricity sector evolves, so too will electric utility ownership and corporate structures. With these changes and the proliferation of new third-party vendors of products and services, new infrastructure investments, and new regulatory mechanisms and pricing options, the incentive for utilities to shift risks to captive customers will likely increase.

By its very nature, innovation can make some legacy technologies obsolete, leading to stranded assets. For example, increasing pressure to decarbonize the electricity and gas industries is likely to increase stranded costs. Current regulatory practices for preventing, mitigating, or sharing the impacts of stranded assets are not likely to be sufficient to address the stranded assets that might be created by innovations over the next 20 years.

Current regulatory practices for preventing, mitigating, or sharing the impacts of stranded assets are not likely to be sufficient to address the stranded assets that might be created by innovations over the next 20 years.

1.3.6 Customer Access and Engagement

Not all customers will have access to innovations in the electricity sector, such as DERs, new services through third-party vendors, and new pricing mechanisms. This exacerbates the risk of creating a gap between the “haves” and the “have-nots,” which could further aggravate existing equity issues. Low- and moderate-income customers may be the least likely to have access to the internet, capital, information, technologies, and time necessary to adapt to innovations, precluding them from participating in programs to deliver energy bill savings and other benefits.

Further, not all customers who are able to access innovative technologies will want to adopt them, because they have other priorities, they are not aware of the options available and the benefits the new technologies might afford, they do not want to incur the costs or hassles associated with new technologies, or for other reasons. This exacerbates the risk of inequities and the potential that some less active customers will be left behind. Consumer advocates will likely need to devote additional attention to customer education and outreach on a variety of fronts.

Customers and third parties will increasingly rely upon access to growing amounts of data, over which utilities currently have physical control—a dynamic that might exacerbate privacy and security concerns. Access to these data will be key to more wide-scale adoption of innovations in the electricity sector. Consumer advocates will need to continue to push regulatory commissions to require utilities to make this information more easily available, both at an individual user level and to third parties, while maintaining and ensuring adequate consumer privacy protections.

1.4 Innovations in Electric Utility Regulation

Generally, consumer advocates do not expect a complete redesign of electric utility regulation over the next 20 years. Instead, they expect that recent trends in regulation will continue, with greater emphasis on some areas, depending upon the technical, economic, and policy innovations that develop.

While the term “innovation” tends to have positive connotations, it does not necessarily always lead to positive outcomes. If innovative regulatory approaches are designed and implemented well, then they will likely have positive implications for electricity customers. But that might not be the case if approaches are designed or implemented poorly. Even where mechanisms have been well designed, benefits may not be evenly or equitably shared. The following sections discuss six expected areas of regulatory innovation,

addressing both potential opportunities from well-designed innovations and potential challenges from those that are poorly designed and implemented. Tables 1–7 provide a summary for each of these areas.

1.4.1 Increasing Prioritization of DERs

DERs are likely to play an increasingly larger role in the electricity sector as a result of technological advances, improvements in economics, new market opportunities, legislation, policies, and regulations. Adoption of some DERs will likely be driven by natural market developments (i.e., customer choices regardless of utility programs and investments) and customer preferences (e.g., EVs). Adoption of other DERs will be more influenced by changes in electricity pricing and utility program support.

1.4.1.1 Trends and Innovations

Examples of expected innovations over the next two decades include:

- *Increased emphasis on cost-effectiveness and impact analyses.* Benefit-cost analysis, as well as analysis of DER-specific rates, bill impacts, and participation, can help ensure the most cost-effective DERs are adopted and mitigate cost-shifting concerns.³⁸
- *Alternative funding sources for DER programs.* Funding might come from wholesale market revenues, proceeds from climate focused policies (e.g., allowance cap and trade mechanisms, carbon taxes), federal tax incentives, general revenue (state and local), third-party loans, or pay-as-you-go financing.
- *Improved compensation mechanisms for distributed generation.* Improved mechanisms to balance the goals of promoting the desired level of distributed generation and minimizing unreasonable cost shifting.
- *Increased consideration of DERs in long-term resource and distribution planning practices.* Utility planning processes will increasingly optimize the combination and contribution of DERs (see Section 1.4.1).
- *Improved operational awareness and controls to manage DERs.* Grid modernization technologies such as advanced distribution management systems will allow for more dynamic control and operation of DERs.
- *Improved financial incentives to deploy and operate DERs.* In most cases, utilities do not have the opportunity to earn a return on customer-sited DER investments, and DERs can reduce the return on other utility investments due to reduced grid-connected electricity consumption. Improved financial incentives can be provided through multi-year rate plans (MRPs), performance incentive mechanisms (PIMs), and perhaps other means (see Section 1.4.3).
- *Increased emphasis on DERs as non-wires solutions.* Improved methodologies for considering DERs to meet capacity, reliability, and resilience needs for the grid will encourage these alternatives, when they are cost-efficient, to reduce rising distribution and transmission costs.
- *Improved customer rate designs to encourage customers to adopt DERs.* These rate designs could include time-varying rates such as TOU, critical peak pricing, peak-time

³⁸ For a comprehensive discussion of benefit-cost analysis of DERs, see National Energy Screening Project (2020).

rebates, and more (see Section 1.4.2). Rate designs also might include more customer education and access to technologies to facilitate economic response from customers who adopt DERs.

- *Improved customer access to DERs.* Examples include increased access to third-party DER aggregators and vendors, seamless interconnection practices, and standardized interconnection practices.
- *Expanded DER programs.* Examples include energy efficiency, demand response, community solar, virtual net metering, and EV programs targeting low-income and disadvantaged customers and neighborhoods to improve access for hard-to-reach customers.³⁹
- *Advancements in DER technologies.* As DERs become more commercially viable there likely will be advancements in their design and capabilities. One example is EVs that increasingly include technologies and software that enable their batteries to be used to (a) optimize consumption in the owner’s building; (b) reduce peak demands on the electric grid; or (c) provide ancillary services to the local utility or regional grid operator.
- *Better information for utility planners, customers, and third parties.* An example is timely updates of hosting capacity analyses and mapping of the utility’s distribution system.

Table 1. Potential Opportunities and Challenges - Increasing Prioritization of DERs

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Reduced utility system costs ▪ Reduced bills for host customers ▪ Increased grid flexibility ▪ Reduced cost of meeting climate goals ▪ More competitive engagement from third parties ▪ Greater customer empowerment ▪ Improved resilience 	<ul style="list-style-type: none"> ▪ Barriers to DER adoption for some customers, including those arising from financial limitations, hosting capacity constraints, and geography ▪ Lack of interest by some customers in DERs ▪ Potential for cost shifting from host customers to other customers ▪ Ensuring that net benefits are equitably distributed ▪ New consumer protection challenges with third-party DER vendors ▪ Increasing vulnerability to cyberattacks

1.4.2 More Complex Cost Allocation, Rate Design, and Pricing

Increased use of DERs and AMI, along with increased access to competitive third-party services, will likely drive the need for increasingly complex electricity pricing practices to facilitate more transparent and efficient electricity service transactions. Rate design and cost allocation practices will need to evolve accordingly to ensure efficient retail electricity rates and mitigate equity and cost-shifting concerns.

³⁹ Community solar programs allow customers to sign up to obtain the power, or the benefits of the power, from shared solar projects that are not sited at their homes or businesses. Similarly, virtual net metering programs allow customers to sign up to obtain benefits from shared net metering projects. Some states require the solar project to serve electricity load connected at the same service delivery point, such as both common and tenant areas in multifamily buildings. Other states do not require that the distributed generation system be located on site.

1.4.2.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *Expanded use of time-varying rates.* Rates that better reflect the temporal cost of electricity services across generation, transmission, and distribution will be available to more customer classes and subclasses.
- *Expanded rate design options.* In addition to more complex time-varying rates, utilities will likely continue to pursue increased use of demand charges, minimum bills, straight/fixed variable rates, distribution cost surcharges, exit fees, and more.⁴⁰
- *Refinements to both cost allocation and rate design methods.* Improved resolution in cost allocation and rate design enabled by technological advancements will support pricing that better reflects the costs of electricity consumption. More accurate and transparent price signals will facilitate economically efficient customer responses, potentially increasing adoption of DERs, “two-way” exchanges between the utility and its customers, and demand flexibility.
- *More detailed segmentation of customers into more customer classes or alternative groupings.* Such breakdowns allow for better allocation of costs according to evolving customer consumption patterns. It might even be appropriate and efficient to allocate costs on the basis of typical customer load factors.
- *Better understanding of DER costs, benefits, rate impacts, bill impacts, and participation levels.* Retail rates and DER compensation mechanisms can be designed in ways that improve customer equity and promote more efficient price signals.
- *Increased unbundling of generation, transmission, and distribution pricing.* Charging separately for these services may facilitate competition, meet infrastructure needs, and provide customers with increasing choices of suppliers for different services.
- *Increased opportunities for third parties.* Service providers and vendors could increasingly provide technologies, services, and pricing options directly to customers.

Table 2. Potential Opportunities and Challenges - Pricing, Rate Design, and Cost Allocation

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Provide more-efficient price signals ▪ Better align prices with cost causation ▪ Provide more accurate incentives for installing DERs ▪ Optimize specific consumption patterns—e.g., for EV charging ▪ Facilitate cost-effective utilization of DERs for capacity and other grid services 	<ul style="list-style-type: none"> ▪ Some customers may lack the ability or interest to respond to complex rate designs. ▪ There is potential for significantly higher bills for customers who do not or cannot respond to advanced rate designs. ▪ Utilities and, in retail choice states, alternative suppliers may not be eager to offer default time-varying rates for basic service. ▪ Some dynamic rates (e.g., real-time pass-through rates) carry significant risk to consumers. ▪ Time-varying rates will not be available to all consumers in service areas where utilities do not invest in AMI deployment (e.g., due to high upfront costs).

⁴⁰ See, e.g., Regulatory Assistance Project (2015).

1.4.3 Expansion of Performance-Based Regulation

Performance-based regulation (PBR) has gained attention in recent years as a set of mechanisms to improve upon traditional cost-of-service regulation by providing clearer financial incentives for a utility to reduce costs or achieve other regulatory objectives. PBR plans typically include a combination of an MRP and performance incentive mechanisms (PIMs).^{41, 42, 43}

MRPs may be well suited for periods of utility innovation because they allow utility management more flexibility for seeking options to improve productivity.⁴⁴ PIMs might be well suited as regulatory options to encourage evolving regulatory goals, such as adoption of DERs, procurement of renewable resources, and encouraging compliance with environmental requirements. On the other hand, MRPs and PIMs can be designed poorly, hamstringing the potential for increasing productivity and rewarding suboptimal performance. Today's practices might need to evolve to account for lessons learned from the past and new demands on utilities and regulators in the future.

1.4.3.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *Longer periods between rate cases (i.e., MRPs) to promote utility efficiency.* Extending the period between rate cases can promote utility financial discipline and investment efficiency. Increasing regulatory lag provides an incentive to increase savings, which the utility retains, and mitigate structural incentives for the utility to make new investments since cost recovery will necessarily be delayed. To ensure that customers derive maximum benefit, MRPs may need to be accompanied by mechanisms to share the cost reductions with customers, such as tighter productivity indices⁴⁵ and better earnings sharing mechanisms (e.g., narrower dead-bands, greater sharing of over-earnings relative to under-earnings).⁴⁶
- *Better options for recovering major capital expenditures to mitigate against capital bias.* For example, combining the treatment of capital expenditures (CAPEX) and operating expenditures (OPEX) to provide more consistent incentives for each type of expenditure. This is sometimes referred to as the TOTEX approach, combining both CAPEX and OPEX. Other examples are better coordination with integrated planning practices (see Section 1.4.4) and increased regulatory pre-review of major capital expenditures (see Section 1.4.5) to ensure there is more regulatory and stakeholder input into major capital expenditure decisions.
- *More holistic integration of MRP and PIMs.* MRPs and PIMs provide different types of incentives that should work together as a coordinated set to achieve desired regulatory outcomes.

⁴¹ PIMs may be specified as incentive-only, penalty-only, or symmetrical (incentive and penalty).

⁴² See, e.g., Lowry, Woolf, and Schwartz (2016) and Lowry et al. (2017).

⁴³ Consumer advocates do not generally consider line-item cost recovery mechanisms as “performance based.” While widely used, they are not considered here.

⁴⁴ MRPs should not be conflated with formula rates, which typically provide a utility with the opportunity to eliminate future-year earnings variances through true-ups. Unlike MRPs, formula rates reduce risk and uncertainty for the utility and may create a disincentive to investment discipline.

⁴⁵ Under an MRP, allowed utility revenues often are determined using a formula that includes a productivity factor (commonly denoted as “X”). This parameter accounts for the expected impact of productivity improvements on the utility’s cost of service and typically is based upon a productivity index that reflects industry aggregate trends.

⁴⁶ The “dead-band” specifies a margin around target earnings that is exempted from earnings sharing between the utility and its customers. Dead-bands are usually specified as a percentage above and below target earnings.

Increased attention to the interaction and combined effect of the two mechanisms could be important as the electricity sector becomes more complex.

- *Expanded use of PIMs.* PIM rewards can be increased in magnitude and/or applied to more performance areas, in combination with a reduction in allowed return on equity, in order to mitigate the capital investment bias created by traditional cost-of-service ratemaking. PIM penalties can be increased in magnitude and/or applied to more performance areas to focus utility attention on technological or regulatory changes over time.
- *More focused metrics, targets, and PIMs to reflect technological, economic, market, and regulatory innovations, as they develop.* PIMs offer the advantage of being modifiable each year, while MRPs are set for longer time periods and thus are less responsive to changes over time.

Table 3. Potential Opportunities and Challenges - Performance-Based Regulation

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ MRPs can encourage utilities to operate more efficiently, reducing utility system costs. ▪ PIMs can encourage utilities to achieve specific desired regulatory outcomes, such as expediting interconnection requests or customer response times, encouraging lower-cost procurement of renewable power, and implementing effective DER programs. ▪ MRPs and PIMs can help mitigate the capital bias created by traditional cost-of-service ratemaking. 	<ul style="list-style-type: none"> ▪ Poorly designed MRPs or PIMs may not deliver the intended benefits to consumers. ▪ Utilities have better information and more resources to control MRP and PIM designs to their advantage. ▪ MRPs and PIMs may not fully capture the desired change in utility operation or system outcomes over time, especially in the context of rapid innovation. ▪ The MRP concept can be interpreted too broadly to include inappropriate ratemaking mechanisms, such as formula rates. ▪ PIMs can increase regulatory burden as regulators seek to ensure that utilities do not receive disproportionate rewards or penalties, PIMs are not subject to gaming or manipulation, and they do not result in other unintended consequences.

1.4.4 Enhanced Integrated Planning

Utilities conduct distribution planning to determine how best to maintain existing distribution equipment and expand distribution systems as necessary to meet load growth. They conduct demand-side resource planning to reduce and manage demand through energy efficiency, demand response, and other DER programs. In vertically integrated states, utilities also use transmission planning to determine how to move electricity generation within and outside their service territories and integrated resource planning to optimize their mix of both supply- and demand-side resources.

Increased levels of DERs, grid modernization, rising costs, and environmental mandates require increasing coordination of generation, transmission, distribution, and DER planning practices. In many states, however, these planning practices are not coordinated, and consumer advocates do not have the resources or expertise to provide sufficient input and oversight. In many cases, distribution and transmission planning happen with little input from consumer advocates.

1.4.4.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *Better integration of DER, distribution, transmission, and generation investments in planning practices.* Comprehensive planning practices could seek to optimize all types of electricity resources across electricity system domains.⁴⁷
- *Better integration of utility planning with ISO/RTO planning.* The increased use of DERs requires that ISOs and RTOs properly account for the impacts of DERs in their load forecasts and market designs. At a minimum, ISOs and RTOs need to have reliable estimates of the type, magnitude, and locations of future DERs on their systems in order to avoid forecast errors that can result in utilities overbuilding or underbuilding transmission facilities.
- *Improved use of technologies at the distribution level.* Detailed information about system capability to handle DERs by location and clear visibility for the utility about when DERs are operating are both required.
- *Better coordination between resource planning, ratemaking, and cost recovery.* Recommendations from integrated resource plans should be more closely tied to ratemaking and cost recovery practices to (a) allow for early regulatory review of investment decisions, mitigating the potential for uneconomic decisions; (b) improve stranded cost recovery practices to place greater risk on the utility; and (c) provide utilities with increased incentives to adhere to the economic actions those plans reveal. This coordination should strike a balance between consumer protection and utility flexibility to change decisions in light of changing conditions.
- *Better planning for meeting future environmental requirements.* The trend is toward better coordination among the utility regulatory commission, state department of environmental protection, and the state energy office is needed. In addition, improved coordination among electric and gas utilities and electric and water utilities is needed, especially considering decarbonization goals. More sophisticated techniques for anticipating and accounting for environmental compliance costs are also needed.
- *Enhanced stakeholder involvement in the planning process.* Comprehensive and integrated electricity planning is complex and requires considerable expertise and time to provide sufficient input from consumer advocates and other stakeholders. Opportunities exist to (a) streamline regulatory processes to facilitate stakeholder input, (b) allow for earlier and more frequent stakeholder input, (c) provide funding for experts to support stakeholders in planning processes (e.g., intervenor funding), (d) enable collaborative and other working group processes to facilitate and coordinate stakeholder input, and (e) provide greater access to open modeling tools to help facilitate more equitable participation in the planning process.

⁴⁷See, e.g., the NARUC/NASEO Task Force on Comprehensive Electricity Planning at <https://www.naruc.org/taskforce/>.

Table 4. Potential Opportunities and Challenges - Integrated Planning

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Increased transparency and stakeholder representation in utility decision-making ▪ Reduced costs through improved optimization of resource decisions ▪ Improved coordination between utilities and ISOs/RTOs ▪ Coordinated transmission expansion and generation build-out ▪ Coordinated distribution and DER planning ▪ Better assessment and assignment of investment risk ▪ Increased ability to proactively identify areas with DER hosting capacity 	<ul style="list-style-type: none"> ▪ Insufficient stakeholder resources to fully participate in increasingly complex planning practices ▪ No central siting authority in ISO/RTO regions to commission and develop new energy infrastructure, like transmission lines and power plants⁴⁸ ▪ Increasingly diverse and complex generation technologies requiring new planning models and assessment skills ▪ Insufficient coordination between federal, regional, and state authorities

1.4.5 Improved Stranded Cost Treatment

Obsolescence can be a natural outcome of innovation. In the electricity sector, generation, transmission, and distribution facilities that become obsolete can result in significant stranded assets and stranded costs. Unlike unregulated companies, whose investors must write off stranded costs, regulated electric utilities have a complex relationship with stranded costs. Utility regulators must strike a balance between utility investors and customers while considering regulatory and economic contexts and the prudence and reasonableness of utility investment decisions.

Innovation in the electricity sector increases the likelihood and potential magnitude of stranded costs. Regulators will need to develop more effective means of reviewing the prudence of utility planning and decision-making to ensure that customers are not allocated costs and risks that should be borne by utility investors. Similarly, regulators will need to develop cost recovery practices that place more of the risk of stranded costs on utility investors, creating a more effective incentive to avoid or mitigate stranded costs before they are incurred. Regulators also will need to ensure that utilities do not hinder positive innovations in order to avoid the creation of stranded costs.

1.4.5.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *More efficient, direct, and timely regulatory review of utility decision-making.* This would allow for (a) regulatory guidance earlier in the decision-making process and (b) more streamlined and robust regulatory determinations of prudence and “used-and-usefulness.” Improved coordination between integrated resource planning and cost recovery practices is one example (see Section 1.4.4).
- *Increased regulatory pre-review of utility investments.* Providing regulatory guidance earlier in the investment decision-making process⁴⁹ can be facilitated by more transparent, comprehensive,

⁴⁸ The FERC Advance Notice of Proposed Rulemaking in RM21-17 seeks to address some of these issues.

⁴⁹ The term “pre-review” refers to the opportunity for a utility to seek regulatory review of an investment before the investment is made. This type of review has become increasingly common in recent years for AMI and other grid modernization investments

and efficient integrated planning practices and with MRP practices that include pre-review of new major capital expenditures (see Section 1.4.3). This guidance can also be accompanied by reductions in the utility's allowed return on equity to account for any reduced risk for the utilities.

- *Clearer guidelines, metrics, standards, and agreements.* Such specifications would define when, and under what circumstances, cost recovery of utility investments will be allowed or denied.
- *More thoughtful planning practices.* The risk of future stranded costs can be recognized and mitigated—for example, by using shorter book lives (i.e., higher depreciation rates) in benefit-cost analysis and through integrated planning practices that reflect the possibility that some new assets are more likely to become obsolete as the electricity sector evolves over time.
- *Better approaches for addressing stranded costs that result from unreasonable or imprudent utility decision-making.* For example, more frequent and expeditious application of prudence and used-and-useful standards could be used to disallow recovery of *utility costs* for inappropriate utility investments and in some cases to disallow recovery of *profits* for inappropriate utility investments.
- *Better approaches for recovery of stranded costs that result from reasonable or prudent utility decision-making.* Using securitization to finance the drawdown of stranded costs is one example.⁵⁰ Securitization might offer benefits to customers as long as (a) the magnitude of stranded costs is determined properly; (b) the utility bears its responsibility for the stranded costs, depending upon the prudence and used-and-usefulness of the investment; and (c) the securitization process and bond timing results in the lowest possible cost to electricity customers.
- *Better approaches for treatment of stranded costs that are the result of federal or state mandates.* These approaches may include, for example, changes to federal or state tax policies to facilitate the retirement of legacy assets that are rendered uneconomic as a result of federal or state greenhouse gas (GHG) mandates.

that are not *prima facie* necessary for serving customers but might nonetheless provide benefits to customers. The implications of cost recovery for pre-reviewed investments are different in each state. A pre-review of utility investments is not necessarily the same as pre-approval of those investments.

⁵⁰ *Securitization* is an alternative form of utility financing whereby utility debt obligations are underwritten by taxpayers, resulting in a lower cost of capital and reduced ratepayer burden. Unlike some alternative cost recovery mechanisms, securitization often requires a legislative mandate. It may provide utilities full recovery of the value of the stranded assets, but not necessarily.

Table 5. Potential Opportunities and Challenges - Stranded Costs

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Reduced stranded costs ▪ Better assignment of decision-making risks to utilities ▪ More appropriate sharing of stranded costs between investors and customers ▪ Better incentives for utilities to minimize stranded costs 	<ul style="list-style-type: none"> ▪ Increased regulatory burden from pre-review of investments ▪ Increased risk to customers from pre-review of investments, especially if that includes pre-approval of investments ▪ Anticipating evolving electricity sector conditions and economics ▪ Difficulty in increasing rates to recover some stranded costs from electricity customers ▪ Risk of utility bankruptcies with increasingly stringent cost recovery practices in conjunction with significant stranded costs ▪ Legislation required prior to utilization of some options, such as securitization

1.4.6 More Attention to Energy Equity

While customer equity has always been a priority for consumer advocates, it warrants increased attention as the electricity sector becomes more complex. The proliferation of new technologies and new pricing options might lead to increased electricity costs in some contexts and reduced electricity costs in others. These benefits and costs will need to be allocated across customers equitably, perhaps requiring new practices to do so.

Many of the innovations discussed in this essay can affect customer equity and should be designed in ways to maintain or improve it. The concept of customer equity itself might need to evolve over time to respond to policy drivers and changes in the electric utility industry. For example, in recent years, the concept of disadvantaged or vulnerable customers has evolved from being limited to low-income customers to include a much broader range of customers, such as moderate-income customers, communities of color, fixed-income elderly customers, those who have been subject to historical injustices, customers in geographically defined environmental justice areas, and more.

1.4.6.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *Better defined and applied concepts of affordability and energy burden.* Regulators and utilities could establish consistent definitions and apply these concepts more consistently in the context of DER program designs, retail rate designs, cost allocation, benefit-cost analysis, integrated planning, and cost recovery.
- *Expanded stakeholder input and participation opportunities, including for vulnerable communities.* These opportunities could include (a) more flexible granting of intervenor status in regulatory dockets, (b) streamlining some of the regulatory processes to facilitate stakeholder input, (c) providing funding for experts to support representatives of disadvantaged communities in regulatory processes (e.g., intervenor funding), and (d) enabling collaborative and other working group processes to facilitate and coordinate stakeholder input. The FERC Office of Public Participation may ultimately provide a useful example.⁵¹

⁵¹ See Federal Energy Regulatory Commission Office of Public Participation (OPP). 2021. "What is OPP?" <https://www.ferc.gov/OPP>.

- *Improved methods for allocating benefits to vulnerable and disadvantaged customers.* President Biden’s Justice40 initiative may provide useful examples for how to more equitably allocate benefits to these customers.^{52, 53}
- *Better approaches for evaluating community impacts in utility decision-making practices.* Local economic, environmental, and employment impacts of utility resources could be better accounted for in benefit-cost analyses and comprehensive electricity planning practices by establishing metrics, regularly reporting results, and reviewing them with stakeholders.
- *More detailed and transparent data on utility customers and utility performance in serving those customers.* Such data would allow utilities, regulators, consumer advocates, and other stakeholders to better identify, serve, and protect disadvantaged and vulnerable customers.^{54, 55}
- *Better coordinate support to low-income customers.* The Low-Income Home Energy Assistance Program, and similar state or local programs, could be expanded with more funding or alternative thresholds to allow for increased participation.⁵⁶
- *Better utility DER programs to serve disadvantaged customers.* Utilities, regulators, and environmental justice advocates could design DER programs to serve disadvantaged customers and communities more effectively. This might include more engagement from local community leaders, better options for identifying disadvantaged customers, targeted marketing and delivery practices, increased engagement with public housing agencies and multifamily building owners, and pay-as-you save programs that enable customers to adopt new technologies without paying upfront costs.
- *Expansion of community choice aggregation.* Where authorized, consumers can choose to buy power from local entities, typically established to offer bill savings, access to DERs, and clean energy to residents and businesses.⁵⁷

⁵² See U.S. Environmental Protection Agency. n.d. “WHEJAC Justice40 Climate and Economic Justice Screening Tool & Executive Order 12898 Revisions Interim Final Recommendations.” *Environmental Justice*.

<https://www.epa.gov/environmentaljustice/whejac-justice40-climate-and-economic-justice-screening-tool-executive-order>.

⁵³ Id.

⁵⁴ See the NASUCA Data Collection Resolution–Joint with NARUC. <https://www.nasuca.org/2019-07-nasuca-data-collection-resolution-joint-with-naruc/>.

⁵⁵ See Critical Consumer Issues Forum (2021).

⁵⁶ A related example that illustrates the potential for expansion of LIHEAP programming is the recently initiated Low Income Household Water Assistance Program. See <https://www.acf.hhs.gov/ocs/programs/lihwap>.

⁵⁷ Community choice aggregation, already in place in several states, allows local not-for-profit public agencies to procure electricity from competitive suppliers for utility customers in their jurisdiction.

Table 6. Potential Opportunities and Challenges - Equity

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Better decision-making that reflects interests and needs of vulnerable customers ▪ More focus on community needs ▪ Better access to DER programs and technologies, allowing more customers to reduce electric bills 	<ul style="list-style-type: none"> ▪ Adoption of some types of DERs for some customers ▪ Expanding current regulatory approaches to account for equity considerations ▪ Providing vulnerable customers and communities with the resources to get meaningful representation

1.4.7 Increased Emphasis on Policies to Address Climate

With each passing year, more states are passing legislation or otherwise adopting policies to address climate issues. These come in the form of GHG emission reduction mandates, renewable generation mandates, increased support for DERs and other clean energy options, increased use of the social cost of carbon in utility planning exercises, policies to electrify the transportation industry, and more. Similarly, the federal government is likely to take increasing actions to address climate issues over the next 20 years. The Biden administration proposed a goal of reducing U.S. GHG emissions by 50%–52% below 2005 levels by 2030,⁵⁸ as well as legislation with ambitious climate policies.⁵⁹

Meeting these evolving climate goals will require significant innovations in the way electric utilities plan for and invest in electricity resources. It also will require enhanced coordination with other industries, such as the gas, transportation, and water industries, especially in the context of electrifying end uses in order to reduce GHG emissions. Electrification developments in these related industries will create both challenges and opportunities as electricity demand will likely increase significantly, creating (a) the need for more electricity infrastructure investments and (b) more customer revenue to pay for it.

The increasing number of states adopting climate goals, and the increasingly ambitious goals being adopted by those states, will likely affect many aspects of electricity regulation, especially as we approach the target year of 2030 and years that follow. Climate goals are likely to affect many of the trends and innovations discussed above in Sections 1.4.1 through 1.4.6.

1.4.7.1 Trends and Innovations

Examples of expected trends and innovations over the next two decades include:

- *Increasing reliance upon carbon-free electricity resources.* This will likely include increased reliance upon currently available renewable resources, such as hydropower, photovoltaics, and on-shore and offshore wind, as well as emerging technologies such as utility-scale solar thermal generating stations, geothermal generation, fuel cells, ocean wave and current generation, and perhaps new nuclear reactor designs.
- *Improved coordination, planning and decarbonization.* Decarbonization efforts will require additional coordination and planning between electric and other utilities to meet the end-use needs of customers. For example, in some areas it may make sense for end users to switch from gas to electric supply. To the extent that end-use supply switching happens, the electricity industry will need to plan for and address the possibility of significantly increased demand on the

⁵⁸ United States (2021).

⁵⁹ The White House. The Build Back Better Framework. n.d. <https://www.whitehouse.gov/build-back-better/>.

electricity system, including peak demands. Similarly, decarbonization efforts also may require improved coordination and planning efforts between electric and water/wastewater utilities.

- *Increasing requirements for storm hardening and resilience.* With increased frequency of storms, floods, wildfires, and more, regulators are likely to direct utilities to make increasing levels of investment in storm hardening and resilience measures at both the distribution and bulk power system level.
- *Increased efforts to capture carbon emissions.* While the electricity industry has not yet developed economically viable carbon capture technologies, this might change as lower-cost technologies are developed and the economics of capturing carbon improves.
- *Increasing prioritization of DERs.* As climate goals proliferate and become more ambitious over time, DERs and other customer-focused clean electricity options will become increasingly important. Increased prioritization of DERs is discussed in Section 1.4.1.
- *Increasing application of decarbonization PIMs.* Promoting carbon-free resources will require increased attention from utility management and might not be consistent with current utility financial incentives. This will likely lead to the development of PIMs in an effort to prioritize decarbonization goals. PBR and PIMs are discussed in Section 1.4.3.
- *Improved treatment of stranded costs.* As utilities take steps to mitigate GHG emissions, they might make some of their investments in fossil fuel-fired power plants obsolete, leading to increased stranded costs. Treatment of stranded costs is discussed in Section 1.4.5

Table 7. Potential Opportunities and Challenges - Decarbonization

Opportunities	Challenges
<ul style="list-style-type: none"> ▪ Efforts such as increased electrification will lead to increased electricity sales and electricity revenues. ▪ Adding carbon-free electricity resources can result in environmental benefits beyond climate mitigation, including reduced air, liquid, and solid-waste emissions. 	<ul style="list-style-type: none"> ▪ Climate policies may lead to increased costs for the electricity industry. ▪ Decarbonization efforts such as increased electrification will place increased demands on the electricity grid. ▪ Installing and operating carbon-free electricity resources may increase electricity costs. ▪ Coordination with gas, transportation, and water industries is critical but poses institutional challenges. ▪ Storm hardening and resilience costs may be hard to justify given the uncertainty of environmental threats.

1.5 Conclusion

If the past 20 years are any indication, the electricity sector two decades from now will be dramatically different than it is today. Technological changes, increased opportunities for DERs, decarbonization goals, new pricing options, increasingly complex planning practices, evolving wholesale market designs, and energy equity needs will clearly have large impacts. While this essay anticipates some of the innovations that might occur over that period, there will likely be innovations that no one can predict at this time.

Innovation will ideally bring many positive outcomes for utility customers and the electricity sector broadly. However, innovation also will bring risks to customers that should be managed.

As utility regulators, utilities, consumer advocates, and other stakeholders encourage or respond to innovations in the electricity sector, they should be mindful of both the opportunities and the challenges associated with those innovations. The task is to ensure that new policies and regulatory practices are well designed and strike the right balance between allowing the industry to evolve in productive directions, achieving current and new policy goals, and ensuring customer protection and equity.

2.0 A Labor Perspective on Innovation to Meet Climate Goals for the Electricity Sector

By Kevin Lee, BlueGreen Alliance

2.1 Introduction

Tackling the climate change crisis will require a massive mobilization of resources. For the U.S. electricity sector, reducing emissions to prevent damaging climate change will require grid modernization investments and infrastructure build-out on a scale not seen in generations.⁶⁰ Meeting this goal is technically feasible, but poses challenges ranging from the purely technological and cost-related to those rooted in social, political, and community-oriented forces. Critically, these challenges are often intertwined, and policymaking to address one facet of the challenge can and should be carefully and intentionally crafted to account for challenges across the socio-political spectrum. In short, we can (and arguably, must) meet the climate challenge while also meeting the challenges of racial and economic equity, fairness for workers, community agency, and environmental health.

[P]olicymaking to address one facet of the challenge can and should be carefully and intentionally crafted to account for challenges across the socio-political spectrum.

This essay addresses one such intersection in climate policy as it relates to regulated electric utilities, by exploring how decisions around a utility's workers—pay, benefits, and staffing levels—impact outcomes for innovation in the context of community response to clean energy development and grid resiliency. Utility staffing levels in particular play an outsized and underreported role in these outcomes and are correspondingly deserving of greater attention by regulators and legislatures.⁶¹ In addition, this essay addresses how the same factors that drive a utility to minimize its labor costs also have produced a regulatory environment that makes it challenging for utilities to make much-needed investments in grid modernization and resiliency. This focus is overdue and critical, and supports the Biden Administration's target to reduce greenhouse gas pollution by at least 50% from 2005 levels in 2030, which envisions the creation of "good-paying, union jobs" among the ways to build back better.⁶²

At the state level, siting of clean energy infrastructure, which needs to be ramped up well beyond record levels, is increasingly met with local opposition. The public is largely supportive of clean energy policy in the abstract, but unconvinced that it (or climate change) will impact them on a personal level,⁶³ and they are increasingly mobilizing to block new renewable generation, transmission, and distribution projects.⁶⁴ By enacting and implementing policies with an eye toward local impacts, including jobs, wages, and tax benefits—particularly in distressed communities—we can ensure that the massive investments required for a clean energy future will benefit communities hosting the needed electricity infrastructure, earning their support along the way.

⁶⁰ Larson et al. (2021).

⁶¹ While outside the scope of this essay, decisions about utility infrastructure investments also result in direct, indirect, and induced impacts for other employers.

⁶² The White House (2021).

⁶³ See, e.g., Leiserowitz et al. (2021).

⁶⁴ Gross (2020).

2.2 The Economic Opportunities Inherent in a Carbon-free Electricity Grid

The scale of clean energy investments required for net-zero carbon emissions in the electricity sector is difficult to overstate. At its core, it means massive amounts of new carbon-free generation capacity, new transmission to unlock regional bottlenecks, and extensive distribution system upgrades to accommodate demand flexibility through distributed energy resources (DERs) like rooftop and community solar, energy storage, and managed electric vehicle (EV) charging. At the same time, electricity systems are servicing growing loads from newly electrified building, transportation, and industry end uses, and the electricity industry and regulators are initiating efforts to improve grid resiliency in the face of ever more extreme weather. No small task, indeed. But each of these investments are first and foremost an opportunity. They offer the chance for local communities and workers to benefit from these projects, often sited in rural areas and near energy burdened households that are more socially and politically distant from most clean energy policy discussions.

New generation is typically top of mind for climate policy, for good reason. Although the contours vary by study, virtually all deep decarbonization modeling of electricity grids involves, to use a technical term, gobs and gobs of wind and solar complemented by a grab bag of non-intermittent clean energy resources (long-term storage, fossil fuel generation with carbon capture and sequestration, hydrogen-fired power plants, geothermal, and nuclear).⁶⁵ The amounts are staggering. Last year, the United States set a record for new renewable capacity with 29 gigawatts (GW) installed.⁶⁶ One estimate of the build-out required to reach a 90% clean grid by 2035 more than doubles that record and keeps building roughly 75 GW every year, cumulatively adding a staggering 1,200 GW of new capacity (Figure 3),⁶⁷ about as much generation capacity as exists in the United States today.⁶⁸ Much of this capacity will be located far from loads, necessitating significant new transmission infrastructure. One study estimates that the transmission network will triple in size by 2050, from 320,000 GW-kilometer⁶⁹ (km) to over 1 million GW-km (Figure 4).⁷⁰

⁶⁵ See Larson et al. (2021); Williams et al. (2021); Davis et al. (2018); and Sepulveda et al. (2018).

⁶⁶ IRENA (2021).

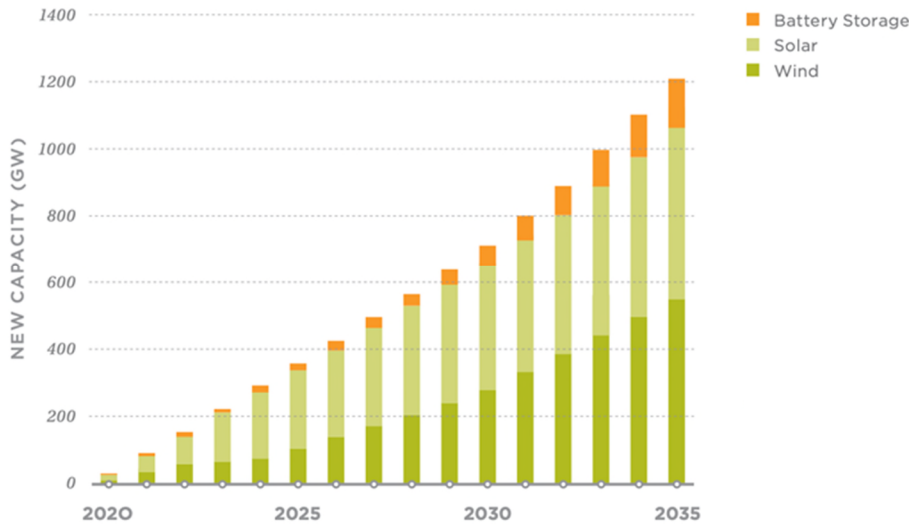
⁶⁷ University of California, Berkeley (2020) at 7. See also Larson et al. at 100 (noting that in all modeled net-zero by 2050 scenarios, “annual wind and solar capacity additions are sustained over multiple decades at historically-unprecedented rates”); California Energy Commission (2021). Docket No. 21-SIT-01, page 5, <https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-SIT-01>. These estimates are also in line with recent analysis of the proposed (but likely defunct) federal Clean Energy Payment Program, which would spur 85 GW of wind and solar annually (Penrod 2021a).

⁶⁸ U.S. Energy Information Administration. n.d. Electricity explained: Electricity generation, capacity, and sales in the United States. <https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php>.

⁶⁹ Transmission lines are built at varying voltages (e.g., 765 kilovolts [kV], 500 kV, 345 kV) with correspondingly different load carrying capacities. To move 2,400 MW of generation capacity 300 miles, for instance, one could use a single 765 kV line or three 500 kV lines (and therefore, three times the length of the higher voltage line). Overall transmission capacity can be expressed in gigawatt-miles as a way of normalizing varying load carrying capabilities. See, e.g., U.S. Dept. of Energy (2004).

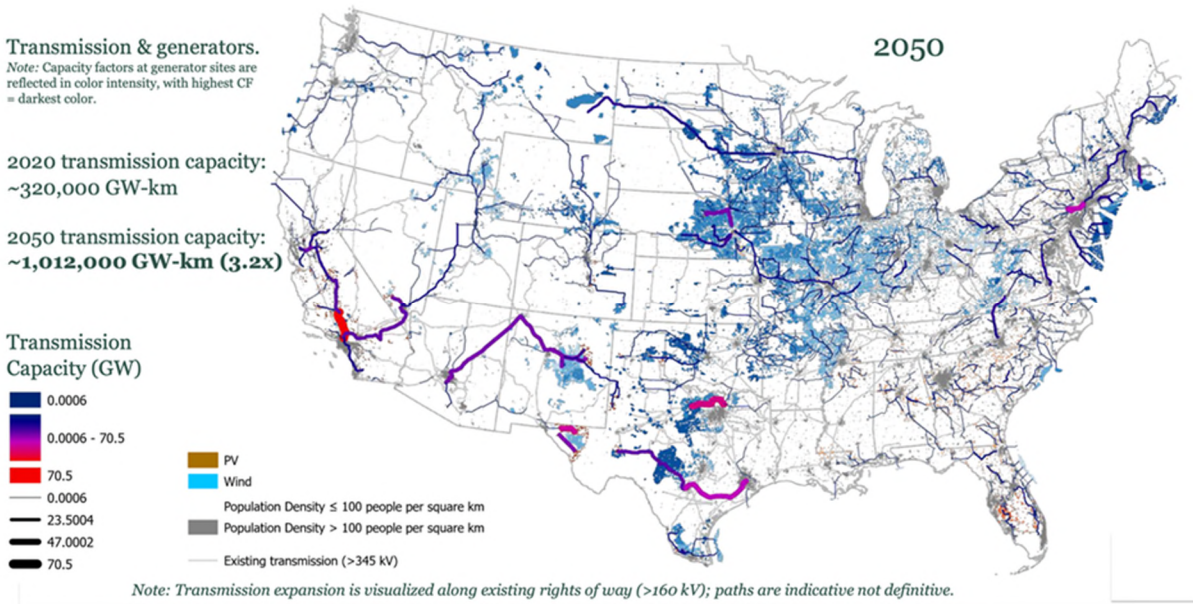
⁷⁰ Larson et al. (2021) at 137.

Figure 3. Cumulative Capacity Additions of Wind, Solar, and Battery Storage in a Modeled 90% Clean Electricity Grid by 2035



Source: UC Berkeley (2020).

Figure 4. Cumulative Transmission Capacity Additions by 2050 in a Modeled Net-Zero Scenario



Source: Princeton University (2020).

Many utilities around the country are planning and implementing distribution system upgrades to ensure their systems will be able to seamlessly host this flood of new generation and transmission. Upgrades include age-related investments to replace distribution infrastructure at the end of its useful life, distribution system expansions for increased capacity and reliability (e.g., new substations, transformers, feeders, tap lines, or service lines), enhanced feeder load monitoring, new communication devices that

connect field devices on the distribution system to the utility’s information systems, voltage regulation devices, and automated system restoration devices.⁷¹

In addition to the distribution system upgrades required to keep up with an expanded grid, net-zero carbon emissions will require a much more flexible grid, to adjust to local fluctuations from DERs, smooth out load peaks with automated demand response, match loads to output from variable renewable energy, and much more. This is nothing short of a paradigm shift in the operation of the power grid, from a highly centralized, top-down supply structure to one that has “fundamentally changed the distribution, diversity, and scale of energy and flexibility resources.”⁷² It is a change, as one author argues, “from economies of scale to economies of flexibility.”⁷³ And this change will be built into new distribution infrastructure. As residential solar increases, for instance, the demand patterns on local distribution networks will change, placing new constraints on system operators that will require advanced meters, digital sensors, and controls for network-connected DERs to ensure system reliability and safety.⁷⁴ The grid of the future will feature “pervasive digitalization of energy via smart grid technologies, including smart meters, energy management systems for smart buildings and smart communities, and distribution system and distribution market platforms.”⁷⁵ New monitors and controls will likely be found in everything from water heaters to electric vehicle (EV) chargers.⁷⁶

This transformation and build-out will happen at the same time demands on the grid increase. As electrified transportation and heating become commonplace, already beefy and peaky loads will be getting beefier and peakier. High levels of EV charging and variable distributed generation can exacerbate this problem, making evening electricity peaks steeper and potentially flipping many areas from summer peaking to winter peaking systems, with effects rippling through the entire grid, including “transmission level operations, [] real-time electricity markets, transmission controls, generator dispatch, and generation reserve requirements.”⁷⁷

The utility imperative to maintain the primacy of system safety and reliability will be getting more difficult at precisely the same time weather that was once extreme is becoming commonplace. This was amply illustrated by weather events in 2020, when the United States’ fifth warmest year on record coincided with the most billion-dollar disasters in history, with 22 events, compared to an annual average of seven.⁷⁸ And 2021 again blew away those averages with an additional 18 weather events of \$1 billion in losses or more,⁷⁹ a pace that is on a track, as of this writing, to set new records.⁸⁰ Warmer temperatures, wildfires, floods, heat waves, and high winds have all exacted extensive damage to the nation’s power grid, stressing storm recovery services to the breaking point. In 2020, utility customers spent a cumulative total of 1.3 billion hours in the dark from extreme weather events, an increase of more

The utility imperative to maintain the primacy of system safety and reliability will be getting more difficult at precisely the same time weather that was once extreme is becoming commonplace.

⁷¹ See, e.g., Xcel Energy (2019) (hereinafter “Xcel IDP”).

⁷² Li (2020) at 5.

⁷³ Li (2020) at 5.

⁷⁴ Schaefer (2020) at 12.

⁷⁵ Mancarella (2020) at 42.

⁷⁶ Masuta and Yokoyama (2012); Zhou et al. (2015); Gelazanskas and Gamage (2016); Pillai and Bak-Jensen (2011); Hu et al. (2013); Liu et al. (2014); and Pakka and Rylatt (2016).

⁷⁷ See Blonsky et al. (2019).

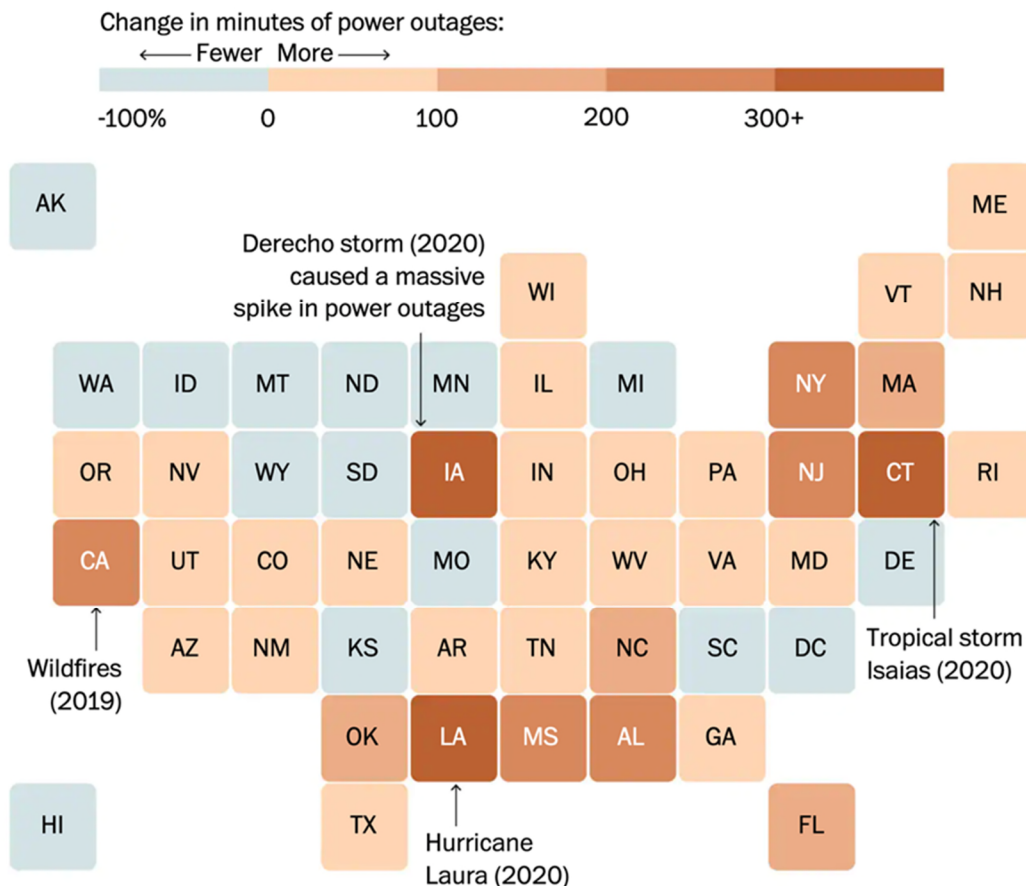
⁷⁸ NOAA (2021).

⁷⁹ NOAA (2022).

⁸⁰ Jeromin (2021).

than 70% from the prior year.⁸¹ Analysts commenting on weather events described the grid as “woefully unprepared,” with impacts to communities that are “severe and life-threatening.”⁸² See Figure 5, illustrating the extent to which severe weather has caused increases in the amount of time that customers are left without power.

Figure 5. Change in Average Annual Power Outage Minutes per Utility Customer, 2013–2015, Compared to the 2018–2020 Three-Year Average



Source: MacMillan and Englund (2021).

⁸¹ S&P Global (2021).

⁸² Saha et al. (2021).

The decarbonization of the electric sector means no less than a total overhaul of electricity systems, undertaken under duress. We are essentially rebuilding the world’s largest machine, bolt by bolt and wire by wire, over the next few decades, while simultaneously minimizing outages and displacements resulting from this unparalleled construction effort. This is both an engineering challenge and an economic opportunity on an unprecedented scale. Questions about who benefits from these investments, how they benefit, and who pays for the investments, are critically important. Utilities also must rethink their engagement and connections with the local communities they serve and the value they can provide in a future with higher levels of DERs and related changes in market structures and market power.

Utilities also must rethink their engagement and connections with the local communities they serve and the value they can provide in a future with higher levels of DERs and related changes in market structures and market power.

2.3 Strengthening Community Ties to Clean Energy

Investments in generation, transmission, and distribution come at a time when climate action is both critical and fragile, with some communities feeling left out or bearing only the burdens and few, if any, of the benefits of climate action. At the same time, other communities are experiencing the burdens of fossil-fuel production transmission, generation, and waste disposal activities.⁸³

Coal plants nationwide have succumbed to competition from natural gas and renewable resources, oftentimes leaving host communities scrambling to replace lost wages and tax revenues.⁸⁴ Although investments in new wind and solar resources are often highlighted as a potential counterbalance to jobs lost in coal-fired power, those jobs are almost always in a distant community and draw from different skill sets.⁸⁵ Traditional electricity generation is also more labor-intensive to operate than wind and solar generation, which means that there are also just fewer jobs to go around.⁸⁶ In reality, relatively few coal plant workers have found jobs in renewable energy.⁸⁷ Abrupt plant closures can have a toxic effect on the perception of clean energy jobs, particularly in already hard hit rural communities.⁸⁸ Most of the retiring coal plants are located in rural areas, many of which are already economically distressed.⁸⁹

But there are encouraging developments in this field, where state and local policymakers, along with regulated utilities, have begun to take steps to ensure that clean energy development meaningfully benefits local communities for the long term. Despite the headwinds for coal plant workers, for instance,

⁸³ See, e.g., Jean Su’s essay, “Climate, Environmental, and Energy Justice: Integrating Justice into Electricity System Design and Decision-Making,” in Farley et al. (2021).

⁸⁴ See, e.g., Macgillis (2018). In states where renewable energy is not exempted from property tax assessments, property tax revenues from a renewable project can be substantial, equaling those from fossil fuel plants. See Tegen (2005) and Brunner, Hoen, and Hyman (2021). Those new revenues, however, are often assessed in a different county or municipality, leaving the host community with a net tax revenue loss from a retiring fossil plant, while the renewable energy-receiving community enjoys a net gain. See Tarekegne, Kazimierczuk, and O’Neil (2021) at 2 (noting that “Twenty-six counties in the United States are classified as ‘coal-mining dependent,’ meaning that coal-related revenue may fund a third or more of local budgets including property taxes, sales taxes, and school districts”).

⁸⁵ See Energywire (2020) and Quadrennial Energy Review (2017).

⁸⁶ Penrod (2021b).

⁸⁷ Patridge and Steigauf (2020) (hereinafter “CEE Host Community Study”) (noting that “in today’s economy, power plant jobs are uniquely high in quality. There are no clear options to replace power plant jobs with positions that are similar in terms of pay, benefits, stability, and location.”); Penrod (2021b).

⁸⁸ Patridge and Steigauf (2020) at 72.

⁸⁹ Carbon Brief (2020) and Headwaters Economics (2017).

clean energy development is an undoubted economic powerhouse, and does provide at least some limited relief for displaced coal workers.⁹⁰

Clean energy jobs tend to be concentrated in the construction sector. Displaced workers who are trained electricians, ironworkers, carpenters, operating engineers, or pipefitters may have easier times transitioning to new work.⁹¹ Recent legislative and regulatory movements toward incentivizing local hiring for these jobs have made great headway toward cementing relationships between clean energy developers and local communities, though much more remains to be done.⁹² One worker noted that, after “significant efforts” from both utilities and clean energy developers that resulted in a local hiring reporting requirement for clean energy projects, “we’ve gone from a wind construction workforce that is less than 20% local . . . in 2017 and 2018 to more than 60% local in 2019, and we expect that trend to continue in 2020.”⁹³

Recent legislative and regulatory movements toward incentivizing local hiring for these jobs have made great headway toward cementing relationships between clean energy developers . . . and local communities, though much more remains to be done.

For other displaced coal plant workers, some have been able to move laterally within the same utility.⁹⁴ Here too, we see that utilities taking account of local job impacts goes a long way toward building important connective tissue between affected communities, workers, and the clean energy industry.⁹⁵ Taking the time to solicit this feedback, however, is all too often neglected,⁹⁶ and the reality is that while these lateral transitions can help some displaced workers, many find themselves in the position of needing to replace lost income and benefits as soon as possible. The most common career pathway for a worker laid off by a closing power plant has been to get a commercial driver’s license.⁹⁷

The upshot here is three-fold:

- (1) Achieving emissions neutrality for the power grid by 2050 is an incredible economic development opportunity for local communities.
- (2) This opportunity will be realized only as a result of intentional regulatory and legislative policymaking that ties community outcomes to clean energy projects.
- (3) The risks of failing to account for these community outcomes is potentially catastrophic to net-zero carbon goals.

It is this last point that is arguably the most underappreciated. Increasing local opposition to the siting of clean energy projects is by now commonly understood as a potent threat to achieving decarbonization goals.⁹⁸ But what is less understood is that this local opposition breeds in an environment where clean energy development follows the path of the resource curse,⁹⁹ where:

⁹⁰ Ferris (2021).

⁹¹ Jones, Philips, and Zabin (2016).

⁹² See Washington Clean Energy Transformation Act, SB 5116 (2019), Laws 2019, ch. 288, May 17, 2019.

⁹³ CEE Host Community Study at 68.

⁹⁴ See, e.g., Booth (2021) and CEE Host Community Study at 63.

⁹⁵ Brasch (2021).

⁹⁶ CEE Host Community Study at 72 (noting that the utility closing a local coal plant “never asked for input” from impacted workers).

⁹⁷ Penrod, Emma (2021b).

⁹⁸ See generally, Marsh, McKee, and Welch (2021) and Motavelli (2021).

⁹⁹ Aragon, Chuhan-Pole, and Land (2015).

- employment is low-wage, low-benefit, ephemeral, or contracted from out of state;
- the burdens of hosting a project are expected to be shouldered by the community without complaint; and
- the benefits of jobs and tax revenues are withheld except under pressure.¹⁰⁰

By some estimates, 55% of clean energy investments go to rural areas, but without a “coherent policy framework,” one analysis notes, distorted incentives have “triggered rent-seeking behaviours” that breed resentment, ultimately leading many local communities to oppose further projects.¹⁰¹

One does not have to look far to see this dynamic playing out in the United States. Local governments in 36 states have ordinances prohibiting or restricting renewable energy development, and at least 160 projects have been actively contested, many successfully so, through excessive delays, outright project cancellation, or scaling down the project’s size.¹⁰² The country is littered with dead renewable projects: 600 MW of wind in Indiana,¹⁰³ 850 MW of solar in Nevada,¹⁰⁴ and 80 MW of solar in Virginia,¹⁰⁵ all cancelled in large part as a result of local opposition (although this phenomenon is of course not unique to clean energy). While projects may be cancelled for other reasons, such as selection of competing project sites, changes in government policies, and reductions in customer load, siting opposition is a formidable obstacle to project success.

Media reports on such battles often frame the debate in terms of impaired aesthetics—neighbors that are concerned about a view or increased traffic. And those are no doubt factors in contributing to opposition (and, indeed, factors that should be given serious consideration by developers). What those media accounts often fail to describe is that local opposition on some scale exists for virtually every development project in the U.S., renewable or otherwise. The other side of the story—successful projects that meaningfully engage local communities in the siting process and hire local workers with good wages and benefits—often goes untold. Successfully building a wind or solar project (or distribution substation or transmission line) simply isn’t much of a news story, at least outside of the local community.

Years of study on the acceptance of renewable energy development confirms that, while impaired aesthetics can play a role, the success of a project is in large part driven by whether the community believes that it will benefit from the project and the degree to which community members participated, and had a say, in the planning and siting of the project.¹⁰⁶ The

Years of study on the acceptance of renewable energy development confirms that ... the success of a project is in large part driven by whether the community believes that it will benefit from the project and the degree to which community members participated, and had a say, in the planning and siting of the project.

¹⁰⁰ See, e.g., Botero (2016) and OECD (2012) at 4.

¹⁰¹ OECD (2012) at 4.

¹⁰² See generally, Marsh, McKee, and Welch (2021).

¹⁰³ Baker and Dent (2019).

¹⁰⁴ AP (2021).

¹⁰⁵ Nir (2020).

¹⁰⁶ Segreto et al. (2020). (“It was found that perceived benefits and costs should be distributed equally amongst residents . . . the studies reveal that a great incentive for local acceptance is a financial benefit for the inconvenience of developing a RES or REP in the community. For instance, lower energy rates, opportunities for employment, or tax returns.”); Rand and Hoen (2017) (Socioeconomic impacts of wind power development are strongly tied to acceptance); Carley et al. (2020) (Primary factors driving support and opposition are trust, perceived benefits and drawbacks, knowledge, and political orientation.); Carley et al.

localization¹⁰⁷ of job wages and benefits is one of the keys to building public support for clean energy and ensuring that economic opportunity becomes economic reality for local, often rural, communities that will host much of the new clean energy development required to reach net-zero. For new renewable projects, the localization of economic benefits can be difficult, because renewable energy facilities have so few ongoing operations and maintenance jobs that it is often not possible for an individual clean energy project to singlehandedly support a local workforce, as large legacy power plants typically do.¹⁰⁸

As noted above, requiring or incentivizing project developers to use locally hired construction trades workers can boost both local benefits and public support, but this workforce is often “local” in a broader, regional sense—for example, workers living in the same state, as opposed to the particular town. Construction work is inherently temporary, so new construction of renewable generation facilities in a particular rural community will not by itself support a permanent construction workforce. But when renewable energy proliferates across the rural landscape, the multitude of construction work can absolutely support a regional workforce. Because an individual wind or solar farm does not support a workforce the way that a large legacy power plant does,¹⁰⁹ states attempting to tie clean energy more closely to local economic benefits have focused on policy levers like reducing electric bills for communities hosting the projects to confer benefits for a local area that may not have many construction workers.¹¹⁰

These dynamics are much different for transmission and distribution (T&D) systems. Work in T&D involves much more ongoing operations and maintenance to keep sprawling networks running safely and reliably. That work is necessarily long term and stable enough to support local communities. Nationwide, electricity T&D work supports over 600,000 jobs, 300,000 of which are in the electric utility sector (as opposed to the T&D jobs in the construction sector), compared to about 183,000 jobs in electric utility power generation.¹¹¹ A large proportion of investments in the electric T&D work supporting these jobs is and will continue to be driven by grid modernization and other utility-funded modernization projects.¹¹²

This core utility workforce is a key source of economic stability for local communities.¹¹³ As utilities nationwide gradually evolve from a labor model that features large numbers of jobs in centralized fossil-

(2020); Hamilton et al. (2018) (“Unsurprisingly, a key factor affecting public support for renewable energy development is perception of local economic benefits”); Rand and Hoen (2017) (finding that public acceptance of wind energy is influenced by socioeconomic impacts and issues of fairness, participation, and trust); Firestone et al. (2017) (finding that a community’s being able to influence the outcome of a wind project is correlated with positive attitudes toward the project).

¹⁰⁷ The term “localization” is used here to signify either retaining workers that reside in the surrounding communities or recruiting more local workers in response to outsourcing trends that have reduced the number of workers that reside in the local area.

¹⁰⁸ CEE Host Community Study at 77–78.

¹⁰⁹ CEE Host Community Study at 77–78.

¹¹⁰ New York Accelerated Renewable Energy Growth and Community Benefit Act, Bill No. S7508b, § 8, April 3, 2021 (directing the public service commission to create a Host Community Benefit Program funded by renewable energy owners “to provide a discount or credit on the utility bills of the utility’s customers in a renewable host community, or a compensatory or environmental benefit to such customers.”)

¹¹¹ National Association of State Energy Officials, Energy Futures Initiative, and BW Research Partnership (2020) at 93, (hereinafter “USEER 2020”). Other subcategories besides utilities include construction, manufacturing, wholesale trade, and professional/business. The dominance of the utility subsector for electric T&D jobs can be usefully contrasted with jobs numbers in electricity generation, which are dominated by construction jobs.

¹¹² USEER 2020 at 40, 92. Data from the U.S. Bureau of Labor Statistics (BLS) differs on the magnitude of this comparison. BLS data, which uses a different survey methodology from the U.S. Energy and Employment Report, estimates total electric utility employment across generation, transmission and distribution at about 380,000, while the USEER report estimates almost 483,000. Although this difference appears large, it is not uncommon to see discrepancies of this magnitude in employment data based on surveys. Data are categorized differently by different assessments, and when aggregated these differences in categorization become magnified. Generally, however, historical trends in these proportions hold true across these differing methodologies.

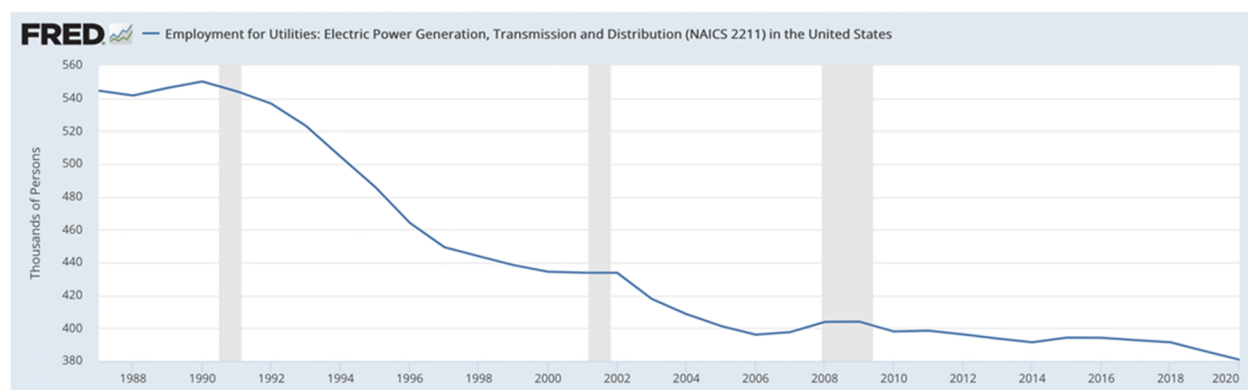
¹¹³ See, e.g., Chaudry (2018).

fuel power plants to one that features fewer utility jobs in generation but potentially many more jobs in transmission and distribution, that core utility workforce will be an increasingly important economic safety net for communities, in addition to being a core source of local support for new energy development.

2.4 The Slow Decline of Utility Workforces and Consequences for Innovation

The utility workforce has unfortunately been experiencing formidable headwinds, with significant implications for both community well-being and the overall pace of decarbonization in the electricity sector. These workforces are a consistent and stable source of economic development for local communities and a critical link that provides local support for innovative projects. When these local workforces have declined or been outsourced to non-local workers, the results have been both immediate and significant: storm response times have suffered, causing widespread customer frustration, and support for important projects has dwindled. Overall, jobs in this sector have declined for decades (Figure 6).

Figure 6. Employment for Utilities: Electric Power Generation, Transmission, and Distribution (NAICS 2211) in the United States



Source: U.S. Bureau of Labor Statistics (2021).

Largely, this has been a matter of utilities not keeping up with attrition from retiring workers¹¹⁴ and investor-owned utilities relying on contracted labor instead of in-house employees.¹¹⁵ For investor-owned electric utilities, the macro-economic trend underlying the data is that over the last decade, they have been under increasing pressure to reduce labor costs. As one trade industry article described it:

At most utilities, little or no opportunity for significant revenue growth has existed for some time while increasing personnel related expenses have continued to squeeze profit margins. To achieve the annual earnings improvement targets of 10–15% their stakeholders have expected, utilities have had no alternative but to reduce ongoing operational expenses dramatically, and often that has meant cutting staff.¹¹⁶

¹¹⁴ Utility Workers Union of America (2013) (hereinafter “UWUA Report”) at 6.

¹¹⁵ Polson (2013). Other factors in the overall decline include increased automation in services like meter reading. See, e.g., U.S. Dept. of Energy (2012) at iii.

¹¹⁶ Kitterman and Dugan (2006). See also Sosa and Perry-Failor (2012) (noting that “the costs of non-cash compensation have climbed swiftly, prompting utilities and other employers to deploy a range of strategies for managing these expenses. Examples include: retirement plan restructuring, increased use of incentive-based compensation, and reductions in headcount.”).

In addition to simply reducing staffing levels, utilities also have been increasingly outsourcing labor to third-party contractors, often at a lower cost in wages and benefits. One industry veteran described his experience:

I've been involved in the industry 32 years. When I first got in, we'd have contractors working only during the summertime, and the utility had plenty of journey-level workers, plenty of apprentices. Somewhere in the mid-90s that started changing. Fast forward to where we are now, they're starting to rely heavily on contractors.... [I]t goes across generation, transmission and distribution. It used to be that contractors did specific projects, now they do everything.¹¹⁷

The available data bears out this experience. Information from the Bureau of Labor Statistics reveals that the number of line workers employed by utilities has declined over a time period in which the employment of line workers by utility contractors has doubled. Those contracted line workers earn, on average, 11% less than their colleagues employed by utilities.¹¹⁸ These wage differentials pose serious questions about work quality, as most utility-employed line workers graduate from a much more rigorous apprenticeship than a non-union linemen school.¹¹⁹ As discussed below, that training difference has real-world consequences. This trend is concerning on multiple levels. Perhaps most obviously, cutting in-house staff makes the utility less able to respond to weather emergencies, prolonging disruptive power outages (see text box on the next page).

Although responding to extreme weather is the most obvious and life-threatening outcome of historical underinvestment in utility workforces, it is not the only consequence. As described above, utility workforces, particularly for the distribution system, are a long-term, stable source of employment for local communities, and therefore a critical connection between local communities and the energy system. When workforces shift into a temporary, contracted model, that connection is severed. In that case, the contractors that perform this work are not local and do not reside in the area.^{120, 121}

Developing widespread, robust support for deployment of clean energy infrastructure requires a perception that the community will benefit economically from these investments, and severing that connection risks severing community support. T&D projects are especially vulnerable, with the lowest

¹¹⁷ Personal communication with Rich Meisinger, Business Manager, Int'l Brotherhood of Electrical Workers Local 111, Sept. 21, 2021.

¹¹⁸ Polson (2013). The increasing reliance on contracted utility workers can also be seen in contemporary public utility commission (PUC) filings. For instance, in some states, utilities are required to file distribution system plans that detail how the utility forecasts distribution system needs for hosting higher penetration levels of distributed generation and EVs, using DERs as other non-wires alternatives in place of some traditional types of upgrades, and implementing advanced metering infrastructure and other grid modernization investments. See Schwartz (2020). These plans offer useful insights into investments and operations and maintenance that impact workforce needs. One recent utility filing showed steady increases in labor costs on the distribution side as grid modernization efforts ramp up, as expected. But the utility planned to increase its reliance on contracted labor for its distribution system by 25%, while its in-house staff levels increased only 16%. See Xcel IDP at 20–21.

¹¹⁹ See, e.g., Manzo et al. (2021, at 1, 12) (noting that union jobsites had 40% fewer health and safety violations than nonunion jobsites, and that union contractors are able to submit competitive projects bids, despite higher union wages, because of the greater productivity of union-trained workers); Robson et al. (2021, at 20) (finding a significant “union safety effect” for union construction sites, and postulating that the safety benefits could be derived from better training, less worker turnover, and longer job tenures for unionized workers).

¹²⁰ Utility workers in Michigan describe how contractors were so plentiful at some sites that trailers were set up to house them. Macmillan and Englund (2021) at 7.

¹²¹ Utility workers in Colorado described a substantial amount of the contracted workforce as nomadic, living out of RVs and hotel rooms. Personal communication with Rich Meisinger, Business Manager, Int'l Brotherhood of Electrical Workers Local 111, Sept. 21, 2021.

popular support of any type of infrastructure required for clean energy development.¹²² When this dynamic plays out in renewable generation projects, the impact is often immediate. As one worker described the situation in Minnesota:

*A lot of projects are not benefiting communities where they're being built in regard to jobs. [Developers] are bringing in a lot of out-of-staters, nonunion to build wind farms. They don't have prevailing wage attached to them, so they don't pay the area standard. They are undercutting.*¹²³

If a local community's experience with clean energy is defined by high-profile coal plant closures, new renewable generation facilities that primarily use out-of-state workers, and a dwindling local utility workforce that causes extended power outages during storms with ever-increasing frequency and severity, the consequences for community perception of clean energy can be nothing short of toxic. As one worker put it:

*The idea of green jobs is a lie. They are including all sorts of things in there like decommissioning or little projects and calling them jobs. Those aren't jobs, those are temporary projects. You're creating something that lasts two weeks long and giving it a credit like you would a permanent job.*¹²⁴

It does not take a leap of imagination to envision the potential impacts for clean energy deployment, particularly given the vastness of the deployment required to meet carbon emissions neutrality by 2050. Although examples of this phenomenon abound, one particular case study serves as a potent reminder of what's at stake. In 2016, Massachusetts passed a law¹²⁵ to grow the state's use of renewable energy, including hydropower and offshore wind. Initially that need was to be met by a 192-mile transmission line through New Hampshire to connect Canadian hydropower with Massachusetts loads, but New Hampshire regulators rejected the project, citing concerns about impacts to the environment and tourism.¹²⁶ Following that project's demise, Central Maine Power proposed to meet the same needs with a transmission line through western Maine.¹²⁷ The Maine project quickly drew similar local opposition, this time fueled not just by concerns about environmental impact and tourism, but by longstanding frustration with the utility over consumer scandals, inadequate storm response, and chronic understaffing. As one local opponent noted,

*. . . CMP shouldn't be trusted to build this corridor.... [The company] doesn't even have a basic handle on how to provide safe power or accurate billing to ratepayers, so how can anyone think they'd be able to handle one of the biggest infrastructure projects in Maine history? There are so many reasons why so many Mainers oppose the corridor, and CMP's terrible track record is at the top of the long list.*¹²⁸

¹²² Carley et al. (2020). "A second theme that emerges from our study is that people tend to be supportive of most types of energy, although there are important exceptions. In studies of attitudes toward waste to energy and transmission and distribution lines, there is some to significant opposition."

¹²³ CEE Host Community Study.

¹²⁴ CEE Host Community Study at 72.

¹²⁵ Massachusetts Bill H. 4568, <https://malegislature.gov/Bills/189/House/H4568>.

¹²⁶ AP (2018).

¹²⁷ Andrews (2021).

¹²⁸ Crisos (2019).

Reduced In-House Workforce Reduces Grid Resilience*

The experience after Hurricane Sandy was arguably the first warning sign of the impact of utility staffing cuts during extreme weather. Sandy struck the East Coast after a period of unusually high hurricane activity, leaving almost 9 million customers without power across New Jersey, New York, and Connecticut.ⁱ

For the decade preceding the storm, utility “line worker staffing levels ha[d] been decimated . . . with no perceived efforts for replenishing them.”ⁱⁱ Given that a utility’s workforce is the “primary resource during large-outage events,”ⁱⁱⁱ the almost inevitable consequence was that power for millions was not restored for many days. Utilities’ attempts to rely on contracted mutual assistance^{iv} was to no avail. For example, “Four days before Hurricane Sandy struck in October, Consolidated Edison Co. sought 1,800 power-line-repair workers from its fellow utilities to help respond to the massive storm brewing in the Atlantic Ocean. It got just 32. Three days later, the New York-based utility boosted its request to 2,500. It got 171.”^v

Many of the workers that did finally arrive “had no training on performing service restoration in the unique urban and underground utility environment in ConEdison’s territory.” The final post-Sandy report for New York state concluded that to better prepare for extreme weather, utilities “should review existing staffing levels and evaluate the impacts of an aging workforce on their abilities to effectively respond to a major event.”^{vi}

The warning shot from Sandy did not have the effect that regulators had hoped for. After Tropical Storm Isaias hit the East Coast in 2020, New York fined utilities a combined \$190 million for inadequate storm preparation, including “inadequate storm staffing,” that again left huge numbers of customers without power for extended periods of time.^{vii}

A post-event investigation by the Connecticut Public Utilities Regulatory Authority found that prior to the storm, the utility’s staffing levels for qualified line workers had declined by 6%, which contributed to the utility’s “failure . . . to meet its obligations to municipalities and customers by not having adequate crews available at the start of the storm and within the first 48 hours afterwards.” The results were, in the Commission’s view, “catastrophic” for towns and residents in the affected areas, “creating a significant risk to public safety.”^{viii} Ultimately, the Commission issued a \$28.5 million fine.^{ix}

This pattern of gradual understaffing leading to inadequate storm response has repeated itself across the country. For example, the Public Service Commission of Michigan launched an investigation in 2021 after a series of strong thunderstorms left almost a million customers without power, noting that “the pace of climate change dictates that such events will likely only become more frequent and planning must be responsive to this reality.”^x Michigan has consistently been among the highest quarter of states in terms of the frequency and duration of power outages.^{xi} Local workers have described deferred tree trimming as part of an overall pattern in both understaffing and underinvesting in critical, but not very profitable, routine maintenance. These workers detail how in-house workforces at Michigan utilities have been “slashed” up to 50% compared to the 1980s. Distribution infrastructure in Michigan, they noted, has been maintained under a “run it until it breaks” approach.^{xii} It’s not hard to see why emergency response would be compromised under this approach.

The same pressures that have created this situation—a reluctance to invest in low-profitability O&M expenses and intense pressures from regulators to keep rates low—have also created an environment in which utility efforts to invest in grid modernization investments have been largely rejected. One study found that utilities proposed \$15.7 billion in grid improvements to enhance resiliency, but only \$3.4 billion of those were approved by regulators.^{xiii} As one state regulator said, after a weather disaster “everyone’s standing around saying, ‘why didn’t you spend more to keep the lights on?’ . . . but when you try to spend more when the system is working, it’s a tough sell.”^{xiv}

**Text box notes appear as endnotes at the end of this essay.*

Part of this problem stemmed from the utility’s failure to hire staff in sufficient numbers, preferring instead to rely on contractors that lacked local knowledge of the system.¹²⁹ A local investigation revealed that understaffing was a key contributing factor to the utility’s “fail[ure] to live up to its long history of service to the state.”¹³⁰ When the utility was purchased by a foreign company and operated as a subsidiary, staffing numbers declined, resulting in what the former CEO described as a “loss of local knowledge.”¹³¹ Existing lineworkers were forced to make up the labor shortfall with overtime, creating a workload that was “killing them.”¹³² After provoking scrutiny from state regulators on the issue, the parent company attempted to reverse course, signing an agreement to increase staffing,¹³³ but the damage in the public trust had been done, and on November 2, 2021, Maine voters passed a referendum to effectively kill the transmission line project.¹³⁴ Although the project’s proponents have committed to litigating the ballot initiative, as of this writing, it is unknown how Massachusetts plans to replace the 1.2 GW of renewable energy the project would have brought to market.

2.5 Strengthening Community Ties by “Relocalizing” Utility Workforces

The increasing distance between local communities and those working in the clean electricity sector is not inevitable. Existing authorities allow state PUCs to take some actions to incentivize more local workforces, and state legislatures can follow examples already passed in some states for policy solutions that are not already available to state regulators.

First, given the inherent connection between staffing levels and the ability to restore power in the event of an outage, state PUCs typically are already empowered under traditional regulatory authorities to place requirements on staffing levels, both in terms of overall numbers as well as the use of contracted versus in-house labor. While regulatory lag can reward utilities for cost savings between rate cases, commissions routinely adopt rules and metrics to help ensure quality of service and reliability.¹³⁵ Second, PUCs can follow the examples set in Michigan and Northeast states to require regulated utilities to file storm-readiness plans with particular attention paid to staffing levels for distribution system maintenance and repairs. In a similar vein, state PUCs can establish specific performance standards pertaining to storm readiness and recovery that include detailed staffing requirements.¹³⁶ Specifically, given the potential risks for service and reliability, and implications for community receptiveness for deployment of clean energy infrastructure, PUCs should require detailed justifications for the use of

[S]tate PUCs typically are already empowered under traditional regulatory authorities to place requirements on staffing levels, both in terms of overall numbers as well as the use of contracted versus in-house labor.

¹²⁹ Keefe (2019).

¹³⁰ Id.

¹³¹ Id.

¹³² Id.

¹³³ Id.

¹³⁴ Sharp (2021).

¹³⁵ Massachusetts Institute of Technology (2016) (hereinafter “MIT Utility Report”) at 138. Rural electric cooperative and municipal utility boards perform the same balancing act that PUCs do in weighing cost savings against quality of service and reliability.

¹³⁶ July 14 PURA Order at 132–134.

outsourced labor and develop specific, enforceable guidelines that determine when contracted labor is appropriate or beneficial.¹³⁷

Without oversight from regulators, existing incentives for many utilities are to focus on new assets that can be capitalized and to minimize expenses for operations and maintenance, including labor costs. When a storm hits and customers suffer extended power outages, the utility makes the required repairs and recovers those costs from its customers, so there is less incentive to prioritize preventative maintenance.

As an MIT analysis pointed out, “Traditional cost of service regulation generally requires utilities to meet minimum performance levels but provides little incentive or reward for utilities that deliver higher-quality service or new outcomes and services . . . Utilities are thus encouraged to focus primarily on short-term cost savings, sacrificing the opportunities that could be unlocked if utilities were incentivized to invest with a longer-term view.”¹³⁸ This same incentive also affects utility perspectives on investing in innovative technologies and systems to modernize grids in alignment with state and federal policy goals. The types of investments required—storage, DERs, microgrids, and other distribution system resiliency efforts—may be costly, and are intensely scrutinized and often rejected by regulators.¹³⁹ The U.S. Department of Energy funded a series of resources for utilities and regulators to aid in review of proposals for investments to improve resilience of electricity systems.¹⁴⁰

This distorted incentive is often made worse by information asymmetries between regulated utilities and regulators.¹⁴¹ In particular, regulators may not always be in a position to evaluate the prudence of a utility’s use of a smaller and more outsourced workforce, or to evaluate the impacts of that decision on system reliability. This could prove especially difficult in distinguishing between instances of decreased labor costs driven by efficiencies and innovation, as opposed to instances of labor cost-cutting that comes at the cost of lower service quality and reliability standards. In such cases, evidence-based guidelines on worker training and certifications can help establish clear standards without the burden of an extensive inquiry and, failing that, public utility commissions can consider hiring a consultant to provide an independent analysis. But the issue clearly cannot be ignored. In an era of more severe thunderstorms and tornadoes in the Midwest, hurricanes in the South and Northeast, and wildfires and severe heat in the West, deferred maintenance is not just a labor equity issue, but a serious public safety issue.¹⁴² Transparency requirements and specific performance standards addressing staffing levels and outsourcing can go a long way toward eliminating this information asymmetry.

¹³⁷ See, e.g., California Public Utilities Commission, Decision Addressing Workforce Requirements and Third-Party Contract Terms and Conditions, Application of Southern California Edison Company for Approval of Energy Efficiency Rolling Portfolio Business Plan, Decision No. 18-10-008, Oct. 11, 2018. Without detailed and enforceable requirements such as the ones implemented in California, the information asymmetries inherent in traditional utility regulation will mean that rebutting a utility’s justification for using cheaper contracted labor could be difficult, and may require legislative solutions that require the utility to overcome an evidentiary burden, as opposed to labor advocates shouldering that burden.

¹³⁸ See, e.g., MIT Utility Report, at 139. Public power utilities are overseen by local governments, which may view these opportunities in a different light than regulators of investor-owned utilities.

¹³⁹ Macmillan and Englund (2021).

¹³⁹ Macmillan and Englund (2021).

¹⁴⁰ See the five Sandia National Laboratories reports posted at <https://www.synapse-energy.com/project/improving-electric-utility-and-community-grid-resilience-planning>.

¹⁴¹ Macmillan and Englund (2021) at 137.

¹⁴² See Blunt and Gold (2019).

Some states have taken steps to expand the traditional authority of PUCs beyond ratemaking and resource planning to include specific responsibilities centered around economic development, ensuring that utility regulation furthers greater societal goals in job creation, retention, and economic fairness for workers and host communities.¹⁴³ Some of these statutory authorities are broad in nature, conferring discretion to the commission to regulate with an eye toward economic fairness. Mississippi, for instance, has declared that it is the policy of the state, “[w]ith respect to rate-regulated public utilities, to foster, encourage, enable and facilitate economic development in the State of Mississippi, and to support and augment economic development activities, and to authorize and empower the Public Service Commission, in carrying out its statutory responsibilities, to take every opportunity to advance the economic development of the state.”¹⁴⁴

Some states have taken steps to expand the traditional authority of PUCs beyond ratemaking and resource planning to include specific responsibilities centered around economic development, ensuring that utility regulation furthers greater societal goals in job creation, retention, and economic fairness for workers and host communities.

Other states have taken a more targeted approach. Wyoming recently authorized its commission to consider “cost externalities incurred by the State of Wyoming, including but not limited to economic and employment impacts” when evaluating proposals to construct or retire major generation facilities.¹⁴⁵ These expanded authorities, alone or in combination with performance-based regulation, could in many cases be used to collect information on utility staffing practices and incorporate staffing decisions into PUC orders in rate cases or resource planning proceedings. Commissions could create employment metrics for such matters, allowing data collection and commission orders covering the use of local labor, the number of lineworkers, and wages and benefits paid by contractors and utility employers.

In addition to expanding regulatory authority to encompass economic development metrics, state legislatures can take specific actions to ensure that the workforce for T&D work is well trained and highly local. Many states have passed laws requiring prevailing wage, apprenticeship utilization, worker licensing and certification, or the use of project labor agreements for electric generation projects.¹⁴⁶ For example:

- Illinois’ recently enacted Clean and Equitable Jobs Act has a multitude of provisions to require or incentivize local hiring, particularly for workers from disadvantaged communities. The Act also expands prevailing wage laws and the use of project labor agreements for most clean energy projects built in the state.¹⁴⁷
- The Colorado PUC Reauthorization Act establishes the criteria by which the PUC evaluates utility proposals for new energy construction based on objective project employment metrics: the “availability of training programs, including training through [registered] apprenticeship programs; employment of Colorado labor as compared to importation of out-of-state workers; long-term career opportunities; and industry standard wages, health care and pension benefits.”¹⁴⁸

¹⁴³ See Zitelman and McAdams (2021).

¹⁴⁴ MS Code § 77-3-2.

¹⁴⁵ Wyo. Stat. § 37-2-122.

¹⁴⁶ See, e.g., BlueGreen Alliance (2020).

¹⁴⁷ Illinois SB 2408, enacted Sept. 15, 2021.

¹⁴⁸ Colorado SB 19-236, enacted May 30, 2019.

- Washington State’s Clean Energy Transformation Act establishes a 100% sales tax exemption for renewable energy projects using a community workforce or project labor agreement.¹⁴⁹
- California’s AB 841 created an Electric Vehicle Infrastructure Training Program certification and requires that certain charging infrastructure projects be installed by electricians certified under the program.¹⁵⁰

Such requirements can be extended to include ongoing operations and maintenance for T&D work. These provisions are powerful ways to offset the utility’s natural incentive between rate cases toward “low-road” jobs (whether contracted or in-house) with low wages, lower benefits, and less robust training standards. Even more powerful, some innovative provisions specifically incentivize the creation of local jobs and career pathways for local communities, including communities historically excluded from jobs in the electricity sector.¹⁵¹ Illinois’ Clean and Equitable Jobs Act, for instance, broadens the use of project labor agreements to include not just wages and benefits but also specific goals related to the hiring of apprentices from historically disadvantaged communities, and requires all clean energy projects to demonstrate recruitment and hiring of women, workers of color, and workers from environmental justice communities.¹⁵²

[S]ome innovative provisions specifically incentivize the creation of local jobs and career pathways for local communities, including communities historically excluded from jobs in the electricity sector.

Mergers and acquisitions are another area of concern. While utility customers can benefit from cost efficiencies from combined utilities’ workforces, excessive labor cost-cutting may impair the capability to build and maintain electricity infrastructure. Stakeholders can recommend other utility demonstrations of public interest aligned with modern electricity systems and state goals—for example, investment commitments for community solar, storage, and microgrids that improve reliability and resilience.

Local communities can support these actions by engaging in PUC proceedings, supporting legislative solutions, and supporting fair labor activities. In all of these venues, they can shine a light on ways to design new electricity infrastructure with value to the community in mind.

2.6 Conclusion

Investor-owned utilities are under unrelenting pressure to keep expenses as low as possible to keep rates low, and while this is a critical protection for consumers, there is a real risk that adherence to this principle can become overly rigid, to the point where customer service, system reliability, and local community support becomes compromised. And although many utilities are incentivized to propose and fight for investments in assets that generate a return, other necessary investments in distribution system upgrades and labor have tended to fall by the wayside in the face of regulatory and shareholder pressure on utility expenses. The long-term results of these trends are that utility workforces have declined precipitously, as utilities have become increasingly reliant on contracted labor that is often poorly paid and poorly trained.¹⁵³ Not only have these declines put grid resiliency at risk, as aging infrastructure

¹⁴⁹ WA SB 5116, enacted May 7, 2019.

¹⁵⁰ CA AB 841, enacted Sept. 30, 2020.

¹⁵¹ See, e.g., New York Senate Bill S2506C (Signed by Governor April 16, 2021), <https://www.nysenate.gov/legislation/bills/2021/s2506/amendment/c> (requiring project labor agreements covering operations and maintenance workers for renewable energy systems).

¹⁵² Illinois SB 2408, enacted Sept. 15, 2021.

¹⁵³ See, e.g., Polson (2013) (citing BLS wage data that contracted lineworkers are paid an average of 11% less than their counterparts at utilities).

demands have overwhelmed smaller, contracted utility workforces, they also have severed important ties between the utility and local communities that are critical for public support of much-needed investments in grid modernization and resiliency.

State regulators and legislatures must take action to ensure that utility workforces are staffed, trained, and paid sufficiently to prepare the grid for increasingly severe weather, as well as to create long-term, stable sources of community support for clean energy projects made vulnerable to local opposition by declines in transparency, fairness, and public trust.

The risk of not undertaking these policy and regulatory solutions is grave. We risk perpetuating the cycle of deferred investments in aging, vulnerable grid infrastructure, delaying investments in critical innovative technologies and systems to modernize grids and support clean energy solutions, and failing to rise to the challenge of storm response in the face of more severe and frequent weather events. Just as important, we risk alienating the very communities we will depend on for critical public support for deployment of clean energy infrastructure. Continuing to ask rural, economically distressed communities to host the vast majority of clean energy generation and transmission to deliver the energy to load centers is beginning to take its toll.

State regulators and legislatures must take action to ensure that utility workforces are staffed, trained, and paid sufficiently to prepare the grid for increasingly severe weather, as well as to create long-term, stable sources of community support for clean energy projects made vulnerable to local opposition by declines in transparency, fairness, and public trust.

Without stronger ties between local communities and workforces in the electric utility and clean energy sectors, the loudest community voices will continue to be those standing in firm opposition to clean energy deployment. By taking action to ensure that utilities provide high-quality jobs for local residents — from resident lineworkers to distributed energy resources (at or near customer sites) — we will establish the foundation we need to set in motion the mobilization of resources that deep decarbonization requires.

ⁱ See FEMA (2013).

ⁱⁱ New York State (2013) at 55.

ⁱⁱⁱ Consolidated Edison Co. of New York. (2013) at 64.

^{iv} Edison Electric Institute's (EEI) mutual assistance program is a voluntary partnership of U.S. investor-owned utilities committed to helping restore power whenever and wherever assistance is needed. The program provides a formal process for electric companies to request support from other electric companies in parts of the country that have not been affected by major outage events. Seven Regional Mutual Assistance Groups throughout the country facilitate the process of identifying available restoration workers and help companies coordinate the logistics and personnel involved in restoration efforts. According to EEI, "Company restoration workers involved in mutual assistance typically travel many miles to help the requesting company rebuild power lines, replace poles, and restore power to customers." Municipal utilities and electric cooperatives have their own mutual aid programs that provide restoration support for participating utilities. See EEI (2016).

^v Polson (2013).

^{vi} New York State (2013) at 55 (quoting Utility Workers Union of America, AFL-CIO. 2013. The Impact of Hurricane Sandy on Consolidated Edison of New York: Assessment of Restoration Efforts and Recommendations for the Future, at 1, Feb.

^{vii} New York State (2021).

^{viii} Public Utilities Regulatory Authority (CT), Docket No. 20-08-03, Investigation into Electric Distribution Companies' Preparation for and Response to Tropical Storm Isaias, April 20, 2021, at 41.

^{ix} Public Utilities Regulatory Authority (CT), Docket No. 20-08-03RE01, PURA Consideration of Civil Penalty and Enforcement Action Against the Electric Distribution Companies After Storm Isaias Investigation, July 14, 2021, at 20 (hereinafter July 14 PURA Order").

^x Public Service Commission (MI), In the Matter, on the Commission's Own Motion, to Review the Response of Alpena Power Company, Consumers Energy Company, DTE Electric Company, Indiana Michigan Power Company, Northern States Power Company, Upper Michigan Energy Resources Corporation, and Upper Peninsula Power Company to Recent Storm Damage in their Territories, Case No. U-21122, Order and Notice of Opportunity to Comment, Aug. 25, 2021, at 4.

^{xi} Perkins (2021).

^{xii} UWUA Report at 4-7.

^{xiii} Macmillan and Englund (2021).

^{xiv} Macmillan and Englund (2021).

3.0 U.S. Electric Companies Are Innovating to Provide the Solutions and Options that Customers Want

by Adam Cooper, Lisa Wood, and Mike Shuster, Institute for Electric Innovation

3.1 Introduction

New technologies, data analytics, partnerships, and regulatory flexibility are enabling U.S. electric companies to provide the innovative energy services and solutions that today's customers want. This essay provides examples of how U.S. investor-owned electric companies are innovating to meet the evolving needs and expectations of their customers, focusing on:

- Innovations in providing services and solutions to residential customers
- Innovations in providing carbon-free energy solutions to corporate customers

The essay also explores regulatory approaches that are needed to support new services and solutions for customers in the future.

3.2 Innovation in Providing Services and Solutions to Residential Customers

Many U.S. electric companies are partnering with technology companies such as Powerley, E Source, and Oracle to provide innovative customer services and solutions in energy management for residential customers—including both energy efficiency (EE) and demand response (DR). Some electric companies also are transitioning customers onto rates that make sense for them and for the power system—from pre-pay to flat fee to time of use (TOU) and more. Innovations are driven by technology and data analytics that are enabled by smart energy grids that include advanced metering infrastructure. However, electric company participation and the speed at which they can adopt these technologies is highly dependent on approvals by state regulators.

Innovations are driven by technology and data analytics that are enabled by smart energy grids that include advanced metering infrastructure. However, electric company participation and the speed at which they can adopt these technologies is highly dependent on approvals by state regulators.

This section provides examples of how electric companies are using technology and data analytics to:

- Advance energy management and clean energy goals
- Effectively transition customers onto time-varying rates
- Provide rate, billing, and payment options tailored to meet customer needs

3.2.1 Using Technology and Data Analytics to Advance Energy Management and Clean Energy Goals

Electric companies are partnering with technology companies to help customers manage both their energy use and carbon footprints. The following are examples of successful partnerships already underway.

3.2.1.1 Advances in Pre-enrolled Smart Thermostat Programs: APS Cool Rewards

The Arizona Public Service (APS) Cool Rewards program shifts and reduces customer energy use during peak periods by adjusting customers' smart thermostats (Figure 7). The innovative design of the demand response program protects customer comfort and maximizes the use of solar energy. Thermostat manufacturers respond to event calls by adjusting participating customers' thermostat settings, while customers remain in control of their home's temperature and comfort because they can override demand response calls. Participating customers receive a one-time \$50 bill credit per thermostat upon enrollment and a \$25 participation bill credit annually. APS can dispatch an event across more than 40,000 customers¹⁵⁴ (via their smart thermostats) and reliably provide about 70 megawatts (MW) of load, avoiding the dispatch of less efficient and higher emitting fossil fuel generators. The Cool Rewards program will help APS meet its goal to deliver 100% clean, carbon-free energy to customers by 2050.

Figure 7. Types of Smart Thermostats in the APS Cool Rewards Program



Key elements that enabled the program's success include the following:

- Pre-enrolling customers in Cool Rewards at point of sale through the APS online marketplace provided a one-stop shopping experience for customers and a flexible, reliable demand resource for APS distribution system planners and operators. Generally, adding a pre-enrollment function to a smart thermostat program can increase enrollment rates by 200%–300%.¹⁵⁵
- APS' partnerships with EnergyHub and Enervee (and in turn, their partnerships with thermostat manufacturers such as Google Nest) that offered low- and no-cost smart thermostats were critical to pre-enrolling customers in the Cool Rewards program and to increasing customer satisfaction.

¹⁵⁴ As of September 2021.

¹⁵⁵ Uplight (2021).

- Omni-channel marketing and seasonal promotional offers (e.g., \$1 or free smart thermostat during Earth Month, April 2021) significantly increased enrollment and created a valuable touchpoint for APS to communicate directly with its customers about the company’s ambitious carbon reduction goals.
- The Cool Rewards program design also increases participation in APS’ TOU rates, enabling APS to precool these customers’ homes during off-peak hours.

Pre-enrollment in electric company programs provides value to both the customer and the electric company by improving the customer’s experience and providing a smart device that already is set up for use in an approved demand response program. Looking forward, the U.S. market potential for smart thermostat programs has plenty of upside—less than 20% of U.S. households own smart thermostats today, whereas 75% have smart meters that would support programs like Cool Rewards.^{156, 157}

3.2.1.2 Empowering Customers with Awareness and Control Over Their Energy Use and Carbon Footprints: DTE Insight App

The DTE Insight App, powered by smart meter data, is a self-serve tool for customers (Figure 8). Through this app, customers can see how much energy they are using on a daily, weekly, or monthly basis. Customers who set an energy budget can compare their usage to their individual energy budget. Today, more than 300,000 DTE Energy households—about 14% of residential customers—use the Insight App as a home energy awareness and management tool, interacting with it more than one million times per year. On average, the Insight App generates 5% energy savings when a customer engages 25 times or more per calendar year. And some of these customers are reducing their carbon footprint by more than 10%.¹⁵⁸

Figure 8. Example of Energy Use Visualization Using the DTE Insight App



Furthermore, this app platform, developed in partnership with Powerley, is expanding to also support customer participation in DTE Energy’s TOU pilot, increase enrollment in the utility’s voluntary

¹⁵⁶ Parks Associates (2020).

¹⁵⁷ Institute for Electric Innovation (IEI) (2021a).

¹⁵⁸ Powerley (2021).

renewable energy program (MIGreenPower),¹⁵⁹ and provide information to customer service representatives so they can more effectively resolve customer issues in real time.¹⁶⁰

DTE Energy further enhances the customer experience and energy use insights for different end uses by combining the DTE Insight App with Powerley's Energy Bridge, a hardware connection that enables a real-time data stream. The Energy Bridge unlocks a three-second interval smart meter data stream that the electric company uses to provide insights directly to customers in real time while complying with cybersecurity requirements. DTE Energy charges customers \$1.99/month for use of the Energy Bridge, and the retention rate for the DTE Insight App plus Energy Bridge solution is 98% after 90 days.

The DTE Insight App proved itself to be a critical tool to meet rapidly changing customer needs during the pandemic. The average number of app downloads increased 51% from March 2020 to April 2020, when many people began working from home.

3.2.2 Using Technology and Data Analytics to Effectively Transition Customers onto Time-varying Rates

As time-varying rates become more commonplace in some parts of the United States, many electric companies are partnering with technology companies to transition customers onto these new rates.¹⁶¹ Following are examples of successful partnerships currently underway.

3.2.2.1 Leveraging Digital Communications and Online Tools to Support Customers Transitioning to New Rates: PG&E's Opt-Out TOU Rate Plan

In 2015, the California Public Utilities Commission (CPUC) issued an order to explore default TOU rates. Over a 19-month span from 2020 to 2022, Pacific Gas & Electric (PG&E) has been transitioning about 2.5 million residential customers, on a rolling monthly geographic basis, onto TOU rates as the standard (opt-out) offering, with bill protection for the first 12 months. For the initial group of customers receiving email transition notifications, which are sent 90 days and again at 30 days prior to the transition, only about 9% of customers opted out. As the transition to TOU rates has progressed, about 20% of customers, on average, are opting out. PG&E has been using a variety of tactics, including web-based tools, to educate customers about the new rates, engage with customers using channels they prefer, and coach customers on how to take actions to manage their energy usage. The addition of the 12-month bill protection provides customers with a unique motivation to engage with PG&E's tools and try the new rate plan without shouldering much risk.

By partnering with Oracle Utilities and using the Opower product suite, PG&E is helping their customers understand and control their energy use by offering high usage alerts, weekly energy updates, and on-demand energy bill insights embedded into web, mobile, and customer service agent desktop tools. In addition, PG&E customers can use a rate comparison tool to understand their potential bill under a TOU rate given their current energy usage behavior, including exploring future energy usage scenarios that include behavioral changes and major energy purchases, such as electric vehicles.

PG&E's outreach to customers with the Opower product suite has extremely high email open rates of 40%–60%, and more than 2.4 million visitors return to PG&E's web tools. Overall, the email open rates

¹⁵⁹ DTE Energy (2022).

¹⁶⁰ Powerley originated in 2015 as a joint venture between DTE Energy and Vectorform.

¹⁶¹ According to 2020 EIA Form-861, 397 U.S. electric companies operating in 48 states offer at least one form of time-varying rates to residential customers, predominantly TOU. Altogether, in 2020, nearly 10 million residential customers were enrolled in a time-varying rate. See October 7, 2021. Form EIA-861 DynamicPricing 2020.

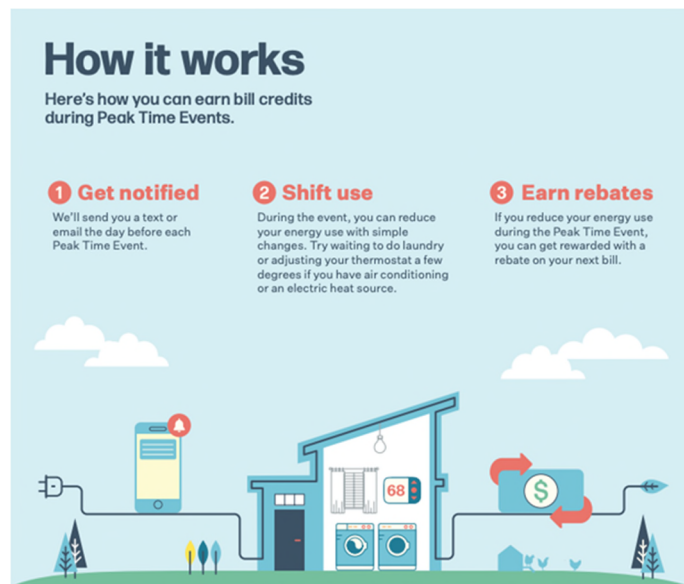
and the number of visitors returning to PG&E’s web tools indicate that the level of customer engagement is very high. PG&E learned that customers respond best to communication that initially focuses on price and bill impacts and follows up on climate and carbon impacts.

PG&E’s outreach with customers demonstrates that providing customers with easy-to-access, personalized, and nuanced communications can help customers understand how their energy use impacts their bills, the community, and the electricity grid as a whole, as well as next best actions that customers can take to manage their energy use. With a goal of transitioning 2.5 million residential customers onto TOU rates by the end of 2022, customer engagement is critical.

3.2.2.2 Using Data Science to Rethink Customer Engagement: PGE Peak Time Rebate Program

Portland General Electric’s (PGE’s) Peak Time Rebate (PTR)¹⁶² gives eligible residential customers the choice to earn rebates on their electricity bills for shifting energy use during times of high demand (Figure 9). There is no cost to join, and customers choose when and how often they participate. The program has quickly scaled up in terms of customer participation and has become a dependable energy resource that avoids the dispatch of less efficient and higher emitting resources.

Figure 9. How Customers Earn Bill Credits During Peak Time Events



The program stems from the Oregon PUC’s order on PGE’s 2016 integrated resource plan,¹⁶³ which in part required the company to establish a test bed that would enable PGE to accelerate the development of new flexible load capability and test new strategies for engaging customers in demand response. Since launching the PTR program at scale in 2019, PGE has enrolled more than 120,000 customers—about 15% of the electric company’s residential customers.

To target the best-fit customers for the PTR program, PGE partnered with E Source to build a virtual profile of every residential customer. This allowed PGE to zero in on individual value propositions for

¹⁶² PGE. n.d. Peak Time Rebates. <https://portlandgeneral.com/save-money/save-money-home/peak-time-rebates>.

¹⁶³ Oregon PUC (2017).

customers and recruit the right customers for the program. Since PGE started targeting customers likely to shift load, participants in the PTR program increased load shifting 50% during a demand response event—from 0.08 kilowatts (kW) to 0.12 kW per event, on average. In addition, predictability of demand response narrowed from +/- 50 to +/- 10.

To keep customers engaged, within 24 hours of a demand response event, PGE digitally communicates with customers to deliver precise feedback on their participation, the kilowatt-watt hours (kWh) saved during the peak period, and the rebate amount for each event. On average, customers engaged in the PTR program are more satisfied than non-participants.

PGE’s PTR program showcases the power of putting data to work to deliver a reliable demand response resource and keep customers satisfied.

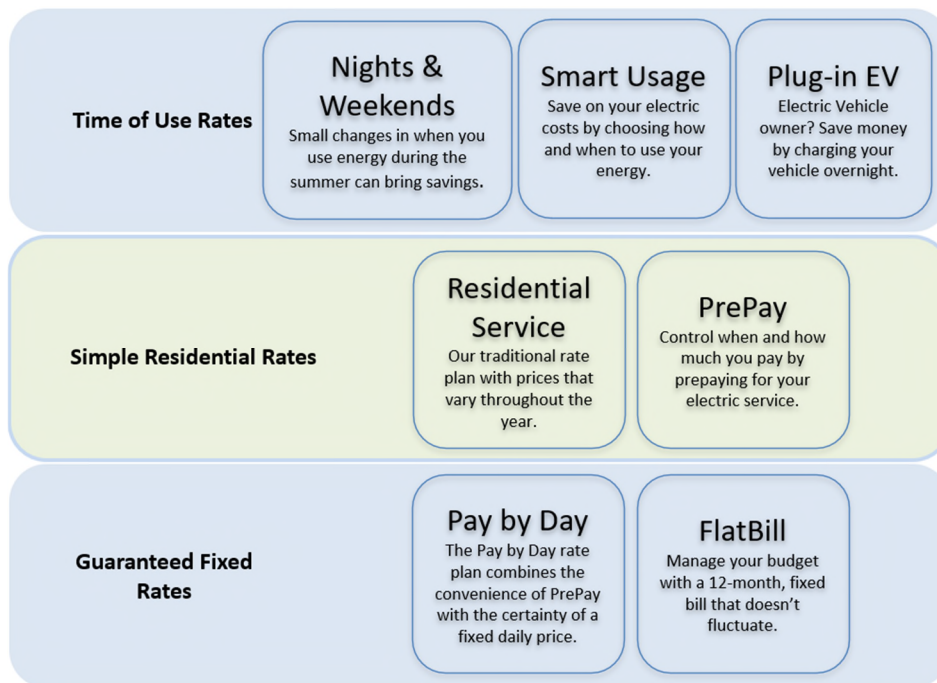
3.2.3 Using Technology and Data Analytics to Expand Rate, Billing, and Payment Options to Meet Customer Needs

Electric companies across the country are partnering with technology companies to expand rate, billing, and payment options to enhance the customer experience. For example, Georgia Power’s robust set of flexible rate and billing options are informed by smart meter data and designed to meet the varied needs of all its customers.

3.2.3.1 Applying Smart Meter Data to Enhance the Customer Billing and Payment Experience: Georgia Power’s Flexible Rate Options

Georgia Power offers multiple TOU rates, demand-based rates, and guaranteed fixed bills to provide residential customers more choice, certainty, and control over their energy bills (Figure 10).

Figure 10. Georgia Power Rate Options



Today, 50% of Georgia Power customers are opting for these “non-standard” rates versus five years ago, when 90% of customers were on the standard rate. In 2020, Georgia Power launched Pay-by-Day, a billing and payment plan that is providing more than 80,000 customers, about 3.5% of customers, with an option to manage their energy use and payments. Pay-by-Day combines the convenience of PrePay with a fixed daily price for electricity based on a customer’s projected consumption over an entire year. In addition, the Pay-by-Day plan helps customers pay down their outstanding balances in small increments over time by including a deferred payment amount in the fixed daily price.

Customer service representatives actively work with customers to help them determine the rate that works best for them.

Importantly, Georgia Power is using the smart meter infrastructure they installed more than a decade ago to inform rate and billing options. The Sensus’ Flex Net point-to-multipoint smart meter network is interoperable with both legacy and modern technology. With enhanced visibility due to smart meter data, Georgia Power’s modeling and load forecasting are accurate to the point where they can offer a Flat Bill option to a customer even before the customer starts service at a new residence. The flat bill has no true-up—it is a fixed monthly bill that doesn’t fluctuate over a 12-month period—attractive to customers who value bill certainty each month. At the end of a year, a new flat bill is calibrated based on a customer’s actual usage for the prior year.

Providing residential customers with pricing choices that better align with their needs and expectations drives measurable and dramatic increases in customer satisfaction. Less than five years ago, 95% of residential customers were on the electric company’s traditional service rate. Today, when given a choice, 50% of residential customers are opting for non-standard rates. This rapid transition demonstrates that many customers want choice and flexibility when it comes to how they pay for electricity.

3.2.4 Innovative Services and Solutions for Residential Customers Require Flexibility in Both Program Design and Regulatory Treatment

3.2.4.1 Recognizing that One-Size-Fits-All Solutions Are Not Nearly as Effective as Tailored Solutions

Residential customers expect seamless engagement with electric companies and solutions tailored to meet their needs. Whether initiated by the electric companies or regulators, the regulated electric power industry will benefit by following the lead of other industries that already are providing flexible, personalized services and solutions to customers.

Deploying one-size-fits-all solutions or services to all residential customers is no longer a recipe for success. It is far more effective to use data analytics and other approaches to focus on providing solutions and services tailored to meet customer needs. This may mean:

- *Providing an energy management app that allows customers to manage both their energy use and carbon footprints by allowing them to enroll in a green tariff, as DTE Energy is doing today.*
 - Potential regulatory issue to explore: Rather than capping the green tariff program enrollment, can the size of the program grow with the number of interested customers without obtaining additional commission approval?
- *Targeting only the customers most likely to shift their energy use (and be counted on as a reliable resource) to join a demand response program, as PGE is doing today.*

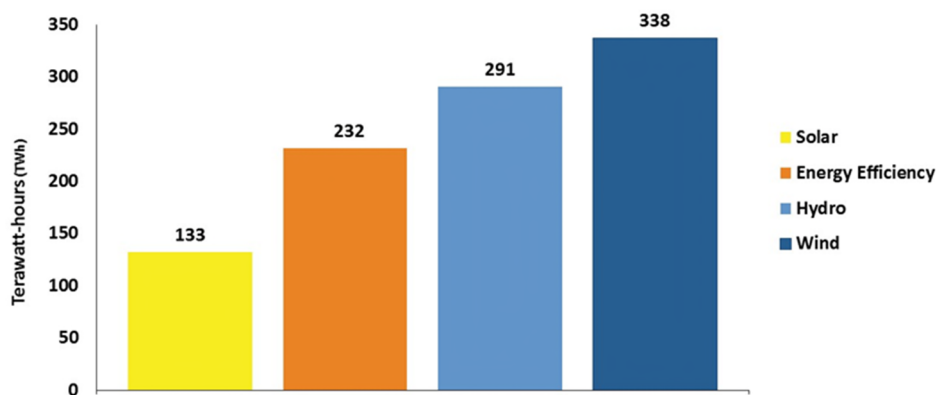
- Potential regulatory issue to explore: Can customers that do not fit the profile or those that do not shift load as projected be excluded or automatically dropped from the program?
- *Offering a wide range of rate options and working with customers to find the rate that fits best, as Georgia Power is doing today.*
 - Potential regulatory issue to explore: When will offering a range of rate options (e.g., pre-pay, pay-by-day, flat bill, smart usage) to residential customers become the new normal and whose responsibility is it (the company or the customer) to ensure that they are on the most advantageous rate?

Electric companies are transforming their operations and enhancing their analytic capabilities to meet customer needs and expectations. In some states, regulators are encouraging electric companies to do this. As more and more customers expect “tailored” services and solutions, will electric companies have the regulatory flexibility and necessary technology to meet this demand or will others provide these services?

3.2.4.2 Removing the Silos Around Energy Efficiency and Demand Response and Putting Demand-side Resources on a Level Playing Field with Supply-side Resources

Traditionally EE and DR programs are developed, deployed, and measured separately from supply-side resources. Yet with technology today, EE and DR can scale rapidly to control not only how much energy is consumed, but when it is consumed, making them flexible capacity resources. Based on EIA data, in 2020 electric company-sponsored EE and DR customer programs saved 232 terawatt-hours—enough electricity to power 26 million U.S. homes for one year—and reduced carbon emissions by 164 million metric tons.¹⁶⁴ In 2020, electric company-sponsored EE programs saved 75% more electricity than the amount generated by U.S. solar energy facilities, and about two-thirds of what wind energy produced (Figure 11).

Figure 11. Comparison of U.S. Electric Company Energy Efficiency Program Savings and Renewable Energy Generation (2020)



Source: IEI (2021b).

¹⁶⁴ IEI (2021b).

To meet carbon emissions reduction goals, it is essential to create a level playing field for all carbon-free resources—both demand-side resources like EE and DR as well as supply-side resources.

While 34 states provide some form of adjustment to compensate electric companies for lost revenue from lower energy sales due to EE, and 29 states provide a performance incentive for EE and DR programs, the regulatory regimes in the remaining states are not fully supportive of significant investments in customer-focused EE and DR programs.¹⁶⁵ Significant disincentives remain. Energy efficiency remains a cost-effective resource that reduces energy use and carbon emissions. However, as has been demonstrated for decades, state regulatory policies that create parity for investing in demand-side or supply-side resources are essential to continue to drive growth in EE and DR.

3.2.4.3 Recognizing that Both Energy Efficiency and Demand Response Are Carbon Emissions Reduction Resources

The policies that have supported EE programs for decades, which measure program performance and success only in terms of kWh reductions, do not support the vital role these programs can play in achieving a carbon-free energy future. Additional metrics are needed to value and evaluate the performance of energy efficiency programs in terms of carbon emissions reductions, energy savings, and capacity savings achieved.¹⁶⁶ One recent step in this direction is the decision by the California Public Utilities Commission (CPUC) to adopt a new metric to measure EE—the Total System Benefit (TSB). The TSB uses a common metric—dollars—and reflects the lifecycle energy, capacity, and greenhouse gas (GHG) reductions achieved through hourly energy savings. This is important because the total value of EE varies significantly based on the hour of the day, season of the year, geographic location, and the specific EE measure. The CPUC’s TSB metric takes these factors into account. Other states that consider GHG emissions in avoided costs for EE are Arizona, Colorado, Connecticut, Delaware, Illinois, Maryland, Minnesota, Nevada, New Hampshire, New York, Rhode Island, Vermont, and Wisconsin, as well as the District of Columbia.¹⁶⁷

Furthermore, the National Standard Practice Manual update for Benefit-Cost Analysis of DERs addresses these factors.¹⁶⁸ State regulators approve the design of electric company EE programs, so they play a pivotal role in the development of next generation EE cost-effectiveness tests and metrics that value all the benefits of EE—carbon emissions reductions, capacity savings, and energy savings.

3.3 Innovations in Providing Carbon-free Energy Solutions to Corporate Customers

Corporate customers increasingly are focused on reducing their carbon footprints, and each year more of these customers track and publicly report their delivered electricity-related carbon emissions.¹⁶⁹ Under the Biden Administration’s Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability, federal agencies also are seeking 100% carbon pollution-free electricity on a net annual basis by 2030, including 50% 24/7 carbon pollution-free electricity.¹⁷⁰

¹⁶⁵ IEI (2021c).

¹⁶⁶ California Public Utilities Commission (CPUC) (2021).

¹⁶⁷ National Energy Screening Project (NESP). n.d. Database of Screening Practices. Accessed January 2022. <https://www.nationalenergyscreeningproject.org/state-database-dsp/>.

¹⁶⁸ NESP (2021).

¹⁶⁹ For example, they are reported as part of the customer’s Scope 2 emissions. Scope 2 emissions are a result of the organization’s energy use and are defined as indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling.

¹⁷⁰ The White House (2021a).

Typically, carbon emissions reporting has been based on an annual accounting of electricity used and the associated carbon intensity in the grid area in which the corporation or government agency operates. Some leading corporate and federal customers now are seeking 100% carbon-free energy across their operations—matching carbon-free energy with the timing of their energy use. With growing interest expressed by major customers and electric companies in this area, efforts are underway to identify the next generation of carbon-free energy solutions.¹⁷¹

Typically, carbon emissions reporting has been based on an annual accounting of electricity used and the associated carbon intensity in the grid area in which the corporation or government agency operates. Some leading corporate and federal customers now are seeking 100% carbon-free energy across their operations—matching carbon-free energy with the timing of their energy use.

To provide the carbon-free energy solutions that corporate and federal customers want, electric companies are offering subscription tariffs, and, in some cases, customized deals. This section provides examples of both, as well as regulatory limitations and innovative regulatory approaches for providing these solutions.

3.3.1 Examples of Carbon-Free Energy Solutions for Corporate Customers Provided by Electric Companies

Electric companies are providing various solutions to help corporate customers meet their carbon emissions reduction goals. Over the last decade, the carbon-free energy solutions that electric companies have developed for corporate customers have evolved. Likewise, the energy procurement practices of leading corporate energy buyers have progressed from purchasing carbon offsets, to purchasing unbundled Renewable Energy Certificates, to subscribing to electric company green tariff programs or third-party bundled power purchase agreements. Several examples of successful electric company programs and solutions for corporate customers follow.

3.3.1.1 FPL’s SolarTogether Program

In March 2020, the Florida Public Service Commission approved Florida Power & Light Company’s (FPL) SolarTogether program,¹⁷² a 1,490 MW community solar resource comprised of 20 solar facilities for both residential and commercial customers (Figure 12). SolarTogether offers contracting flexibility, bill savings over time, and convenience to customers who want to participate in a solar subscription with no upfront costs. Customers participating in SolarTogether are not tied to a long-term contract and can cancel or reduce their subscription at any time with no penalty, after the first billing cycle.

The subscription stays with the FPL account holder (not the address or location), and customers can transfer their subscription within FPL’s service territory. This is especially important to small/medium business customers who may move locations.

¹⁷¹ Byrd, O’Shaughnessy, and Hutchinson (2021).

¹⁷² FPL. 2022. Solar Together. <https://www.fpl.com/energy-my-way/solar/solartogether-res.html>.

Figure 12. Solar Power Plant Under Construction



The SolarTogether program reserved 75% of the solar capacity for commercial and industrial (C&I) customers and was fully subscribed at program launch due to a successful pre-registration campaign. The remaining 25% of program capacity allocated for residential customers also has been fully subscribed. This program is an effective way to offer low-cost solar energy to customers with no cost shift to other customers. FPL pays the upfront cost of building the facilities, and customers do not need to deal with developing, installing, operating, and maintaining solar at their own facilities.

The flexible SolarTogether program was designed based on customer input, and the fact that it is fully subscribed points to its success with customers. With customer demand outstripping the size of the program, FPL filed a Joint Motion for Approval of a Settlement Agreement with the Commission in August 2021 that includes expanding the program through construction of an additional 1,788 MW of community solar through 2025. As approved, the total capacity of SolarTogether will be 3,278 MW, with 40% of the incremental capacity allocated to residential and small business customers and 60% allocated to commercial, industrial, and governmental customers.¹⁷³

3.3.1.2 Georgia Power's Customer Renewable Supply Procurement Program

As the result of a stipulated integrated resource plan agreement in July 2019, Georgia Power launched the first of two application periods for its Customer Renewable Supply Procurement program in April 2020; the second application period began in Q3 of 2021.¹⁷⁴ Of the 1,000 MW of new utility-scale renewable energy available by subscription for C&I customers, a total of 600 MW (300 MW in the first application period and 300 MW in the second application period) were available for existing customers with an aggregated peak demand of at least 3 MW. The remaining 400 MW were available on a first-come, first-served basis for existing or new customers with incremental new load additions in Georgia Power's service territory greater than 15 MW.

Participating customers purchase a monthly subscription at a fixed portfolio price. Subscription levels are limited to 100% of the existing customer's total energy consumption in the preceding year. Subscription levels for new customer loads are limited to 100% of their projected annual energy consumption. Participants receive hourly credits on their bill for the energy replaced by the portfolio of renewable energy facilities procured to supply the program, based on their actual production.

¹⁷³ See Florida Public Service Commission (2021).

¹⁸ Georgia Power. 2022. Customer Renewable Supply Procurement (CRSP). <https://www.georgiapower.com/company/energy-industry/energy-sources/solar-energy/solar/customer-renewable-supply-procurement.html>.

3.3.1.3 AES-Google 24/7 Carbon Free Energy Solution¹⁷⁵

In September 2020, Google announced a first-of-its-kind goal to decarbonize its electricity supply and operate on 24/7 carbon-free energy by 2030. In May 2021, Google and AES announced a partnership wherein AES is the energy manager responsible to serve Google’s Virginia data centers with carbon-free energy 90% of the time, measured on an hourly basis. As the energy manager, AES is responsible for resource procurement, dispatch, and hedging. AES bears the risk of under- or over-generation and transacting in the PJM market on an hourly basis as needed, while Google pays for its load at a stable dollar per megawatt-hour price.

Reducing the complexity to a single supply deal that encompasses multiple resources is a major development for commercial clean energy procurement. This model lays out a blueprint for other electric companies and corporate customers to follow to advance carbon-free energy solutions.

3.3.1.4 NV Energy’s Solar/Storage Solution for Google

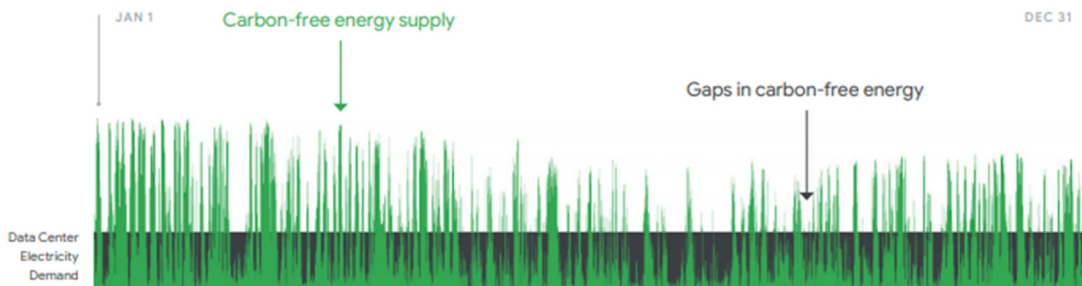
Google is one of the many notable corporations exploring ways to bridge the gap between electricity consumption and real-time electricity production from carbon-free sources (Figure 13). In December 2020, the Public Utilities Commission of Nevada approved an energy supply agreement between NV Energy and Google to power a Google data center by the end of 2023. As part of the arrangement, Google will receive 350 MW of solar capacity and 280 MW of battery storage under an energy supply agreement that is modeled after NV Energy’s Large Customer Market Price Energy tariff.

The agreement includes a novel capacity-sharing mechanism for the energy storage resource. The batteries will dispatch stored renewable energy on behalf of all NV Energy customers during peak summer evening hours (June–August from 4–9 p.m.) During other times of the year, the storage resource will be dispatched to serve the specific energy needs of the Google data center. NV Energy will provide Google a fixed-price agreement for bundled electric service and bill credits for providing a carbon-free summer peaking capacity resource.

Figure 13. Heat Map Showing Gaps in Google’s Carbon-Free Energy Supply.¹⁷⁶

Hourly carbon-free energy performance at an example data center

While Google buys large amounts of wind and solar power (symbolized by green spikes below), these resources are variable, meaning that our data centers still sometimes rely on carbon-based resources.



¹⁷⁵ AES Corporation (2021).

¹⁷⁶ Google (2020).

The agreement with Google provides multiple benefits to the company, NV Energy, and the broader customer base.

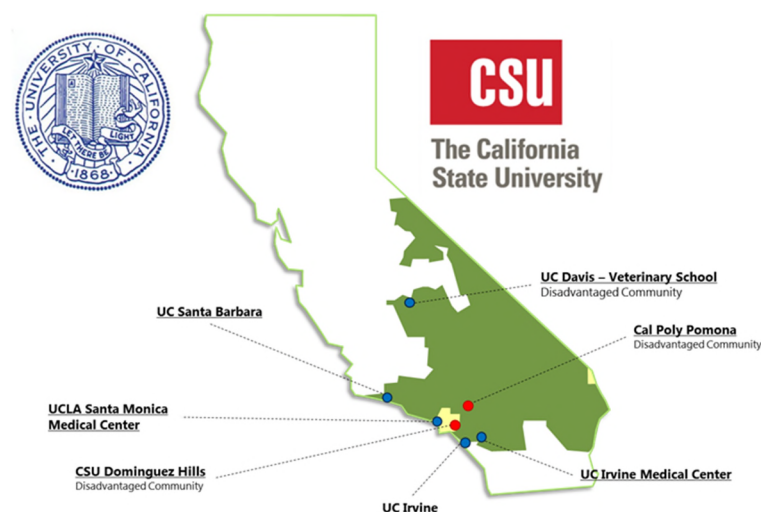
Like many states, Nevada has established carbon-reduction goals, including passage of Senate Bill 254 in 2019 that sets the state on the path towards achieving net-zero GHG emissions by 2050. NV Energy’s agreement with Google provides a greater degree of stability in the planning and development of integrated resource plans that underpin NV Energy’s ability to meet renewable energy and carbon-reduction goals.

3.3.1.5 Southern California Edison’s Clean Energy Optimization Pilot

As part of their efforts to help customers make clean energy choices, Southern California Edison (SCE) partnered with the University of California and Cal State University (Figure 14) on a \$20 million Clean Energy Optimization Pilot, funded through state cap-and-trade revenue rather than electric company energy efficiency budgets. The pilot provides these university customers with a portfolio of options—including energy efficiency, demand responses, on-site renewables, clean transportation, and energy storage—and will evaluate the effectiveness of performance-based GHG incentives to reduce emissions.

The first step in calculating the GHG incentive is to establish a “fence line” of metered energy data that feeds into a baseline GHG trajectory relative to actual metered energy use reductions. The baseline is weather-normalized and dynamic, allowing adjustments for prior performance, naturally occurring reductions (or additions), and evolving grid emission factors. For each campus, SCE uses a performance payment tool to calculate the GHG baseline, GHG reductions, and the incentive payment using data and tools from the CPUC-approved integrated resource plan, including a price per metric ton of CO₂ reduction and hourly electric grid emission factors to account for differences in time- and location-specific GHG emissions reductions across the seven pilot participants. To date, participants have received \$4.6 million in performance payments.¹⁷⁷

Figure 14. Clean Energy Optimization Pilot Participants



¹⁷⁷ See Southern California Edison (2020) for additional details.

Universities make great partners for pilots because they have a wide range of residential, commercial, and industrial buildings that are representative of other customer types, and they are interested in engaging in the study design. The goal of the program is to incent incremental and persistent GHG emissions reductions and allow the universities to choose and implement technology solutions that best suit their needs. The pilot results will inform future opportunities to scale programs utilizing customer preferences for solutions as a component.

3.3.2 Innovative Regulatory Approaches for Clean Energy Procurement Needs of the Future

As demonstrated by the preceding examples, electric companies are actively engaging with customers and regulators to develop new tariffs and subscription services and to pilot solutions to meet the demand for 100% carbon-free energy by corporate customers. More recently, federal agencies, including the U.S. Department of Defense, are following the lead of corporate customers in seeking carbon-free energy solutions.¹⁷⁸

For example, many corporate customers find value in the established electric company green tariff programs available in 21 states.¹⁷⁹ Recent trends are for much more flexibility in green tariff programs including a shift towards shorter-contract length, extremely flexible contract terms, and expanded program eligibility (e.g., FPL's SolarTogether program). Customer trends include the following:

- Many customers, especially those not tied to industrial or data center applications, prefer shorter contract lengths to align with real estate leases.
- Some customers seek fixed-price offerings, while others prefer tariff structures that reflect variable market-based rates.
- Many customers are interested in partnering with electric companies on carbon-free energy projects in lieu of entering into power purchase agreements with third parties.

For the most part, until very recently, energy buyers accounted for their annual carbon emissions by comparing energy used to carbon-free energy (CFE) procured on an annual megawatt-hour basis.

Today's leading corporate energy buyers want to procure carbon-free energy that matches their energy use on an hourly basis. In addition, corporate energy buyers recognize that all carbon-free energy resources—both supply side and demand side resources—must be considered to meet their ambitious goals. While the number of companies with goals to procure CFE with hourly matching is small today, customer demand for CFE with hourly matching will continue to grow in the future.

¹⁷⁸ The White House. 2021b. Executive Order on Tackling the Climate Crisis at Home and Abroad. January 27. <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/>.

¹⁷⁹ IEI (2020).

Electric companies have taken on the energy management role and the risk of delivering electricity at a stable price for decades. In addition, when the electric company offers a subscription service for solar, the electric company assumes the risk of investing in the resource. However, to encourage deployment of newer technologies such as battery storage, electric companies might be willing to take on more risk if the potential returns were sufficiently high or if they can share the risk and return with subscribing customers.

Some electric companies are exploring opportunities to become the end-to-end CFE solution provider for corporate customers, the integrator of variable supply and flexible demand resources, the coordinator via appropriate and available tariffs, and the tracker of emissions and resource availability. The following regulatory innovations are needed to meet the future needs of customers:

[W]hen the electric company offers a subscription service for solar, the electric company assumes the risk of investing in the resource. However, to encourage deployment of newer technologies such as battery storage, electric companies might be willing to take on more risk if the potential returns were sufficiently high or if they can share the risk and return with subscribing customers.

1. *Transition from annual matching of renewable or carbon-free energy purchasing to hourly matching of customer load using a diverse set of regional, carbon-free resources.*

Capacity-sharing arrangements, such as in the NV Energy-Google deal, demonstrate how co-optimized resources can meet the specific needs of one large energy buyer while providing environmental benefits to all customers and making progress towards the state's clean energy and climate goals. It also underscores that even the most sophisticated customers often prefer that the electric company—in this case NV Energy—act as the energy manager on the customer's behalf. NV Energy manages the behind-the-scenes efforts required to deliver carbon-free energy at a stable dollar per megawatt-hour price to Google.

2. *Make carbon-free energy resources available to all customers.*

In its Clean Energy Optimization Pilot, SCE provides a portfolio of resources—including energy efficiency, demand response, on-site renewable energy, clean transportation, and energy storage—to give their university customers a variety of clean energy choices that can be tailored to their individual needs. Subscription offerings and green tariffs such as FPL's SolarTogether Program and Georgia Power's Customer Renewable Supply Procurement Program are other ways to provide carbon-free energy to customers.

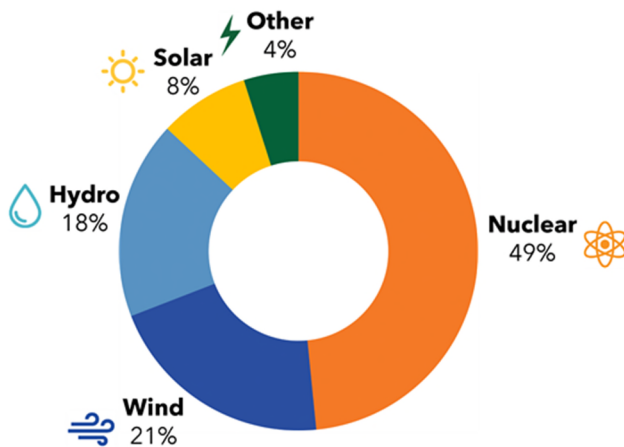
A critical element in developing 24/7 CFE products and solutions is the availability of *high-fidelity hour-by-hour carbon emissions intensity data* and the associated analytics to assess how regional grid dynamics influence hourly matching CFE products. This is a big and important first step. To provide context, the Edison Electric Institute currently provides an electric company carbon emissions and electricity mix database that reports *annual* carbon emissions intensity rates for delivered electricity annually by electric company, by state.¹⁸⁰ High fidelity reporting means moving from providing annual carbon emissions intensity rates to hourly carbon emissions intensity rates for all 8,760 hours each year.

¹⁸⁰ EEI. n.d. Electric Company Carbon Emissions and Electricity Mix Reporting Database. <https://www.eei.org/Pages/CO2Emissions-Access.aspx>.

3. *Plan for the availability of CFE resources.*

As more CFE solutions are developed, it is critical to maintain existing clean energy resources on the grid. CFE solutions require, in part, some amount of 24/7, zero-carbon generation. Today nuclear energy provides that generation. In 2020, nuclear energy accounted for nearly 50% of carbon-free electricity generated in the United States (Figure 15). Retaining this resource through license extensions underpins 100% CFE solutions. The cost of developing and scaling carbon-free electricity resources will be significantly impacted by planning. In the future, other resources to consider include hydrogen, natural gas with carbon capture and storage, advanced wind and solar energy systems, and long-duration storage.

Figure 15. U.S. Carbon-free Electricity Generated, by Source (2020)



Source: IEI (2021b).

3.4 Conclusion

Across the United States, regulated electric companies are developing innovative solutions that meet the evolving needs and expectations of residential and corporate customers in the areas of energy management and carbon-free energy solutions. However, these solutions are just the tip of the iceberg. Much more progress is needed.

Some electric companies are partnering with technology companies such as E Source, Oracle, and Powerley to provide innovative customer services and solutions in energy management for residential customers—both EE and DR. Traditionally EE and DR programs are developed, deployed, and measured separately from supply-side resources. Yet with technology today, EE and DR can scale rapidly to control not only how much energy is consumed, but when it is consumed, making them flexible capacity resources and cost-effective ways to reduce carbon emissions. Additional metrics need to be adopted to value and evaluate EE and DR programs to simultaneously measure carbon emissions reductions, energy savings, and capacity savings achieved.

Deploying one-size-fits-all solutions or services for residential customers is no longer a recipe for success. Some electric companies are offering multiple options and transitioning customers onto rates that are more advantageous for them than the standard residential rate—from pre-pay to flat fee to TOU, and more. These innovations are driven by technology and data analytics and enabled by smart meters.

To meet the growing needs of many corporate customers for CFE, the ability to plan for and develop cost-effective and scalable carbon-free energy solutions is essential. Electric companies, regulators, corporate customers, and other stakeholders must work together effectively to adapt existing policy and regulatory frameworks to ensure the availability of these solutions. Otherwise, corporate customers are likely to look for CFE solutions elsewhere.

While the number of corporate customers with goals to procure CFE that matches hourly energy use is small today, customer demand will grow in the future. Some electric companies are exploring opportunities to become the end-to-end CFE solution provider for corporate customers, the integrator of variable supply and flexible demand resources, the coordinator of resources via tariffs, and the tracker of carbon emissions and resource availability.

Working with regulators, customers, and other stakeholders is the right thing for electric companies to do. Will it be fast enough to satisfy the evolving expectations and needs of both residential and corporate customers? That will depend on the pace of regulatory change.

Working with regulators, customers, and other stakeholders is the right thing for electric companies to do. Will it be fast enough to satisfy the evolving expectations and needs of both residential and corporate customers? That will depend on the pace of regulatory change.

4.0 Innovating the Electricity System from the Hearing Room to the Edge of the Grid

By Anne E. Hoskins, Christopher M. Worley, and Keyle Horton, Sunrun ¹⁸¹

4.1 Introduction

The climate crisis requires a dramatic shift in how the United States produces and consumes energy. The switch from fossil fuels to cleaner alternatives will require trillions of dollars in investment in order to meet local, state, and national objectives, including building gigawatts of renewable energy and electrifying buildings and the transportation sector.¹⁸² In addition, the climate crisis is exposing the fragility of our energy system to extreme weather events and natural disasters. Our aged centralized electricity systems failed to provide reliable power during California's wildfires and the Texas freeze of 2021. Without a fundamental



Electric vehicle charging with inverter and home solar battery

change in the way we generate and distribute power, repeated outages and related harm to people and communities will increase as the Earth's temperature rises and extreme weather events become more common.^{183, 184}

Disasters like these indicate that many utilities across the country are not providing the resilience and reliability that customers need and are not moving fast enough to decarbonize. Further, a long history of policy decisions has left low-income and disadvantaged communities with fewer resources and little infrastructure to respond to power emergencies and climate disasters.¹⁸⁵ A rapid, equitable, and orderly transition away from fossil fuels will require a different approach than relying on top-down, centralized power generation and long-distance transmission of power.

Without a fundamental change in the way we generate and distribute power, repeated outages and related harm to people and communities will increase as the Earth's temperature rises and extreme weather events become more common.

¹⁸¹ Thank you for research and writing support from current and former Sunrun Policy colleagues: Robert Harris, Lauren Randall, and Christopher Rauscher. Photos courtesy of Sunrun.

¹⁸² Shreve and Shauer (2019) at 2.

¹⁸³ American Society of Civil Engineers (2021) at 44–54.

¹⁸⁴ Sturmer, Plietzsch, and Anvari (2021).

¹⁸⁵ Jessel, Sawyer, and Hernandez (2019).

4.1.1 Shortcomings of the Traditional Utility Business Model

The traditional investor-owned utility (IOU or utility) business model is built upon capital investment in power plants, poles, and wires. Much of that investment is measured at scales of hundreds of megawatts, hundreds of miles, and billions of dollars. Under the traditional cost-of-service regulatory model, the utility's profit is based on the size of its investment and the approved rate of return.¹⁸⁶

Utilities usually respond to load growth, clean energy mandates, or calls to increase the resilience of their grid by building more infrastructure, adding to their rate bases, and then recovering those costs through higher customer rates.

While electricity load growth in the United States has been largely flat over the last 20 years,¹⁸⁷ electricity rates have not stayed flat, as utilities have increased their capital expenditures.¹⁸⁸ Electrification of buildings and transportation is expected to increase electricity load significantly over the next 20 years.¹⁸⁹ Under cost-of-service regulation¹⁹⁰ and in the absence of specific corrective regulatory actions, utilities will be incentivized to support this new era of electrification with centralized capital expenditures instead of facilitating investment in distributed solutions that could better meet the reliability and resiliency needs of customers.

The effects of the traditional IOU model go beyond the issue of misaligned incentives for capital expenditure. There is little incentive for innovation for utilities under cost-of-service regulation. Competitive alternatives to fossil fuels are available, as rapidly advancing technologies have made renewable energy, energy efficiency, and demand response affordable and accessible. Distributed energy resources (DERs),¹⁹¹ including customer-sited solar and battery storage, are proliferating as customers seek more affordable and reliable sources of power.¹⁹² Electricity rates are expected to continue to increase around the country¹⁹³ as utilities increase capital spending and pay for deferred maintenance. As utility bills rise, customers will have strong economic incentives to reduce their reliance on power provided by their local utility.¹⁹⁴ For customers facing utility bill spikes as COVID-19 moratoria protections end, the need for a more affordable and reliable electricity system is urgent.¹⁹⁵ Society cannot afford to over-invest in electricity systems that are not meeting society's needs.



Customer discussing Brightbox solar battery system with neighbor in West Corona, California

¹⁸⁶ Cawley and Kennard (2018) at 79, 141–145.

¹⁸⁷ EIA Annual Energy Outlook 2021 (2021).

¹⁸⁸ Two posts to the U.S. Energy Information Administration's *Today in Energy* blog illustrate the general, long-run trend of increased capital investment by utilities. The first post, "Utilities continue to increase spending on transmission infrastructure" (EIA 2018a), shows the increase in transmission investment. The second post "Major utilities continue to increase spending on U.S. electric distribution systems" (EIA 2018b) shows the increase in distribution system investment.

¹⁸⁹ Sin et al. (2020) at 49.

¹⁹⁰ Under cost-of-service regulation, the regulator determines the revenue requirement (i.e., the cost of service) that reflects the total amount that must be collected in rates for the utility to recover its authorized costs and earn a reasonable return.

¹⁹¹ As defined in this essay, *DERs* are electric power sources that are not directly connected to the bulk power system, including energy generation and storage technologies, that are capable of exporting power to the grid. IEEE Std 1547-2018.

¹⁹² See Hiller (February 19, 2022) and Penn (March 13, 2022).

¹⁹³ See the EIA's Short-Term Energy Outlook (EIA 2021b), which shows the general trend of average electricity price increases over time.

¹⁹⁴ Creyts and Guccione (2014) at 11.

¹⁹⁵ The National Association of Regulatory Utility Commissioners (NARUC) assembled a Map of Disconnection Moratoria, last updated Sept. 9, 2021 (<https://www.naruc.org/compilation-of-covid-19-news-resources/map-of-disconnection-moratoria/>).

Some regulated utilities view onsite solar as a competitive threat, eroding retail sales.¹⁹⁶ They respond by seeking regulatory approval to increase or add new fixed fees and lower compensation rates for distributed generation, reducing the value proposition of innovative DER investments by customers and third parties.¹⁹⁷ In effect, these actions disincentivize customer adoption of innovative technologies. Increases in DER-specific fees make new DER technologies that can boost resiliency less accessible, particularly for lower-income customers and underserved communities that could benefit the most.¹⁹⁸ Access to solar for low- and moderate-income customers has improved with declining solar panel costs, expanded financing options, and targeted public programs.¹⁹⁹ These market changes have enabled more equitable access to DERs, but there is more work to be done. The progress to date will be undermined if regulators impose fixed fees and reduce compensation for power shared by solar consumers.²⁰⁰ Instead of imposing extra costs on DERs, regulators can enable broader access to DERs with rate reforms and targeted incentives.

Without onsite generation and storage, utilities will need more power plants, lines, and poles to meet the expected future demand from electrification. These investments will be funded by charging customers higher electricity rates and will increase the energy burden on those who can least afford it.²⁰¹ While EVs and home electrification will likely warrant some new grid infrastructure, distributed generation and batteries can reduce that need, and ratepayer expense, particularly by incorporating the right rate designs. Continuing to treat DER technologies as a competitive threat will undermine efforts to rapidly decarbonize the grid and make the grid more resilient, and will reduce customers' ability to manage their energy bills.

Continuing to treat DER technologies as a competitive threat will undermine efforts to rapidly decarbonize the grid and make the grid more resilient, and will reduce customers' ability to manage their energy bills.

4.1.2 Why Is Change Needed?

Decarbonizing the grid cannot be accomplished solely by relying on gigawatts of utility-scale renewable resources and thousands of miles of new transmission lines to bring energy to load centers. With frequent extreme weather events and greater demand for electricity for buildings and transportation, renewable DERs must be part of the solution. For example, a recent California study shows that in order to meet a goal of 100% renewable energy, 27% of the power will need to be generated through distributed solar.²⁰²

¹⁹⁶ Glick and Lehrman (2014) at 23.

¹⁹⁷ See discussion on pages 3 through 7 of the “Joint Opening Comments of Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company on the Proposed Decision of the ALJ Hymes Revising Net Metering Tariff and Subtariffs” brief filed in the California PUC R.20-08-020 docket.

¹⁹⁸ While utilities may claim to be protecting low-income customers when seeking to impose fees on DER customers, there are many options to expand DER access for low-income customers without reducing access for others. These include targeted low-income subsidies, community solar, and affordable multifamily solar (such as through California’s Solar on Multifamily Affordable Housing program). For more information on low income solar, see Stanton (2020).

¹⁹⁹ The 2021 Update to Berkeley Lab’s *Residential Solar-Adopter Income and Demographic Trends* notes, “Solar adopters generally skew towards higher incomes, though that trend continues to diminish over time.” See Barbose et al. (2021).

²⁰⁰ See general discussion in the “Opening Comments of the Solar Energy Industries Association and Vote Solar on the Proposed Decision Revising Net Energy Metering Tariff and Subtariffs” brief filed in the California PUC Docket R.20-08-020. https://apps.cpuc.ca.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R2008020.

²⁰¹ In some states, an estimated 20% to 30% of all residential and small commercial customers face energy affordability challenges, threatening massive dislocations when COVID shut-off moratoria expire. For more information, see Farley et al. (2021).

²⁰² See Jacobson et al. (2022).

A market-based approach that facilitates participation of third-party providers to yield a high penetration of DERs and integration of related innovative technologies, products, and services will result in a more flexible, equitable, and resilient grid at lower cost, while providing greatly improved results and benefits for local economies.²⁰³

Given the magnitude of investment needed for a clean energy transition, customers should be encouraged to invest in DERs, whether their interest is economic or to improve reliability and resilience. If customers invest their own capital in assets that provide benefits to the grid and society, that is money that does not have to be raised through electricity rates. To achieve this aim, state public utility commissions should require regulated utilities to establish rate structures and program incentives that fairly compensate behind-the-meter DERs for the benefits they provide the grid. In addition, to support a decentralized energy system over the long term, utility incentives must be realigned so that onsite generation is not a source of lost revenue and lost profit. Instead of cost-of-service regulation, which is designed to recover utility costs through the one-way flow of electricity, utility regulators should usher in a change of incentives and updated rate designs that promote innovation, serve the customer, and support two-way flows of electricity in a modern electric system.²⁰⁴

In parts of the country, this change is underway. Under alternative regulation in Vermont,²⁰⁵ Green Mountain Power (GMP) is leading utility innovation that includes testing new approaches through pilot programs. For example, GMP's Bring Your Own Device (BYOD) battery storage program has unlocked millions in utility cost savings, provides onsite resiliency benefits to customers, and has been a model for similar utility programs around the country.²⁰⁶ In Hawaii, the Public Utilities Commission has adopted several innovative regulatory approaches, including integrating resource, transmission, and distribution system planning; instituting performance-based regulation (PBR); and quickly launching the Emergency Demand Response Program to address immediate system needs.²⁰⁷ At the federal level, the Federal Energy Regulatory Commission (FERC) issued Order 2222, which mandates that behind-the-meter resources be able to participate in organized wholesale energy, capacity, and ancillary services markets.²⁰⁸



Customers with their home solar battery in West Mission Viejo, California

Instead of cost-of-service regulation, which is designed to recover utility costs through the one-way flow of electricity, utility regulators should usher in a change of incentives and updated rate designs that promote innovation, serve the customer, and support two-way flows of electricity in a modern electric system.

²⁰³ For example, see Maryland Department of the Environment (2021). Appendix H reports on derivative positive economic and employment impacts on manufacturing from greenhouse gas reductions.

²⁰⁴ For a recent study of DER rate design options, see LeBel et al. (2021).

²⁰⁵ As used in this essay, *alternative regulation* entails the realignment of utility incentives, including revenue decoupling, performance-based ratemaking, rate restructuring, or another deviation from traditional regulation. See Vermont's description of alternative regulation at <https://puc.vermont.gov/electric/electric-alternative-regulation>.

²⁰⁶ Vermont PUC Case No. 19-3537-TF, Final Order.

²⁰⁷ Hawaii PUC Docket No. 2019-0323, Order No. 36538.

²⁰⁸ FERC 18 CFR Part 35, Docket No. RM18-9-000, Order No. 2222.

These examples shed light on some of the most innovative actions underway in the electric utility sector, underscoring the benefits of strong leadership, regulatory flexibility, and data transparency among stakeholders. However, these steps are not enough to ensure the transition to a modern electric system.

To decarbonize our energy system in a way that prioritizes grid resilience, the U.S. needs forward-looking regulators in every state and at the federal level to develop and promote policies that enable a future with high integration of DERs. In the near term, regulators should enact policies that remove market barriers for DERs, promote market transparency, and ensure compensation for services provided to the grid. In the longer term, regulators should realign utility incentives away from capital expenditure and towards enabling



Rooftop solar installation

competitive supply of renewable generation and reducing barriers to innovation. This future regulatory regime may be more akin to a distribution service operator utility model, shifting the role of utilities to a platform provider that enables a competitive market of third-party DER providers.²⁰⁹

4.2 Case Studies in Innovation

In most parts of the U.S., utility regulation is not keeping up with the ever-changing dynamics of the electric system, including evolving technologies, grid failures, and socioeconomic impacts. DERs can play a central role in improving the electric system, but only with regulatory innovation, including elimination of adverse utility incentives that impede DER adoption. Regulators must act swiftly given the compounding concerns of aging infrastructure, the climate crisis, and urgent environmental justice issues. As time advances we lose opportunities to efficiently electrify our economy.

The following case studies provide examples of innovative state regulation that can be replicated and adapted to promote the widespread integration of DERs. Both Vermont and Hawaii are cases where the regulatory regime shifted from traditional cost-of-service regulation to alternative regulation enhanced utility-based programs. By providing more flexibility than traditional regulatory processes, alternative regulation promotes innovative actions by utilities that can enable and facilitate the transition to a modern electric system.

²⁰⁹ For more information on DSO models, see the roadmaps prepared by the NARUC-NASEO Task Force for Comprehensive Electricity Planning at <https://www.naruc.org/taskforce/resources-for-action/roadmaps/>. See also [De Martini and Kristov \(2015\)](#) in the Future Electric Utility Regulation series.

4.2.1 Vermont: Green Mountain Power

Vermont's largest investor-owned utility, GMP,²¹⁰ recognized the need for more clean energy and began to push for innovation in its 2014 Integrated Resource Plan. This established the city of Rutland as a hub for pilot programs to rapidly test and implement nascent DERs, demand response, and energy efficiency technologies, as well as other energy services. GMP understood the potential for a high-DER future and took early action to move away from the traditional centralized grid model. Through the 2014 plan, GMP established a long-term vision to create open new markets for energy products and services, while focusing on the short-term goals of creating customer value, increasing grid efficiency and intelligence, and increasing reliance on local, distributed grid resources.^{211, 212}



Installed solar panels in New England

The GMP Solar Map,²¹³ launched in 2017, visualizes a model of circuit-level hosting capacity to guide developers away from constrained sections of the grid and ultimately led to development of a tariff that allows for more distributed generation.^{214, 215} The Solar Map provides transparency and exemplifies that access to data can benefit all stakeholders in the transition to a high-DER future.²¹⁶ These initial efforts laid the foundation for a new regulatory regime in Vermont, including GMP's alternative regulation proposal in place of traditional utility cost-of-service regulation.

GMP proposed the restructuring of rates and incentives to promote innovation and improve customer service. The GMP Multi-Year Regulation Plan (MRP), as modified in 2020, sets out to stabilize rates for customers over a three-year period by:²¹⁷

1. Fixing non-power costs, including infrastructure and operation and maintenance costs, in order to disincentivize excessive capital expenditures.
2. Using formulaic and forecasted components, including equity, retail revenue, and power supply costs to provide predictability where possible.
3. Applying rate-smoothing and other adjustment mechanisms to ensure a steady rate path for customers.

Through this form of alternative regulation, GMP decouples its financial interests from electricity sales, creating an environment that rewards the utility for innovation and providing quality, low-cost service to ratepayers. The Vermont Public Utilities Commission (PUC) approved the initial MRP in 2019, verifying

²¹⁰ GMP's former CEO Mary Powell now serves as Sunrun's CEO.

²¹¹ Green Mountain Power (2014) at 2-2.

²¹² It is notable that GMP became a certified B-Corp in 2014. As a B-Corp it is required to meet standards of social and environmental performance, accountability, and transparency (Green Mountain Power 2017). A B-Corp certification is conferred by B Lab, a global nonprofit organization.

²¹³ GMP Solar Map 2.0. <https://gmp.maps.arcgis.com/apps/webappviewer/index.html?id=4eae2b58c4c4820b24c408a95ee8956>.

²¹⁴ Vermont Energy Investment Corporation (2018) at 35-51.

²¹⁵ NARUC (2020) at 1-5.

²¹⁶ A growing number of states are undertaking proceedings to direct utilities to provide hosting capacity data for DER developers. For more on hosting capacity developments, see IREC (2021).

²¹⁷ Green Mountain Power (2020a) at 3-12.

that it met the statutory criteria for alternative regulation: least-cost, safe, and reliable service; just and reasonable rates; promoting innovation; and meeting the state’s energy policies.²¹⁸

The Innovative Pilots Program, now a provision within the MRP, plays a role in reducing risk. Pilot programs provide a means for GMP to better understand the needs of their customers through data and impact assessments, while meeting statewide objectives to reduce fossil fuel consumption and greenhouse gas emissions. Notably, with a 15-day advance notice to regulatory authorities for projects under \$5 million, GMP can quickly implement pilots without the delays that other utilities face.²¹⁹

Although initially pilots were closed to market participants outside of the utility, GMP subsequently partnered with third parties to increase opportunities for customers through a competitive market. During the MRP proceeding in 2019, the differing approaches of GMP and Renewable Energy Vermont, a coalition of clean energy organizations and individuals, led to a memorandum of understanding (MOU) to work together in accomplishing the shared goal of a more distributed and cleaner grid.²²⁰

Through the MOU, GMP provides market participants with access to its DER platform, marketing, and billing system to streamline integration into the grid. GMP also offers a level playing field for third parties by creating comparable, parallel opportunities when a new pilot program for a consumer product is initiated and allows Renewable Energy Vermont to provide input on proposed pilots before they are filed. These organizations are positioned to work collaboratively in transforming the electric system, promoting a decentralized grid with competitive options for energy services.²²¹

...GMP provides market participants with access to its DER platform, marketing, and billing system to streamline integration into the grid. GMP also offers a level playing field for third parties by creating comparable, parallel opportunities when a new pilot program for a consumer product is initiated....

GMP and Renewable Energy Vermont set a new standard for innovative programs at the start of their relationship by launching the nation’s first Bring Your Own Device (BYOD) program. Originally created as a pilot in 2018, the program has supported a competitive market for battery storage.²²² The expanded BYOD tariff, developed in cooperation with Renewable Energy Vermont, received approval from the Vermont PUC in 2020.²²³ Customers that purchase and install third-party battery storage systems through the BYOD program receive upfront incentives in exchange for giving the utility access to the stored energy to reduce peak demand and the data on battery usage. The utility recognized the ability of DERs to make the grid more reliable and resilient by increasing system capacity and providing customer data.²²⁴ The BYOD tariff provides a net benefit to all customers by decreasing GMP’s power supply costs, which is passed onto customers in the form of bill savings.²²⁵ GMP’s BYOD program is an example of utilities and third parties working together to foster a competitive market for DERs, resulting in increased efficiency, lower electricity prices, and better quality service for consumers.

²¹⁸ 30 V.S.A. § 218d; Vermont PUC Case No. 18-1633-PET.

²¹⁹ Green Mountain Power (2020a), Attachment 2.

²²⁰ Vermont PUC Case No. 18-1633-PET.

²²¹ GMP and REV (2019) at 3–8.

²²² In the press release announcing Vermont PUC’s approval of the program, more than 30 companies are listed as vendors providing battery storage installation service (Green Mountain Power 2020b).

²²³ Green Mountain Power (2020b).

²²⁴ See Green Mountain Power (2020b) and Green Mountain Power (2020c).

²²⁵ Vermont PUC Case No. 19-3537-TF, Final Order.

While the alternative regulation incorporated in the MRP will end in September 2022,²²⁶ the structure of the MRP, including the Innovation Pilots Program, provides lessons that can support future programmatic and policy decisions. For near-term action, the Innovation Pilot Program provides a means of rapid testing and implementation of innovative efforts. Additionally, GMP has created a system of innovation that builds on itself in order to maximize opportunities. For instance, the Solar Map platform has created a more effective BYOD Program: the tariff awards greater upfront incentives to customers in areas of the grid with greater capacity constraints identified in the Solar Map.²²⁷ A key lesson from the GMP experience is that effective short-term solutions require quick implementation of programs through open communication and collaboration between stakeholders and the utility, in addition to transparency throughout the process. Regulators can support this by requiring sharing of data (such as through hosting capacity rules) and enabling trials of creative partnerships through flexible pilot programs.

There remains a longer-term question about the appropriate roles for utilities in a competitive market. The partnership between GMP and Renewable Energy Vermont opened up the market for DERs to third-party companies. Investor-owned utilities are regulated as natural monopolies to ensure a distribution system that is reliable, safe, and equitably priced for customers.²²⁸ Competition from third-party DER developers is challenging the historical paradigm and offering ways to improve service, reliability, and cost-effectiveness through distributed, customer produced generation and grid engagement.²²⁹

As other utilities seek to replicate the GMP model and engage in provision of DERs under alternative regulation, regulators will play a critical role in ensuring a paradigm where competitors can flourish and bring forth innovative solutions. The success of GMP's alternative regulation initiative lays the foundation for a longer-term solution that draws on the complementary strengths of regulated distribution utilities and competitive DER providers. This will likely require utilities to transform and take on new roles as the energy system transitions to a high-DER future.

The success of GMP's alternative regulation initiative lays the foundation for a longer-term solution that draws on the complementary strengths of regulated distribution utilities and competitive DER providers.

4.2.2 Hawaii: Public Utilities Commission

Hawaii experiences the highest electricity rates among U.S. states—more than twice the national average.²³⁰ Isolated from the rest of the world, the state has long depended on imported oil to fuel its energy sector, accounting for 61.3% of electricity generation in 2018.²³¹ Renewable energy and aggregated DERs are critical for helping Hawaii reduce its reliance on imported and carbon-intensive energy.²³²

²²⁶ Green Mountain Power (2020a) at 3.

²²⁷ Green Mountain Power (2019) at 2.

²²⁸ Lazar (2016) at 3-13.

²²⁹ For one view on potential future structure and roles of electric utilities, see Fox-Penner (2020).

²³⁰ Hawaii State Energy Office (2020) at 9.

²³¹ Hawaii State Energy Office (2019) at 2.

²³² Spector (February 14, 2022).



Customer home with installed solar panels in Oahu

In 2015, the Hawaii Legislature set a Renewable Portfolio Standard to generate 100% of electricity from renewable energy sources by 2045.²³³ It met its interim 2020 target of 30% renewable energy generation.²³⁴ Accounting for 10.9% of electricity sales in 2018, DER installations collectively produced the largest source of renewable energy statewide.²³⁵ With grid storage capacity, demand response technologies, grid modernization, and market signals, distributed solar has the potential to contribute approximately 40% of Hawaii's projected energy needs.²³⁶

The Hawaii PUC closed its net energy metering program in 2015, in part based on the “finite capacity of each island grid to accommodate uncontrolled export of energy during mid-day hours.”²³⁷ As a result of this decision, the total number of rooftop solar building permits dropped between 30% and 50% from 2015 to 2018.²³⁸ The total number of rooftop solar contractors dropped from 300 to 98 over the same period.

In the face of this significant setback, the Hawaii PUC opened a number of regulatory dockets to drive the transition to a modern electric system that incorporates DERs. The HI PUC is a prime example for other commissions that want to lead on resilience, reliability, and rapid decarbonization.²³⁹ The Integrated Grid Planning docket²⁴⁰ and the Performance-Based Regulation docket²⁴¹ both launched in 2018, followed by the Emergency Demand Response Program docket²⁴² in 2019, provide insight into the important role of the PUC in this transformation.

4.2.2.1 Integrated Grid Planning

The PUC opened the Integrated Grid Planning (IGP) docket after the utilities housed under the state's largest electricity supplier, Hawaiian Electric Industries, Inc., issued their 2018 IGP report. This docket established a holistic approach to create a more reliable and resilient energy future, promote affordability, and minimize risk through customer-focused, market-based solutions. By integrating planning processes across generation, transmission, and distribution, stakeholder and customer engagement at all levels can create cost-effective pathways to a low-carbon future.²⁴³ The docket intended to assess Hawaiian Electric Industries' proposal to address the total needs of the system and consider all alternatives in order to produce the optimum levels of reliability, resilience, and affordability.²⁴⁴ A tall order, but one the Commission has taken important steps towards achieving.

²³³ §269-92. Renewable portfolio standards. https://www.capitol.hawaii.gov/hrscurrent/vol05_ch0261-0319/hrs0269/hrs_0269-0092.htm.

²³⁴ Hawaii State Energy Office (2020) at 4.

²³⁵ Hawaii State Energy Office (2019) at 36.

²³⁶ Hawaii State Energy Office (2020) at 14.

²³⁷ Hawaii PUC Docket No. 2014-0192, Decision and Order No. 33258 (October 12, 2015).

²³⁸ See, e.g., Foehringer Merchant (2019).

²³⁹ For a thorough discussion on Hawaii's clean energy transition, see Lee, Glick, and Lee (2020).

²⁴⁰ Hawaii PUC Docket No. 2018-0165, Order No. 35569.

²⁴¹ Hawaii PUC Docket No. 2018-0088, Order No. 35411.

²⁴² Hawaii PUC (2021a) at 1.

²⁴³ Hawaiian Electric, Maui Electric, and Hawai'i Electric Light (2018a) at 1–3.

²⁴⁴ Hawaiian Electric, Maui Electric, and Hawai'i Electric Light (2018b) at 1–3.

The Commission prioritized collaboration between utilities, third parties, and customers in establishing an efficient and competitive marketplace to support the IGP process.^{245, 246}

The PUC found that access to information was key in planning the future electric system. In order to lead with transparency, the PUC granted some parties to the proceeding access to Hawaiian Electric Industries’

RESOLVE capacity expansion modeling tool that assisted the utilities in determining resource needs.²⁴⁷

By allowing the parties to use the utilities’ analysis tool to assess the feasibility and costs of implementing DER technologies, everyone involved could assess any associated risks and benefits using the same baseline measurements. Understanding the inputs that the utilities use to run the model can reveal any bias toward solutions most favorable to the utility. Collaborative stakeholder contributions can help remedy any such bias. This level of transparency has laid the foundation for other Hawaii PUC proceedings.

The PUC found that access to information was key in planning the future electric system.

4.2.2.2 Performance-Based Regulation

While fostering competition through an integrated planning process was an important step towards reshaping the energy system at least cost and reducing the state’s dependence on fossil fuels, the PUC went a step further. Shortly after initiating the IGP docket, the PUC opened a proceeding to investigate how PBR could transform utility incentives and promote an innovative and modern power system in Hawaii.²⁴⁸ After identifying the need for renewable energy resources to gain energy independence, deliver customer savings, and provide grid services, the PUC found that the traditional cost-of-service regulation was not fostering a modern electric grid.²⁴⁹

The resulting PBR framework provides the means to align utility financial incentives with customer needs to reduce electricity rates and foster a market for DERs and utility-scale renewables, while rewarding utilities for exemplary performance and desired outcomes in renewable energy generation, reducing electricity costs, and providing high quality customer service. The PUC sees the PBR framework as a way to reduce risk by addressing customer concerns about rising prices and utility concerns over load defection due to high adoption of distributed solar.²⁵⁰ The three facets of the PBR framework—(1) the multi-year rate plan; (2) annual revenue adjustment mechanisms, such as revenue decoupling and earnings sharing; and (3) performance mechanisms, such as performance incentives and scorecards with reported metrics—

incent utilities to operate with a customer-centric approach while promoting administrative efficiency and

The resulting PBR framework provides the means to align utility financial incentives with customer needs to reduce electricity rates and foster a market for DERs and utility-scale renewables, while rewarding utilities for exemplary performance and desired outcomes in renewable energy generation, reducing electricity costs, and providing high quality customer service.

²⁴⁵ Hawaii PUC Docket No. 2018-0165, Order No. 37419.

²⁴⁶ Hawaii PUC Docket No. 2018-0165, Order No. 36725.

²⁴⁷ NARUC (2020) at 2.

²⁴⁸ Hawaii PUC Docket No. 2018-0088, Order No. 35411.

²⁴⁹ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507.

²⁵⁰ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 36326.

utility financial integrity.²⁵¹ This framework emphasizes the utility's role as a service provider, supporting innovation and offering utilities a fair return on investment.

While the revenue adjustment mechanisms in the framework, such as revenue decoupling, mitigate utility biases to seek capital investment, financially incentivized performance mechanisms can provide utilities with motivation to innovate²⁵² and modernize the grid.²⁵³ Throughout this transformation, regulators will need to ensure that PBR strikes an equitable balance between customer needs, the fair return utilities are allowed to earn, and the potential innovations of the electric utility sector.



Solar installation in Hawaii

As the first alternative regulatory regime to completely break away from the traditional cost-of-service model in favor of utility regulation based on performance, the PBR framework is a significant act of innovation.²⁵⁴ The key takeaways so far in Hawaii are as follows:

DER deployment, integration, and services can be incentivized with PBR. In the face of energy insecurity due to reliance on costly imported fuels, DERs provide a way for Hawaii to quickly and efficiently generate electricity from local resources at affordable prices. The PUC also recognized the value of grid services that DERs could provide, such as frequency regulation and demand response. The PBR framework

incentivizes the deployment and integration of DERs, the services they provide to the grid, and the speed at which these technologies are interconnected.²⁵⁵

Flexibility needs to be included in the design of PBR. The PBR framework was created as a tool that can adapt over time, with continual assessments of both revenue adjustments and performance mechanisms. Although the PUC has stated that the PBR framework will be reviewed after four years, there is no plan to return to the traditional cost-of-service model.²⁵⁶ While there is a path to a high-DER future, flexibility will be necessary in any regulatory regime as technologies and stakeholder roles change over time.

PUC leadership is key to success. In pursuing such an innovative approach to utility regulation, the importance of PUC leadership cannot be overstated. Regulatory authorities around the United States should look to the Hawaii PUC as an example of leading the way to a modern power system.

4.2.2.3 Distributed Energy Resource Tariffs

While initiating long-term efforts such as IGP and PBR are necessary to transform the energy system, it is valuable to start the transition with solutions that can be implemented quickly. After closing its net

²⁵¹ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507.

²⁵² Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507.

²⁵³ Utility incentives for capital investment may be mitigated during periods with a sustained rise in interest rates. When interest rates rise, utilities may be less likely to make capital investments. For a more detailed discussion, see Kihm, Satchwell, and Cappers (2015).

²⁵⁴ Interestingly, the Hawaii PUC based elements of the PBR framework on the GMP pilot framework. See Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507, at 166–167 and 178–179.

²⁵⁵ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507.

²⁵⁶ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37507.

metering program in 2015, Hawaii has now embraced clean energy solutions through energy efficiency, demand response, and DER technologies.

Recognizing the need for a viable path for customer-based rooftop solar, the PUC established the Customer Grid-Supply program in 2016. Customers with distributed solar can export excess solar energy to the grid in exchange for compensation in the form of bill credits at Commission-established rates for the program, rather than at the customer’s retail rate. A new iteration of this program, the Customer Grid-Supply Plus program, was created in 2017 with one difference: customers need advanced metering infrastructure so that utilities can manage output and maintain safe, reliable grid operations. The Smart Export program provided another means for customers installing solar-plus-storage to receive additional bill credit for exporting energy during the electrical grid system peak (generally in the early evening).²⁵⁷

4.2.2.4 Emergency Demand Response Program

In March 2021, the PUC sought proposals for an Emergency Demand Response Program (EDRP) to address decreased generation capacity expected in 2022 upon retirement of the Oahu coal-fired power plant.²⁵⁸ Although Hawaiian Electric demand response programs using customer-sited solar and solar-plus-storage systems had seen success, demand response technologies had not yet been used on a scale large enough to replace a fossil-fuel power plant. In June 2021, three months after the request for proposals, the PUC approved the EDRP Scheduled Dispatch Program (SDP),²⁵⁹ followed almost immediately by the approval of the EDRP/SDP Implementation Plan, effective July 1, 2021. Contributing a 50 megawatt resource to the grid during peak hours, the SDP allows eligible solar-plus-storage customers to dispatch electricity, up to five kilowatts per system, for a two-hour period every day in exchange for an upfront incentive payment.²⁶⁰ In other words, the local energy infrastructure used in the SDP will promote reliability throughout the island’s transmission and distribution system.

While customers receive a one-time incentive to enroll in the SDP, they are also compensated for the power they export to the grid. Created as an amendment to programs already offered through the utilities under Hawaiian Electric Industries, such as Customer Grid Supply Plus or Solar Export programs, new and existing solar-plus-storage customers may receive credit for the energy dispatched from their systems. Moreover, the EDRP will be implemented as a new rule—Rule 31—and the SDP will be added as a rider to the program, allowing the EDRP to be modified in the future with additional riders.²⁶¹ This structure will streamline the process of creating other demand response programs. Further EDRP opportunities are being considered. The DER Parties’ proposal for the EDRP Docket included not only an SDP for load shifting at specific peak demand times, but also a program involving remote emergency dispatch to address grid needs as they arise with utility-controlled software systems.²⁶² Adding more flexibility to demand response programs will result in increased resilience for the entire electric grid.



Installing a home solar battery

²⁵⁷ Hawaii State Energy Office (2019) at 37–38.

²⁵⁸ Hawaii PUC Docket No. 2019-0323, Order No. 36538.

²⁵⁹ Hawaii PUC Docket No. 2019-0323, Order No. 37816.

²⁶⁰ Hawaii PUC Docket No. 2019-0323, Order No. 37853.

²⁶¹ Hawaiian Electric Industries, Inc. (2021), Exhibit 1.

²⁶² Hawaii PUC Docket No. 2019-0323, Order No. 37816.

The speed at which the PUC approved the EDRP must be highlighted. The Hawaii PUC recognized the need to implement DER technologies as a means to promote a safe, reliable transmission and distribution system and fast-tracked an innovative, yet attainable, solution in a matter of a few months. In addition, the PUC ensured that the true value of solar-plus-storage systems was realized, including the benefits received via grid services as well as the reduced risk associated with the consistency of the scheduled dispatch of energy to the grid.²⁶³ As a result, individual utility customers and third-party owners of solar-plus-storage systems enrolled in the EDRP can now be compensated more fully for supporting the electric grid. The PUC's efforts to include a remote dispatch program has the potential to increase resilience for the utility as well as the customer in their own home by providing sustained power during system disruptions.²⁶⁴ Overall, the EDRP will help secure Hawaii's energy independence, expanding the market for DERs and demand response technologies and making innovation in the electric utility sector more accessible.

The Hawaii PUC recognized the need to implement DER technologies as a means to promote a safe, reliable transmission and distribution system and fast-tracked an innovative, yet attainable, solution in a matter of a few months.

An important take-away from the Hawaii experience is the value of PUCs having broad legal authority to implement alternative strategies for ensuring the provision of safe, reliable, clean, and affordable power. Given the pace of technological change and the urgency for solutions to climate challenges, vesting commissions with broad authority to undertake regulatory innovation, like the PBR and Emergency Demand Response initiatives in Hawaii, is warranted.

4.3 A Vision for the Future

The case studies shed light on some of the most innovative actions underway in the electric utility sector, underscoring the benefits of bold and effective leadership, regulatory flexibility, and data transparency in advancing electricity systems towards predominantly distributed generation and modern energy technologies. Regulators in Vermont and Hawaii seized attainable near-term solutions in concert with long-term transformations that will create lasting change.

To enable innovation in the transition to a modern electric grid, there must be a vision of the future whereby competitive market engagement for DER technologies leads to greater innovation, as market participants compete to drive down prices and provide the best products and services. While not central to the Vermont and Hawaii discussions above, recognition of the value of resiliency benefits will also play an important role in supporting widespread adoption of DERs such as solar, battery storage, and managed charging for electric vehicles. The decentralized, two-way power system is being embraced in some states as an important strategy to

To enable innovation in the transition to a modern electric grid, there must be a vision of the future whereby competitive market engagement for DER technologies leads to greater innovation, as market participants compete to drive down prices and provide the best products and services.

²⁶³ Hawaii PUC Docket No. 2019-0323, Order No. 37816.

²⁶⁴ Hawaii PUC Docket No. 2018-0088, Decision and Order No. 37787.

decarbonize the grid and meet commitments to reduce their dependence on fossil fuel.²⁶⁵ As the system evolves over time, regulation is adapting as it pushes the electric utility sector towards a more decentralized, resilient, and affordable clean energy future.

In order to make this vision a reality, stakeholders should first focus on innovative and attainable near-term solutions, paving a path for transformative, long-term solutions to modernize the electric grid.

4.3.1 Near-Term Solutions

There is no time to waste for modernizing the electricity system due to the growing threats from climate change. Fortunately, there are actionable solutions, described below, that regulators, utilities, and competitive providers can deploy in the short term to begin the transition to a decentralized power system. Utilities and regulatory authorities should seize these opportunities for short-term progress while working towards longer term structural change.

4.3.1.1 Reduce Barriers to Innovation

Innovation is the key to rapidly modernizing the electric grid. The GMP Innovative Pilots Program discussed above exemplifies how streamlining regulatory processes for testing and implementation of pilot programs can help spur a more modern electric utility sector. In addition, the Hawaii PUC set a new standard for timely regulatory processes by approving the Emergency Demand Response Program, from its request for proposals to approval of the implementation plan in only three months.

Further, a Connecticut Public Utilities Regulatory Authority proceeding²⁶⁶ is investigating innovative technology applications and programs. The Straw Proposal for an Innovation Pilots Framework for a “regulatory sandbox” outlines how utilities, third-party developers, or a collaboration among them will be able to submit pilot proposals and deploy programs upon selection in a “fail fast” model as a means of quickly identifying and scaling successful projects.²⁶⁷ Allowing non-utility actors to propose pilots is innovative in itself. To be successful, there will need to be political and regulatory tolerance for pilot failures. Setting reasonable cost guardrails and accountability metrics will be important. Michigan provides a helpful example through its framework for pilots as part of the Michigan Power Grid. The Public Service Commission (PSC) requires pilots to include clear expectations, objectives, and evaluation criteria from the outset.²⁶⁸



Solar panels installed by Sunrun employee

While these examples provide insight into innovative efforts to modernize the electric utility sector, under the cost-of-service regulatory model the majority of utilities continue to lack sufficient incentives to innovate. States with particularly lengthy regulatory processes could benefit from innovative utility regulation pathways similar to the ideas described in this essay.

²⁶⁵ See Hawaii PUC Docket No. 2019-0323, Order No. 38239.

²⁶⁶ Connecticut PURA Docket No. 17-12-03RE05.

²⁶⁷ Connecticut PURA (2021) at 6–7, 15.

²⁶⁸ See PSC orders, the staff report, and pilot directory at https://www.michigan.gov/mpsc/0,9535,7-395-93307_93312_93593_95590_95594_95685-508663--00.html.

4.3.1.2 Foster a Market for Distributed Energy Resources

DER technologies offer significant economic, reliability, and resilience benefits for the electric grid as well as electricity consumers. This value can be delivered at both the wholesale and distribution system levels. In the last few years, distributed storage has transformed distributed solar into reliability and resilience resources by enabling power to be stored for use in emergencies or times of peak demand.²⁶⁹ Advances in demand response, distributed generation, energy storage, and other DER technologies are now paving the way for a cleaner, more reliable, and resilient electric grid.²⁷⁰



Installer with solar panels

Aggregations of DERs, also known as virtual power plants, provide grid services, shifting energy demand or exporting energy to the grid in response to price signals, load shaping, or other triggers. When incorporated into the bulk power system, virtual power plants can replace high-emissions peaker plants, regulate voltage, and defer costly upgrades to the grid infrastructure.²⁷¹ Such DER investment can be encouraged by valuing DERs for resilience as well as energy and capacity.²⁷² In 2020, FERC issued Order 2222, providing support for innovation by requiring regional grid operators to allow DER aggregations to participate in wholesale energy and grid services markets. While we are still awaiting compliance filings and plans from ISOs and RTOs to implement FERC’s direction, Order 2222 provides a pathway to lower costs for consumers, greater flexibility for the bulk power system, and reduced dependence on fossil fuel resources.²⁷³

State regulators can account for the full value that DERs bring to the grid using a framework like the *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources*.²⁷⁴ Utility

commissions should establish and refine rules over time to promote the beneficial use of DERs. Utilities can maximize the benefits of DERs and optimize their distribution through DER management software, and effectively address the needs of both consumers and the electric grid.²⁷⁵

4.3.1.3 Incentivize the Use of DERs as a Resiliency Resource

Resilience and reliability are related. Both refer to electricity system operation during unexpected events or disturbances; however, resilience involves the grid’s ability to withstand, absorb, recover, and adapt to disturbances.²⁷⁶ Thus, the term *resilience* recognizes that disturbances will inevitably occur—and unfortunately with greater frequency due to climate change—and electricity systems must be ready for such events. DER technologies have the capability to operate outside of the centralized power system,

²⁶⁹ Reliable grid operation is defined under the Energy Policy Act of 2005 as maintaining an equilibrium among the elements of the bulk power system in order to avoid instability and outages during an unexpected event—in other words, keeping the lights on.

²⁷⁰ Cleary and Palmer (2020) at 4–5.

²⁷¹ Silicon Valley Clean Energy and Gridworks (2019) at 3–5.

²⁷² Lowder and Xu (2020).

²⁷³ FERC 18 CFR Part 35, Docket No. RM18-9-000, Order No. 2222.

²⁷⁴ NESP (2020).

²⁷⁵ This approach is like Peter Fox-Penner’s notion of the utility as a “smart integrator,” which would provide a service platform to foster a marketplace of energy products and services. See Fox-Penner (2020).

²⁷⁶ Bhusal et al. (2020) at 18082.

maintaining power for host customers. Thus, resilience can be considered a local attribute,²⁷⁷ supporting the operation of essential local functions when major disturbances affect the wider-area grid. Hurricane Ida provides insight into this kind of micro-scale resilience.

Making landfall in late August 2021 with wind speeds of 150 miles per hour, Hurricane Ida severely damaged the electric utility’s system and left nearly 950,000 customers of Entergy Louisiana and Entergy New Orleans without power.²⁷⁸ Despite proposals by stakeholders to build a more resilient, distributed energy system to augment Entergy’s centralized electric grid, the utility had failed to modernize. Instead, cost-of-service regulation incentivized the utility to invest in a new gas-fired power plant—a plant that was useless during this natural disaster.²⁷⁹

Meanwhile, a microgrid²⁸⁰ in Entergy’s service area using a solar-plus-storage system that powers a 50-unit mixed income apartment complex provided resilience in the wake of destruction. The microgrid provided sustained power through Hurricane Zeda and winter storm Uri in 2020. The record-breaking winds of Hurricane Ida knocked the microgrid offline temporarily; however, it was back online within two days of the event, compared to restoration of power to some customers from Entergy’s gas-fired power plant three days after the event.²⁸¹

While there is increasing interest in microgrids to help provide resiliency, many regulatory commissions have been hesitant to approve requests for ratepayer funding to support microgrids.²⁸² “Public purpose microgrids”²⁸³ can play a critical role in ensuring that essential facilities in communities can be operated during grid outages. Some examples of public purpose microgrid types that warrant regulatory consideration for ratepayer or other public funding and have been evaluated include: emergency response, emergency shelters and housing for immobile populations, and essential public infrastructure (schools, public safety, health and community centers).²⁸⁴

There is also resiliency value enabling individual homes to operate off-grid during an outage with home solar and batteries. There are numerous stories of neighbors helping neighbors with refrigeration, heat, and shelter during grid outages over the past few years.²⁸⁵ Moreover, individual home “microgrids” reduce strain on the grid and thereby reduce the risk of related wildfire from damaged lines.²⁸⁶

Energy efficiency is also a valuable DER for supporting resiliency. Insulation and other efficiency measures help maintain habitable temperatures for longer periods during extended outages.²⁸⁷

These examples demonstrate the ability and potential of DERs to augment the centralized power system to provide resilience and meet the needs of consumers at every income level. Federal funding could be utilized to further

These examples demonstrate the ability and potential of DERs to augment the centralized power system to provide resilience and meet the needs of consumers at every income level.

²⁷⁷ Kristov (2021).

²⁷⁸ Entergy Corporation (2021a).

²⁷⁹ St. John (2021).

²⁸⁰ Solar Alternatives (2020).

²⁸¹ St. John (2021). For more information on resiliency benefits of microgrids, see Rickerson and Zitelman (2022).

²⁸² Synapse Energy Economics and Sandia National Laboratories (2021).

²⁸³ A public purpose microgrid can be defined as “microgrids that serve the public interest in island mode on extreme events days, in addition to interconnected mode on normal days.”

²⁸⁴ Id.

²⁸⁵ See Sunrun (2019).

²⁸⁶ Id.

²⁸⁷ Frick, Carvallo, and Schwartz (2021).

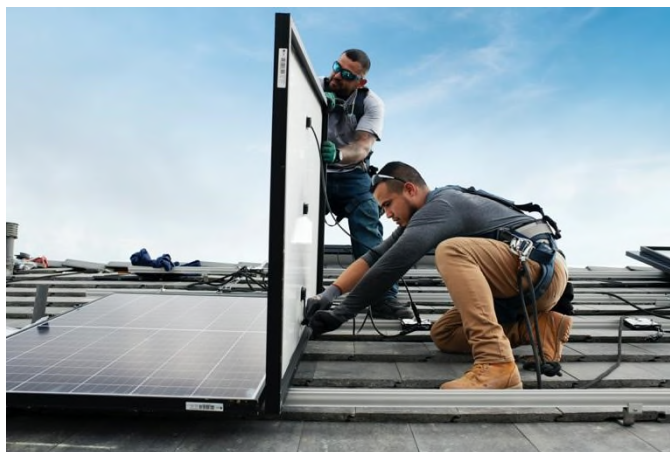
promote the integration of DER technologies in disaster-prone areas and ensure that the most disadvantaged communities benefit from grid modernization.

4.3.1.4 Require Utilities to Facilitate Service Upgrades and Interconnection

As exemplified by GMP’s BYOD Program and Hawaii’s Emergency Demand Response Program, it is possible to create pathways that expand the market for DER technologies to improve grid resilience while considering the interests of all stakeholders. To expand this market effectively throughout the United States, certain infrastructure improvements are necessary. Specifically, utilities need to provide or facilitate timely service line and main panel upgrades. Much of the country’s residential building stock and utility service infrastructure was not constructed to accommodate new electric appliances, solar, battery storage, and electric vehicle charging. As a result, main panel upgrades are commonly required to comply with building and electrical codes before these technologies can be installed. Policies for timely upgrades and cost allocation for these upgrades can accelerate projects and enable swift integration.

There are technological solutions through “smart” panels that can manage on-site power intelligently during grid outages. These panels can support home electrification by directing power where it is most needed in a home during an outage. However, these benefits cannot be realized unless the process for service upgrades by utilities is simplified and expedited.

Infrastructure improvements, including main panel and service line upgrades, will be essential for electric vehicles with bidirectional inverter functionalities as well. High costs and limited hosting capacity on the grid will create barriers for what could ultimately become a key grid asset. NREL estimates that by 2050, the electrification of transportation and other sectors will require a doubling of total U.S. generation capacity.²⁸⁸ To reliably meet state and federal climate goals, policymakers need to both scale clean energy deployment and efficiently use battery capacity, including batteries that will be sitting in peoples’ driveways via vehicle-to-grid integration.²⁸⁹



Installers placing panels on roof, Bakersfield, California

²⁸⁸ NREL (2021).

²⁸⁹ In May 2021, Sunrun announced that it will serve as the preferred installer for Ford Intelligent Backup Power, debuting on the all-electric F-150 Lightning light-duty truck. Sunrun will facilitate installation of the bidirectional 80-amp Ford Charge Station Pro and home integration system. With Ford Intelligent Backup Power and later the introduction of Ford Intelligent Power, the F-150 Lightning can serve as a reliable home backup energy source by powering the home during a power outage event. The charging system has the ability to manage energy needs by exporting electricity to the grid in the future as well. Through the partnership, customers will be provided with the opportunity to install a solar and battery system on their home, enabling them to charge their F-150 Lightning with the power of the sun.

4.3.1.5 Promote Transparency and Accountability

While reducing barriers to innovation and fostering a competitive market for DERs will drive a more affordable and resilient modern electric system, transparency and accountability are critical for effective programs, policies, and regulations in the electric utility sector.²⁹⁰ As expressed in the case study of the Hawaii PUC, allowing parties to the IGP docket to access the utility’s capacity expansion modeling tool resulted in greater transparency and input from stakeholders, and reduced the ability of the utility to act on any capital investment bias to influence its decision-making process. This is especially important in situations where utility regulators defer to utility feasibility, risk, and cost-effectiveness assessments when approving or denying utility investment proposals and the associated requests for cost recovery.

While reducing barriers to innovation and fostering a competitive market for DERs will drive a more affordable and resilient modern electric system, transparency and accountability are critical for the creation of effective programs, policies, and regulations in the electric utility sector.

Requiring utilities to share data analysis with other stakeholders will reduce the asymmetry of information²⁹¹ and ensure utilities are held accountable for their actions. Moreover, open access use of these tools can help identify pathways for progress that all stakeholders can agree on, toward transforming the electric grid to prepare for a high DER future.

While the Hawaii PUC’s efforts were successful in establishing greater visibility into the utility decision-making process, decision-makers can undertake accurate assessments on their own. Many PUCs do not do their own modeling analysis, but more commissions are acquiring capacity expansion models and conducting independent analysis. Local Solar for All²⁹²—an organization with a mission to create a safer, more affordable and equitable way to supply power to communities—commissioned a study using the WIS:dom-P (Weather-Informed energy Systems: for design, operations and markets planning) capacity expansion and production modeling tool to assess DER value and optimize integration of DER technologies in the U.S. electricity system.²⁹³ Notably, the study highlights the role of local DER technologies in job creation, emissions reduction, and modernizing the nation’s electric system at the lowest cost.²⁹⁴ By using sophisticated tools such as WIS:dom-P for grid planning on the local level, decision-makers have the opportunity to fully value DER integration and share the results with all stakeholders, promoting a more inclusive and transparent decision-making process for the future of the electric grid.

An important additional step is to involve diverse community-based organizations in program development and implementation, so that energy justice is a goal and outcome of utility commission processes. Utility programs that prioritize energy justice should strive to increase DER access to communities of color and low-wealth communities that have lower amounts of DER adoption, as well as remediate the cumulative environmental and social impacts of decades of fossil energy production.²⁹⁵

²⁹⁰ Data privacy and ownership issues can and must be resolved by PUCs so as to not hinder critical access to data. Audrey Zibelman, former CEO of the Australia Energy Market Operator and former Chair of the New York PSC, discusses the need for access to data, referring to the “democratization of data” based on her experience in Australia in Zibelman, Audrey (2021).

²⁹¹ California PUC (2020) at 86.

²⁹² Coalition for Community Solar Access (2020).

²⁹³ Clack et al. (2020).

²⁹⁴ Clack et al. (2020) at 1–14.

²⁹⁵ Farley et al. (2021).

4.3.2 Long-Term Solutions

While the near-term solutions described above provide ways to initiate grid transformation, the long-term solutions will push electricity systems over the threshold into modern grids. In a future where DER technologies allow customers to be electricity providers in a decentralized, two-way power system that promotes grid reliability and resilience, innovative regulation is needed for this to become reality. As the market for DERs in the United States continues to grow, utilities must evolve as well. Despite the benefits that DERs provide to the grid and customers alike, a high DER future could reduce regulated-utility revenue under traditional cost-of-service regulation.²⁹⁶



Sales representative talking with new customer in Chicago, Illinois

Some utilities are actively participating in the market for DERs. As described above, GMP in Vermont offers a program for customers for utility-owned energy storage systems, in addition to its BYOD program, that allows the utility to engage in the DER marketplace. Through this program, GMP customers can lease Tesla Powerwall batteries along with a gateway device, further fostering a market for nascent energy storage technologies and expanding options for customers to participate in this market. The program is contributing to a reduction in greenhouse gas emissions, providing net positive benefits for participating customers, and improving grid reliability and resilience for all customers.²⁹⁷

While utilities can help foster a nascent market today, long-term participation may result in monopolistic control. That could potentially lead utilities, given their revenue-based incentive structure, to significantly raise DER prices in excess of the checks of market-based pricing.²⁹⁸ The appropriate role of utilities in competitive markets must be determined on a case-by-case basis—and might be justified for expanding a new market or providing services to historically underrepresented communities—with frequent evaluation to ensure that benefits of utility participation outweigh the costs.

The appropriate role of utilities in competitive markets must be determined on a case-by-case basis—and might be justified for expanding a new market or providing services to historically underrepresented communities—with frequent evaluation to ensure that benefits of utility participation outweigh the costs.

In acknowledging the potential risks and rewards of utility participation in the competitive market for DERs, the Vermont PUC established a time-limited tariff for the storage program in order to reassess GMP's direct role in 2022.²⁹⁹ If the vision of a high DER future is to be successful in the long run, the regulatory structure of utilities must adapt so that innovation can bring reliability and resilience to a low-carbon grid.

²⁹⁶ CPUC (2020).

²⁹⁷ Vermont PUC Case No. 19-3537-TF, Final Order.

²⁹⁸ Schwartz (ed.) (2017) at 30–39.

²⁹⁹ Vermont PUC Case No. 19-3537-TF, Final Order.

An appropriate role for utilities in a high DER future might be that of a Distribution System Operator (DSO). While the DSO model can be tailored to each regulatory regime, the basic functions of the DSO model include:

1. Promoting a safe and reliable distribution system
2. Procuring and coordinating distributed reliability services
3. Coordinating and distributing power to customers, as well as across the transmission and distribution interface.³⁰⁰



Customer home with solar panels

There are already utilities with structures in place throughout the United States that carry out many functions of the simple DSO, making these entities ideal candidates to shift into this new role.³⁰¹ States should assess the best way to implement the DSO model to meet the needs of customers, provide utilities with fair returns, and continue to support innovation. As a DSO, a utility will functionally become a platform provider for both hardware and software systems. In a competitive market, the DER provider role will be held by third-party vendors. Allowing third parties to take on this role should result in lower prices for DERs, more competitive options as innovation sparks creation of new technologies, and an opportunity for third parties to work in partnership with utilities, instead of competing with them, to provide better services to customers and promote transparency.³⁰²

Further, in the two-way energy system of the modern era, customers will increasingly take on the role of electricity providers through automated and dispatchable DER technologies and provide utilities with more information about electricity demand, supporting a more reliable and resilient electric grid.³⁰³ The utility's coordination of all these actors will promote a high DER future.

While the theoretical concept of a DSO model has been extensively researched,^{304, 305, 306, 307} only one state has attempted to shift the roles of the utility to a DSO. Track One of the New York Reforming the Energy Vision (REV) regulatory docket sought to tackle the inefficiencies of top-down utility regulation by transitioning to a DSO model—called a *distributed system platform*, in this case—to usher in a distributed, modern electric system. Facing increasing electricity rates, load defection from DER installation, and inequitable distribution of DER technologies, the New York Public Service Commission saw the DSO model as a means to promote a customer-centric approach that uses the power of technologies and markets to ensure the affordable provision of electricity to customers and enhance reliability and resilience of the grid.³⁰⁸ While New York REV promised a bold vision, REV did not yield a DSO model. Restructuring the electric distribution system and the role of regulated utilities is not an easy task.

³⁰⁰ Kristov & De Martini (2014) at 4–6.

³⁰¹ California PUC R.21-06-017.

³⁰² Schwartz (ed.) (2017) at 32–35.

³⁰³ Bronski et al. (2015a) at 14.

³⁰⁴ Kristov and De Martini (2014).

³⁰⁵ Kristov and De Martini (2015).

³⁰⁶ Martinot, Kristov, and Erickson (2015).

³⁰⁷ CAISO et al. (2017).

³⁰⁸ New York PSC Case No. 14-M-0101 – Order Adopting Regulatory Policy Framework and Implementation Plan.

This real-world example demonstrates the importance of pursuing near-term solutions in a way that sets up the long-term shift to a DSO model. This theoretical framework has the potential to become a reality, but will require stakeholders (regulated utilities, competitive providers, and customers) to embrace innovative technologies and regulatory methods that support a high-DER future.

Although utilities are aptly positioned to take on the DSO role, concerns remain about incentives that investor-owned utilities face under traditional cost-of-service regulation. If electricity sales from central generating sources decline with the widespread installation of DERs, it will become more difficult for utilities to recover costs under a revenue-based incentive structure.³⁰⁹ Both GMP and the Hawaii PUC pushed for alternative regulation that would realign or completely alter the incentives of the electric utility while still offering a fair return on investment. There is no one-size-fits-all approach to incentivizing utilities to invest in a modern electric system.



Solar panel installer

Utility regulators can adopt a number of mechanisms that would alter electricity rate structures and promote a high DER future, such as the following:

- *Setting a cap on non-power costs.* Forecasting all non-power costs, including infrastructure and operating costs, based on expected expenditures and establishing a cap on spending to be recovered through the utility's rate base for a set number of years³¹⁰
- *Enabling shared savings with utilities.* Providing utilities with a share of the benefits from implementing programs and initiatives that result in customer savings³¹¹
- *Establishing performance-based regulation.* Rewarding utilities for exemplary performance and desired outcomes (and reducing earnings for poor performance) in areas such as renewable energy generation, reducing electricity costs, and providing quality customer service above what is expected³¹²
- *Decoupling revenue from retail electricity sales.* Realigning utility shareholder incentives to allow utilities to receive a fair return on their investments independent of electricity sales³¹³

By restructuring the roles of electric utilities, third parties, and consumers as well as realigning utility shareholder incentives to provide customers with quality service and lower rates (instead of favoring capital expenditures), the vision of a high-DER, low-carbon future supported by a reliable and resilient energy system can be realized.

³⁰⁹ Bronski et al. (2015b) at 34. Note, however, that widespread electrification of homes and businesses would result in increasing utility revenues and an opportunity, and need, for increased electricity supply from both DERs and centralized renewable resources. See Jacobson (2022).

³¹⁰ See GMP's Multi-Year Regulation Plan 2020–2022. Green Mountain Power (2020a) at 1–33.

³¹¹ Schwartz (ed.) (2017) at 42–43.

³¹² See the Hawaii PUC's Performance-Based Regulation Framework. Hawaii PUC (2021b).

³¹³ Lazar (2016) at 89.

4.4 Conclusion

The modernization of the electric grid will not be easy and will require hundreds of billions of dollars invested in both electricity systems and buildings. Given our climate crisis, state utility commissions must act with urgency and prioritize innovation in the way utilities are regulated and how customers engage with the grid. This will require a fundamental rethinking of how utilities make money and the role of customers and third parties in the generation and consumption of energy.

By establishing an ambitious, yet achievable, vision for the future premised on the integration of vast numbers of DERs in a competitive market for energy and grid services, decision-makers at every level will be able to implement policies and programs that will fulfill that vision. The case studies discussed here provide insight into what it takes to spur innovation in this sector, including bold leadership, flexible regulations, and transparency among stakeholders. Regulators and legislators have the opportunity to use these models as an example, seeking out near-term solutions that will reduce barriers to innovation, foster markets for DERs, and promote transparency and accountability. Innovative near-term solutions can lay the foundation for much-needed transformative solutions. The goal is to deliver a more sustainable electricity system by activating innovation with roles for consumers, third-party providers, and utilities under a market-driven model, such as a DSO. Through this new system, the electric utility sector will be revolutionized to support the needs of customers, reduce greenhouse gas emissions, and enable an electrified, high-DER future.

Given our climate crisis, state utility commissions must act with urgency and prioritize innovation in the way utilities are regulated and how customers engage with the grid. This will require a fundamental rethinking of how utilities make money and the role of customers and third parties in the generation and consumption of energy.

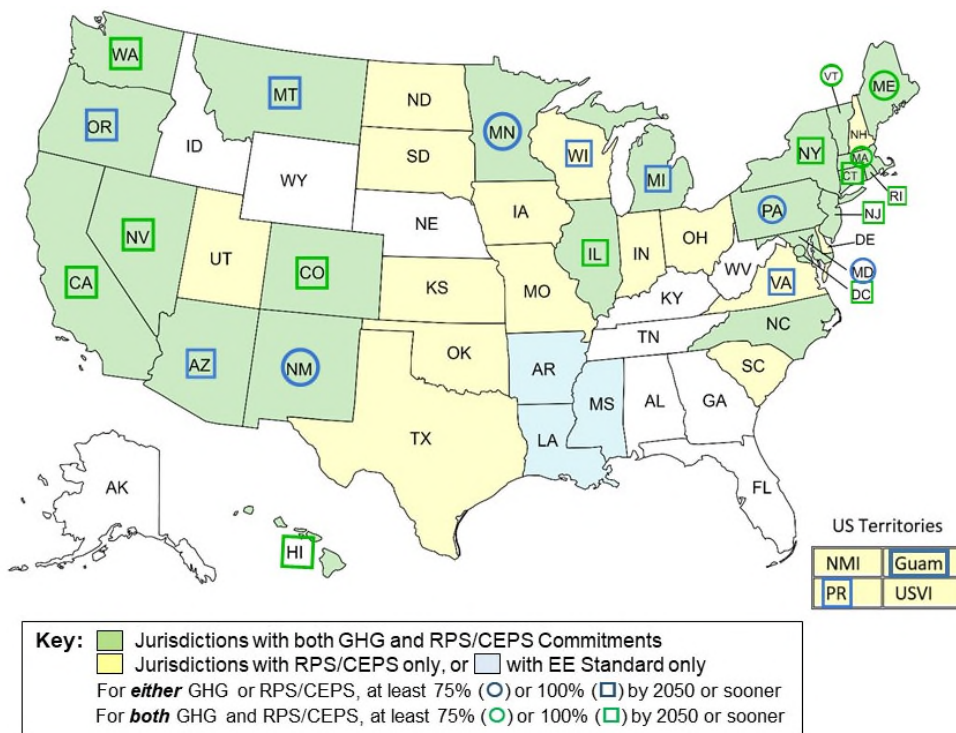
5.0 Scaling Utility Innovation: Identifying a Path to Action

By Kristin Barbato, Barbara Kates-Garnick, and Max McCafferty, Build Edison

5.1 Introduction

Energy and climate goals are accelerating around the country (Figure 16). Increasingly, states are moving in the direction of sustainable energy practices, and the targets for renewable generation, energy storage, electric mobility, energy efficiency, and energy equity continue to grow. States including Massachusetts, Maine, New York, California, and fourteen others have developed substantive clean energy and climate action policies, linked with strict timelines.³¹⁴

Figure 16. State Renewable and Clean Energy Goals



Source: National Regulatory Research Institute. November 2021

At the same time, our energy infrastructure is failing to cope with major storms, and the strain on the grid will continue to mount as we further electrify our energy usage, energy resources become increasingly decentralized, and variable renewable resources grow to a substantial level of generation.³¹⁵ Efficiently scaling innovative clean energy solutions is critical to meeting these goals and to cope with the rapidly evolving needs of the grid. According to the International Energy Agency, “Without a major acceleration in clean energy innovation, net-zero emissions targets will not be achievable.”³¹⁶

³¹⁴ Clean Energy States Alliance. “Table of 100% Clean Energy States” and “State Legislation, Plans Reports and Other Documents.” <https://www.cesa.org/projects/100-clean-energy-collaborative/guide/state-legislation-plans-reports/>.

³¹⁵ EIA (2021).

³¹⁶ IEA. n.d. Clean Energy Innovation Overview. <https://www.iea.org/reports/clean-energy-innovation?mode=overview>.

Utilities are a critical component of our electrical infrastructure and have a leading role to play in enabling innovation in the transition to a clean energy future. They have access not only to the physical assets of the grid, but data on customers and, in the case of vertically integrated utilities, generation and transmission data. This understanding of the technical demands of the grid, as well as the demands of customers and grid assets, means that utilities are central in identifying, deploying, and scaling necessary innovative energy solutions. No third parties have the combined access, resources, expertise, and reach to achieve the same level of impact. Since utilities have a role to play in achieving state energy policy goals, utility regulators have an increasing responsibility to incentivize utilities to engage with and scale innovative solutions. As stated by the National Conference of State Legislatures, the challenge is “craft[ing] policies that promote cost-effective investment in the electric system while allowing innovative technologies and new energy management approaches to flourish and compete in a rapidly shifting environment.”³¹⁷

This understanding of the technical demands of the grid, as well as the demands of customers and grid assets, means that utilities are central in identifying, deploying, and scaling necessary innovative energy solutions. No third parties have the combined access, resources, expertise, and reach to achieve the same level of impact.

Yet in the process of identifying and deploying new solutions, scaling has been largely neglected by both utilities and regulators. First, innovative solutions to energy and grid challenges are often trapped in pilot after pilot with no clear path to scaled deployment.³¹⁸ Second, regulators broadly do not allow sufficient opportunity for utilities to recover the costs of scaling of new technologies. There is a gap in the process of deploying innovation solutions, which must be addressed by both utilities and regulators to efficiently meet accelerating energy goals.

This essay seeks to understand and define the challenges in the utility innovation adoption process and recommends potential solutions for both utilities and regulators to enable solutions to scale more consistently and efficiently.³¹⁹ It focuses on technologies which support utility infrastructure, with the understanding that many technologies straddle the divide between utility infrastructure and private assets—for example, energy storage and electric vehicle chargers. Our observations about where we have come from, and where we need to be in terms of integrating innovation in both the regulatory and utility mindsets, were reinforced by our interviews with experienced participants in both regulatory processes and utility decision-making.

5.2 The Gap

The road from conception to a scaled energy solution is long and arduous. Developing and scaling a technology, particularly an energy technology, is capital- and time-intensive and fraught with risk. The Rocky Mountain Institute identified four “Valleys of Death” for energy companies as they struggle to identify the best path to broad deployment (Figure 17).³²⁰

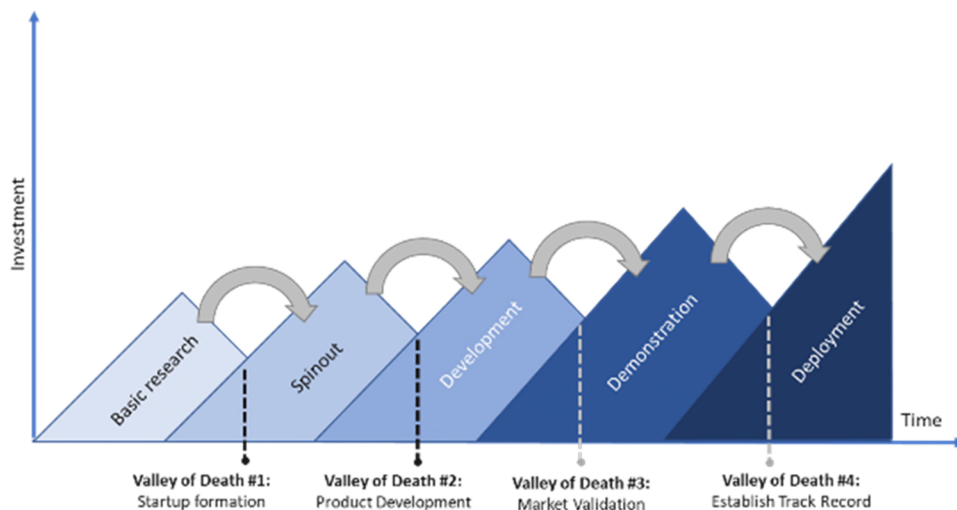
³¹⁷ National Conference of State Legislators (NCSL) (2021) at 1.

³¹⁸ See Michigan Public Service Commission (2022) at 11. Also see Faruqui (2020).

³¹⁹ Rogers (2003).

³²⁰ Wang and Yee (2020).

Figure 17. Valleys of Death for Energy Technologies



Source: Wang and Yee (2020)

Here, our focus is Valley of Death #4: “Establish Track Record.” That is the process between demonstration projects (Valleys of Death #1–3) and broad deployment, where a technology is proven but not yet scaled. At this point, technologies need to have eliminated technical risk and demonstrated reliability at scale.

One example of this challenge is the utility deployment of time of use (TOU) electricity rates. Between 1975 and 2020, there were four generations of pilots for TOU rates.³²¹ Today, the deployment of TOU rates is accelerating, as recent pilots have shown that they can “effectively shift power consumption from peak demand and drive significant savings for both utilities and customers.”³²² While there were issues to resolve related to advanced metering technology and customer education for the deployment of TOU rates to gain traction, it nevertheless took 43 years and 4 generations of pilots to achieve only 4% residential customer penetration for TOU rates by 2018, and 15 utilities in 8 states plus the District of Columbia accounted for 86% of all TOU deployments.³²³

The timelines for grid modernization projects tell a similar story. From the date of petition filing, the timeline for approving utility grid modernization projects for innovative solutions is a year and one month on average, and can be as long as three years. Furthermore, the average project takes five to eight years to complete from the initial filing.³²⁴ These long timelines (Figure 18) prevent solutions from efficiently scaling to broad deployment and represent a key challenge in deploying innovative technologies and meeting legislative goals.

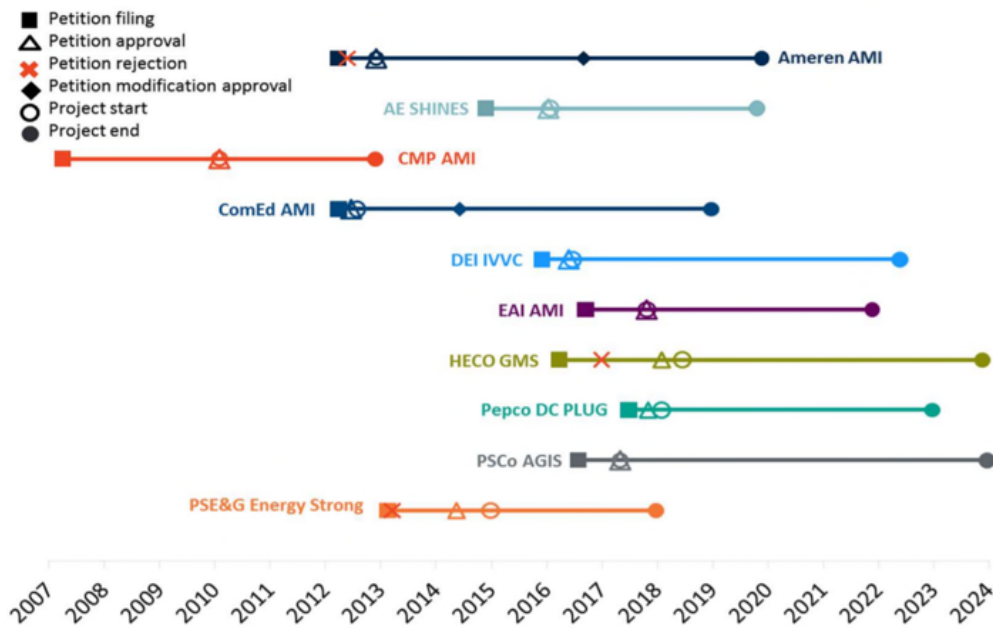
³²¹ Faruqui (2020).

³²² Trabish (2019).

³²³ Faruqui (2020).

³²⁴ Sergici (2018).

Figure 18. Timelines for Approval and Completion of Utility Grid Modernization Projects.³²⁵



The deployment of TOU rates, as well as grid modernization project timelines, illustrate challenges facing innovative solutions in scaling from demonstration to deployment. Regulatory, cultural, and process challenges slow the scaled deployment of energy infrastructure solutions, and by extension progress towards energy and climate goals.

The following sections examine utility and government innovation programs, as well as regulatory funding mechanisms and processes. These sections explain the motivation, design, strengths, and limitations of these entities, programs, and processes, and identify opportunities to improve them. Namely, regulatory processes must be reexamined to facilitate utilities investing in innovative solutions, and pilot programs must be reexamined to understand the cultural and process challenges that prevent solutions from scaling to deployment efficiently.

5.3 Regulatory Processes

Several regulatory mechanisms provide utilities with fair compensation for their investments and operations to enable reliable access to power for all retail customers in their territory. As regulators and utilities have begun to recognize the importance of innovation investment, many of these mechanisms have been used as a dedicated channel to allocate funding for the sole purpose of spurring innovation. These mechanisms include policy dockets, rulemakings, and programs such as the Electric Power Investment Charge (EPIC) in California, which has successfully allocated millions of dollars towards research and development (R&D) and other pilot activities.³²⁶ However, these mechanisms are often secondary to the rate case, the central compensation mechanism for investor-owned utilities (IOUs). If scaling innovation becomes a core responsibility of the utility, state regulators will be approving billions

³²⁵ Sergici (2019).

³²⁶ Electric Program Investment Charge Program – EPIC. 2022. <https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program>.

of dollars in spending for utilities to invest the necessary capital and address energy and climate challenges.

The principles and tenets underlying traditional utility ratemaking are well documented from legal, public policy, economic, and utility perspectives.³²⁷ The rate case process that has developed over the twentieth century and into the twenty-first century has allowed utilities to be financially healthy and invest in necessary infrastructure and programs, while protecting customers from exploitation by a natural monopoly. The process has been robust and flexible in responding to a range of circumstances and has operated within a clear framework of the “public interest” to provide “fair and reasonable rates” to customers. But the system that has survived over the years has also supported incumbency, promoted resistance to change, and delayed meaningful investment in innovation both in process and technology application.

[T]he system that has survived over the years has also supported incumbency, promoted resistance to change, and delayed meaningful investment in innovation both in process and technology application.

5.3.1 Utility Framework Overview

Utilities have the right to operate in a geographic franchise territory and recover their costs of service through retail rates in exchange for an obligation to provide all customers in that area with reliable and non-discriminatory service. This framework has benefited both the utility and its customers under the mantra of “just and reasonable rates.”³²⁸ To summarize, this has meant rates are developed through an extensive regulatory investigation guided by the following tenets:

- Fairness, affordability, and reasonable rates applied to all customer classes
- Appropriate cost to serve applied to distinct customer classes, while avoiding discriminatory pricing for any customer class
- Recovery of costs prudently incurred by the utility
- Sufficient revenues and returns to attract investment for utility infrastructure and customer service

Participation by a broad range of intervenors—stakeholders that formally participate in proceedings—may result in more balanced outcomes, although regulatory precedent tends to favor incumbents. Given the legal framework, decisions are based on precedent, which poses a serious challenge to funding innovative solutions. There is a monetary cost to intervene and an implied knowledge that the process, though appearing fair and open, is arcane, and tends to favor a set of incumbent interests. Yet the inherent uncertainty of this process creates regulatory risk for utilities seeking rate relief for their expenses and capital investments, and for consumer advocates seeking to minimize costs. The rate case seeks to balance the public interest, the economic interest of the utility, and the financial needs of the customer. In a sense, the overarching goal of the rate case is to minimize investment risk taken by the utility while protecting customers from exploitation. However, we are now in a situation where scaling new technologies, a process which inherently involves some risk, has become a priority.

In general, the current rate case paradigm worked well within a framework of incumbency. Utility and customer risks are constrained. Society’s broad goals of universal service and affordable rates have

³²⁷ Phillips (1993).

³²⁸ See *Bluefield Waterworks v. Pub. Serv. Comm’n*, 262 U.S. 679 (1923) and *FPC v. Hope Natural Gas Co.*, 320 U.S. 591 (1944). Also see *Bonbright* (1961).

largely been achieved. Investment in infrastructure, particularly delivery systems, have flourished. Moreover, traditional utility ratemaking has proven to be adaptive and robust over the years in dealing with new needs—for example, new ratemaking conventions, industry restructuring in many states, energy efficiency, and even mechanisms designed to deal with the declining growth of electricity sales and non-revenue producing infrastructure.

However, recent focus on energy equity has pointed to a deeper consideration of procedural, distributive, and restorative justice within the utility regulatory framework and the need to address the inequities baked into the existing system.³²⁹ Efforts to bring 40% of all benefits from federal climate initiatives to disadvantaged communities also has implications for state regulatory and policy decisions. While traditional ratemaking has focused on addressing equity concerns through implementation of low-income rates, equity may now be broadened to encompass innovation. For example, new technologies and utility demonstration projects should be available to historically excluded ratepayers and communities.³³⁰

Over time, adaptive mechanisms have supported public policy choices within the traditional regulatory framework, although these mechanisms often are implemented outside traditional rate cases. Thus, we have cost trackers, system benefits charges, infrastructure surcharges, future test years, capital allocated for Construction Work in Progress, revenue decoupling, performance-based regulation, and formula rate plans. Another mechanism to deal with regulatory risk and after the fact second guessing is pre-approval of utility activities, expenses, and capital investments, often constrained by budgetary limits and subject to meeting pre-approved metrics and goals.

While the driving philosophy of the rate case has been successful up to this point, the role of the utility is shifting as sources and uses of electricity continue to evolve. As a former New York State energy advisor put it in one of our interviews, “Although it is a challenge to provide reliable power to over 300 million customers, utilities have historically not offered a whole lot. Customers have limited choice in providers, they are not being provided clean energy at the pace that they need to be, the utility was largely failing to stimulate innovation, and utilities were holding on tightly to this business model. It was a golden cage, and they were protected by regulations focused solely on anachronistic KPIs [key performance indicators] around reliability and access.”

The principles of the rate case need to be reexamined to account for the evolving role of the utility. The dangers of climate change are looming, natural disasters are massively disrupting utility services around the country, and state energy and climate goals are increasingly ambitious. Going forward, the role of the utility needs to include identifying and scaling the solutions that will allow us to overcome and thrive in the face of these challenges. While the core principles of the rate case, including prudence, affordability, and fairness, should certainly not be abandoned, these principles should be reexamined. Regulators ought to begin taking a broader view and consider these customer safeguards in the context of rising energy and climate challenges and the importance of identifying and deploying innovative solutions to address these challenges.

While the core principles of the rate case, including prudence, affordability, and fairness, should certainly not be abandoned, these principles should be reexamined. Regulators ought to begin taking a broader view and consider these customer safeguards in the context of rising energy and climate challenges and the importance of identifying and deploying innovative solutions to address these challenges.

³²⁹ See Farley et al. (2021).

³³⁰ The White House (2021).

5.3.2 Technology Examples

The following principles govern utility investment decisions in innovative technologies:

- Risk is inherent with new technologies, and while it can be managed it is rarely eliminated.
- The reward for any new technology investment must outweigh the risk of failure.

In many ways, these principles about accepting and managing risk are opposed to the principles of the rate case, which stress prudence, low cost, and minimizing risk. If regulators want to influence how the utility supports and scales innovation, aligning their respective interests is key. To better understand the disconnect between principles of the utility rate case and principles of investing in innovative solutions, we examine grid modernization technologies at different phases of deployment, and the successes and failures of each in the context of the technology, the value to the utility, the value to the customer, the perspective of the regulator, and how the technology was funded. While there are many considerations when it comes to maximizing the value of new technologies, this section focuses on successes and failures of technology deployments in the context of utility and customer interests.

5.3.2.1 Advanced Metering Infrastructure

Advanced metering infrastructure (AMI) is comprised of several technologies that provide enhanced capabilities to the grid and its customers, but here we focus on smart meters. Historically, utility meters performed the basic function of recording energy consumed over the billing period. Smart meters shortened the measurement time period dramatically, are programmable, and are capable of supporting time-varying pricing, providing timely consumption data to customers and third parties of their choosing, registering both energy consumed and energy delivered for power generated on site, providing notifications of loss of power outages, detecting energy theft, and more.³³¹ Smart meters also have enabled utilities to offer additional services to customers. For example, Baltimore Gas and Electric offers Energy Savings Day, which allows residential customers to participate in demand response events through an app connected to their smart meter. Georgia Power offers Pay by Day, a payment plan that allows customers to pay their bills in advance using a fixed daily energy price based on the projected usage of the customer over an entire year.³³²



Smart meter for farm solar electric system

Critically, smart meters provide tangible value to both utilities and their customers, and smart meters have been deployed broadly across the country. Between 2012 and 2019, 57 million smart meters were installed in the U.S., with an estimated 107 million meters deployed by the end of 2020, representing 75% of U.S. households.³³³ The 2009 American Recovery and Reinvestment Act provided substantial federal grants for grid modernization, including AMI, making the capital expense more palatable for many regulators. Regulators facilitated utility investment in this infrastructure by approving AMI proposals or broader grid modernization proposals, as well as approving recovery of AMI costs through rate cases.³³⁴

³³¹ National Energy Technology Laboratory (NETL) (2008).

³³² Cooper and Shuster (2021).

³³³ Cooper and Shuster (2021).

³³⁴ U.S. Department of Energy (n.d.).

Some regulators believe that AMI deployment has failed to generate the value promised to customers and has mainly benefitted utilities through lower operations costs.³³⁵ However, this is not universally true, and some utilities have been able to generate considerable value and engagement for their customers including Pepco, Duke Energy, NV Energy, and AEP Ohio.³³⁶ AMI infrastructure deployment represents the first step, and it is necessary that regulators push utilities to utilize this infrastructure to its fullest potential. It is critical that as utilities are allowed to invest capital and recoup their costs, that their investments be used to the fullest potential in service of the ratepayers. However, failure to utilize the tools provided by AMI is not an indictment of the technology, or an argument against its deployment, it is an indictment of the utilities who are not providing the services they promised to regulators and ratepayers.

While there are still unrealized opportunities for utilities to capitalize on smart meters and realize value for the grid and their customers, AMI deployment represents a successful example of scaling of a new technology. It found success because it aligned with regulatory principles as well as the principles of utility innovation investment decisions. The utilities bore the risk of deploying a new technology, but it unlocked huge amounts of data and utility business opportunities that were previously untapped. Likewise, federal funding improved the cost-effectiveness of the technology. And it has the potential to provide value to customers in the form of operational cost savings for utilities and unlocking additional options for customers to control their electricity bills.

5.3.2.2 Electric Vehicles



Electric vehicle charging station

Electric vehicle (EV) charging infrastructure is critical to facilitate state goals for electrifying transportation over the coming decades. Among the benefits for utilities and customers is the opportunity to reduce carbon emissions, particularly for states with GHG mandates. Wider adoption of EVs also enables utilities to use the distribution grid more efficiently if customers charge during off-peak hours, and greater consumption of electricity for transportation can spread electric utility system costs over more kilowatt-hours.³³⁷

However, EV infrastructure is still nascent in many states. Fewer than 10% of Americans have access to an EV charger.³³⁸

Unfortunately, there are gaps in charging infrastructure deployment that the private sector is failing to fill. One such failure is DC fast-charging, due to its high capital cost. Another market failure is the public level-two charging market.³³⁹ The potential benefits of EV charging, along with failures of the private sector to meet some important market demands, create an opportunity for utilities to support deployment of this critical infrastructure.

There also are risks associated with utilities deploying EV charging infrastructure. The greatest risk is stranded assets. If EVs fail to be adopted at the rate projected by the utility, or if certain technologies become obsolete, the cost to the utility could be significant.³⁴⁰ This raises questions about how EV charging infrastructure should be funded, and whether and how utilities should deploy these assets.

³³⁵ Trabish (2020).

³³⁶ Trabish (2020).

³³⁷ Jones et al. (2018).

³³⁸ Muller (2021).

³³⁹ Jones et al. (2018).

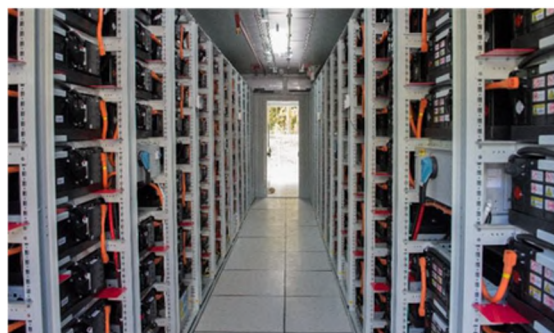
³⁴⁰ Jones et al. (2018).

Utilities around the country have petitioned regulatory commissions for EV infrastructure and rate designs with varying results. California and Hawaii utilities, for example, can use a cost-benefit methodology called the Societal Cost Test, which factors in the total benefits to society that would result from a project. Many other states, several of which have no emissions mandates, do not consider this test.

As a result, California and Hawaii lead the country in EV charger density.³⁴¹ When considering the deployment of new technologies, regulators should consider not only the downsides and risks, but also potential benefits in serving societal and legislative goals.

5.3.2.3 Energy Storage

Another technology often featured in state energy goals is energy storage.³⁴² Despite its importance in providing increased resiliency and flexibility to the grid, U.S. energy storage capacity is only 23.2 gigawatts (GW), compared to 1,110 GW of generation capacity.³⁴³



Puget Sound Energy's four-hour storage pilot in Glacier, Washington

As interest in these systems continues to grow, several challenges must be addressed. First is the difficulty of quantifying the value of energy storage to the utility system. Rocky Mountain Institute identified 13 value streams that energy storage systems can deliver, representing combinations of independent system operator (ISO) services, utility services, and customer services. Utility services include resource adequacy, distribution deferral, transmission congestion relief, and transmission deferral. Several studies have attempted to quantify the dollar value of these services, but estimates vary dramatically.³⁴⁴ Second, energy storage regulations are lagging in many regions, as they were crafted when the only viable utility-scale energy storage solution was pumped hydro.³⁴⁵ Utilities then are operating within an outdated regulatory construct.

Another key challenge to deploying energy storage projects is classification. Many resource classifications do not fit energy storage systems and can prevent consideration of a full range of services. Ownership also poses a challenge. In restructured states, utilities may be prevented from owning generation assets and, by extension, energy storage assets. That may run counter to a key function of utility-scale energy storage—grid resiliency and reliability. Interconnection and operation pose additional barriers. Integrating energy storage operations with the grid can be a complex undertaking. Existing interconnection rules and procedures might not always require energy storage devices to define and communicate to utility grid operators the parameters under which they are operating.

Energy storage is a key technology for the future of the grid, but there is misalignment of principles, utilities are not clear on how they will generate value from these assets, and numerous legislative challenges make it difficult for regulators to support their deployment.³⁴⁶

³⁴¹ Doll (2022).

³⁴² Twenty-three states, according to Pacific Northwest National Laboratory. 2021. Energy Storage Policy Database. <https://energystorage.pnnl.gov/regulatoryactivities.asp>.

³⁴³ Center for Sustainable Systems (2021).

³⁴⁴ Fitzgerald et al. (2015).

³⁴⁵ Edison Electric Institute (EEI) (2017).

³⁴⁶ Twitchell et al. (2021).

These examples highlight the importance of considering the broader value of innovative technology investment. When regulators consider the long-term value to ratepayers beyond immediate returns, utilities invest in key infrastructure for our evolving energy needs. Affordability, prudence, value to ratepayers, and other principles still need to be considered in these decisions, and utilities need to be held accountable for delivering on their promises. Innovative infrastructure deployment can open opportunities for utilities to cut costs and for ratepayers to generate value. For example, deployment of AMI technology was successful. Now utilities need to be held accountable for using this technology to its fullest potential.

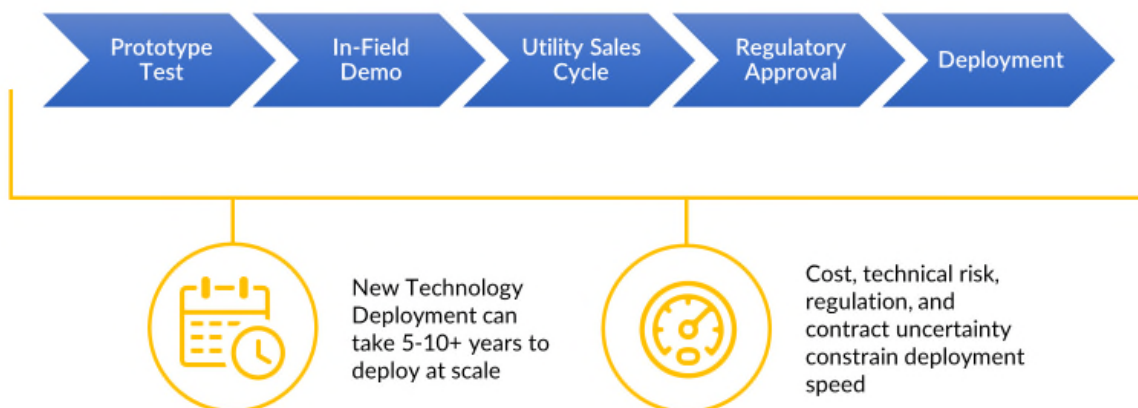
As regulatory and legislative mandates loom, considering the importance of scaling innovative energy solutions in the regulatory process and aligning regulators and utilities is crucial. The following section discusses this alignment and how it might be implemented by regulators and utilities to accelerate deployment of innovative projects.

5.3.3 Regulatory Challenges for Innovation

With the urgency of state energy and climate goals, we contend that an overly risk-averse approach—a hallmark of how utilities and regulators respond to change—ought to be reevaluated to better support the deployment of innovative solutions. While each individual step in the scaling process is critical, the traditional time frames governing regulated utility investments are simply too long to meet the present needs in the context of energy and climate goals (Figure 19) concerning electrification, decarbonization, and decentralization. Even with the quickly improving economics of renewable energy generation, electric vehicles, energy storage, and other distributed energy resources and grid modernization technologies, technology adoption through regulatory processes is slow and incremental by design, due to the traditional ratemaking principles of affordability, prudence, and equity. While these principles are intended to protect customers, they stifle the deployment and scaling of innovative solutions.

With the urgency of state energy and climate goals, we contend that an overly risk-averse approach—a hallmark of how utilities and regulators respond to change—ought to be reevaluated to better support the deployment of innovative solutions.

Figure 19. Implementation time frame for new technology deployment³⁴⁷



³⁴⁷ Sergici (2019).

Regulatory Considerations for Innovation

1. **Cost of service regulation** is backward looking and rewards past—not future—investments, adding regulatory and financial risk to innovation investments by the utility.
2. **Prudency** is applied conservatively and focuses on weeding out today’s unnecessary investments rather than looking forward to tomorrow’s needs.
3. **Affordability** is skewed by incomplete benefit-cost analyses—making it inherently difficult to assess new technologies and the value of enhancing grid capabilities grid.

Today’s ambitious 2050 climate goals passed in New York, California, New England states, and other states should spur the drive for innovation. Without new technologies and new business models, success in achieving those goals will be even more difficult.^{348, 349, 350} While catalyzing, some argue these laws need to be strengthened by directly linking public utility commission actions to low carbon mandates and equity.³⁵¹ Climate legislation in states like Massachusetts is helpful in pushing the envelope toward integrating innovation, but perhaps more explicit legislative guidance may be needed to address regulatory constraints and tensions, such as those between affordable rates and the potential costs of clean energy investments. More complete benefit-cost analysis can help.³⁵² In the interim, regulators across the country and their associated state agencies generally have limited approaches to innovation, such as those supporting traditional regulatory frameworks that provide a rate of return for transformers and other assets rather than demand optimization. As a result, some consumer advocates assert the grid is overbuilt, inefficient, and expensive rather than environmentally improved and empowering customers.³⁵³

Perspectives on risk affect approaches to innovation. For the utility, prudence determinations loom large as a regulatory risk. For regulators, they safeguard utility customers against unnecessary utility spending. In terms of innovation, this tenet of ratemaking is also a constraint, not simply a protection. It has reinforced the conservative nature inherent in the regulatory paradigm and in utility culture, whose focus on reliability and redundancy³⁵⁴ often leaves little tolerance for failure.

There is common ground in recognizing the symbiosis between risk-averse regulators and utilities. According to a former senior utility regulator and utility executive: “There is reluctance since everyone is risk-averse in this situation. The regulators are risk-averse on behalf of ratepayers. The utilities are risk-averse because they lack the precedent to recover the costs for innovative technology investments.” However, from this senior regulator’s perspective, this does not mean that utilities should not be deploying new technologies.

³⁴⁸ New York State Senate (2019).

³⁴⁹ Commonwealth of Massachusetts (2021).

³⁵⁰ UpLiftCA. 2020. California’s Climate Laws, a Quick Guide. <https://upliftca.org/quick-guide-to-californias-climate-laws/>.

³⁵¹ Acadia Center (2021).

³⁵² See the “Jurisdiction-Specific Test” in National Energy Screening Project (2020).

³⁵³ Shattuck, Anthony, and LeBel (2016).

³⁵⁴ N-1 contingency modeling is used to identify risks and plan for speedy restoration of service if any one component fails.

An issue raised in all our interviews with regulatory and innovation experts is the risk of failure, especially prohibitions against cost recovery for investments determined to be imprudent.³⁵⁵ Utilities fear that they will not fully recover their costs or might incur other penalties related to imprudent decisions. More than anything else, this fear is an impediment to deployment. Both a senior regulator and a former Vermont administrative law judge, seasoned participants in the regulatory sphere, agree that for utilities to deploy innovation there needs to be recognition that a failed technology deployment, at least at the pilot stage, should not mean the absence of compensation if the utility met a prudence standard. A failed pilot deployment is still “used and useful” if it enables the utility to determine whether the technology is systemically viable and learn from the pilot. According to Berkeley Lab’s pilot best practices handbook, “So long as the pilot is implemented as designed and the outcome is determined to meet the necessary level of rigor, accuracy, and precision that subsequent decision-making requires, an outcome counter to initial expectations should be viewed as a learning experience, not as a failure.”³⁵⁶

A failed pilot deployment is still “used and useful” if it enables the utility to determine whether the technology is systemically viable and learn from the pilot.

Consumer advocates are also necessarily wary of incentivizing innovation that splits customers into winners and losers, participants and non-participants, or “haves and have nots.” Introduction of new technologies can shift costs between customers within a customer class, depending upon their ability to shift their consumption or take advantage of a particular technology offer. A technology that enables a group of customers to leave the system or reduce their utility usage, such a rooftop solar, could ultimately raise rates for those who remain. These issues need to be recognized as potentially serious outcomes, particularly as the growing emphasis on energy justice and democratization of the grid highlights these considerations. Innovative rate design solutions and technologies that lower household costs and risks must be a critical part of regulatory and utility decision-making criteria for implementing innovation, because they support more consumer focus.

Takeaways

1. **Fear of failure**, and the economic punishment for failure, prevents utilities from investing in pilots and new technologies.
2. More regulators should recognize that a **“failed” pilot is still used and useful**, as it can provide valuable insights into the technology and future pilots, and treat these investments as such when it comes to utility cost recovery.
3. **Utilities ought to communicate earlier and more closely with regulators** in terms of pilot design, technology providers, and customer impacts.

5.3.4 Proposed Changes

Our interviews with regulatory and utility experts highlighted several potential changes to the rate case process. The recommendations revolve around shifting perspective; examining not only the impacts of

³⁵⁵ The authors conducted several interviews with experts on utilities, utility regulation, utility innovation programs, and clean energy innovation.

³⁵⁶ Cappers and Spurlock (2020).

investments today, but their potential impacts for the grid of tomorrow; and aligning principles of the rate case with principles guiding utility innovative solutions investment.

First, if the goal is for utilities to invest in scaling solutions to meet state energy and climate goals, utilities need to have the opportunity to make money doing it, above their base rate of return. There are many avenues to compensate utilities, such as allowing them to own and operate certain assets, allowing them to earn a higher return on certain investments, and establishing performance-based incentives. Different technologies will require different approaches.

Second, the principles of the rate case should be adjusted to account for a future of enhanced electrification. Modeling studies of projected energy usage define a range of demand that will be added to the grid in the next decades.³⁵⁷ Investments in grid infrastructure need to support not only the needs of customers and the grid today, but future needs as well. In that vein, methodologies for assessing reliability, resilience, affordability, and functionality ought to be expanded. The current risk assessment process for resilience and reliability typically identifies critical infrastructure and resources, assessing vulnerabilities during a reliability or resilience event, evaluating the consequences of losing critical infrastructure, evaluating the technical effectiveness of potential solutions, and conducting cost-benefit analysis.³⁵⁸

These analyses do not give enough consideration as to what the grid might look like 10 or 20 years in the future, the value of reliability and resilience when a significant percentage of generation is from variable renewable energy resources, or the needs of the grid when a significant percentage of customers are driving EVs. Thus, enhanced analyses of reliability and resilience needs should consider not only grid vulnerabilities today, but grid vulnerabilities in a highly electrified future.

These analyses do not give enough consideration as to what the grid might look like 10 or 20 years in the future, the value of reliability and resilience when a significant percentage of generation is from variable renewable energy resources, or the needs of the grid when a significant percentage of customers are driving EVs.

As a result, technologies which are not yet scaled but would increase the reliability of the future grid should be given the same consideration as investments which would increase reliability today. Due consideration still needs to be given to the time horizon, as well as the stage of the technology and ensuring that approved technologies are proven and in line with energy goals and needs of future customers. Cost-benefit analyses need to be consistent and transparent within this new framework, and due consideration always needs to be given to expense-oriented alternatives. However, regulators and utilities should be proactive. Stranded asset risk must be considered in the context of an increasingly vulnerable grid, as we have seen in California, which was forced to cut power to 2.7 million customers to prevent wildfires, with an economic cost of over \$2 billion by some estimates.³⁵⁹

Prudence should receive similar reconsideration. Prudence could be judged not only from the perspective of today, but also from the perspective of the future requirements of customers and the grid. For example, is it prudent to do nothing to improve the flexibility of the grid and ensure its continued reliability as we massively expand distributed energy resources and electrification of heating and transportation? The consequences of ignoring this challenge include stranded assets, increased grid defection, and potentially catastrophic climate risks. Some investments could result in higher costs for customers in the short term,

³⁵⁷ Sun et al. (2020).

³⁵⁸ Elliot et al. (2019).

³⁵⁹ Stevens (2019).

while helping to reduce costs in the foreseeable future. These investments need regulatory support to meet state energy goals, mitigate climate risks, and help avoid catastrophic incidents.

One technology that is critical in the face of climate and energy challenges is energy storage, which can support resiliency of the grid and provide backup power to essential equipment for customers in the event of an outage. For example, California has begun to experience severe climate disasters, and the state is testing energy storage solutions to avoid a repeat of the catastrophic outages experienced in 2020.³⁶⁰

Finally, if there is to be innovation within utilities and their regulatory system, cultural change within the parameters of ratemaking tenets is necessary. There is a great deal of literature on corporate cultures that are conducive to innovation,³⁶¹ as well as on theories of disruptive innovation.³⁶² Innovative cultures are characterized by a tolerance for failure, a willingness to experiment, and high degrees of collaboration.³⁶³ With this in mind, regulators should evolve in three key areas: (1) showing an increased tolerance for “failure,” (2) being prepared to reward utilities for taking risks to meet legislative goals, and (3) fostering a culture of collaboration and education. For utilities to be able to make investments in innovative solutions, it is critical to recognize that they may not succeed in some situations. As a senior regulator puts it, “Regulators have to make it clear that in a pilot where utilities try a new solution and it fails, that it is ok. Utilities have still learned something valuable to customers, and therefore should still be able to recover the costs. Otherwise, utilities will not try new technologies, and it would make no sense for them to do so.”

This attitude should be limited to the testing and scaling of innovative solutions that are in line with legislative goals.³⁶⁴ Furthermore, utilities still need to demonstrate that the pilot was conducted prudently and rigorously, according to the senior regulator: “Sometimes a utility deploys a pilot to test a new technology, and it was implemented and managed properly and prudently, and it turned out not to work as expected. If the utility then makes the decision not to deploy the technology broadly because it does not work, then these investments meet prudence and used and useful standards and should qualify for cost recovery.”

Regulators need to understand the importance of utilities having the freedom to take these risks in testing unproven solutions, and that there is value to ratepayers through learning even if the technology deployment is unsuccessful. On the flip side, regulators also need to be comfortable with utilities benefitting financially from their investments that are in line with legislative goals. The fundamental way to incentivize utilities to take more risks, experiment more, and work to identify innovative solutions and opportunities is to increase the reward for them to undertake these activities. “Business as usual” for the utility is comfortable, and they are confident they will be able achieve their regulated rate of return. For utilities to evolve, grow, and disrupt, they need to be financially motivated. Business as usual and a normal return on equity lead to utilities with no motivation to scale innovative solutions. Fixing this lack of financial motivation is critical to overcoming this broader challenge in innovation. As a senior New York policy advisor put it, “If you want this transition to be market-enabling, if you want it

The fundamental way to incentivize utilities to take more risks, experiment more, and work to identify innovative solutions and opportunities is to increase the reward for them to undertake these activities.

³⁶⁰ Baker (2021).

³⁶¹ Pisano (2019).

³⁶² Christiansen, Raynor, and MacDonald (2015).

³⁶³ Pisano (2019).

³⁶⁴ National Conference of State Legislators (NCSL) (2021).

to be sustainable, you have to create avenues for new opportunities and be comfortable with utilities sometimes making more than their guaranteed rate of return.”

Finally, regulators need to develop a culture of engaging experts and utilities to educate, listen, and learn about their blind spots, and opportunities to be more effective. Regulators need to be open to actively refining their goals and definitions of success and working collaboratively to most effectively regulate the utilities, while driving them to achieve legislative goals.

Fundamentally, if utilities are to spend billions of dollars on innovative infrastructure solutions and support technologies to meet state energy and climate goals, they need to be able to recover the costs, and they need to be financially incentivized to make these investments. This will work to bridge the Valley of Death, encouraging utilities to invest more capital into scaling and managing innovative infrastructure solutions, and enabling more solutions to scale to broad adoption quickly and efficiently. However, scaled deployment and funding are only two aspects of the innovation ecosystem. In the next section, we examine innovation programs around the country, and how these programs can be expanded throughout the U.S. to better support the deployment and scaling of innovative energy infrastructure solutions.

5.4 Innovation Programs

In addition to regulatory funding mechanisms, innovation programs are another key mechanism through which technologies are scaled. We define *innovation programs* to be any programs by utilities, public utility commissions, or other government agencies with the stated purpose of identifying, piloting, and potentially scaling new energy infrastructure technology solutions to broad adoption. Regulators in some states have recognized the urgency of supporting R&D in clean energy technologies, adapting the utility’s technology and business models to meet these challenges, and regulatory flexibility to drive utilities towards these goals and reward them for their success.³⁶⁵

Historically, innovation programs have been critical to sourcing potential new infrastructure solutions and demonstrating their technical and economic viability. However, these programs are often siloed, instead of being coordinated with other programs and processes that could help them achieve scale. That approach contributes to the Valley of Death. This issue of scale and the interaction among multiple sectors that play a role in the innovation process is a critical area of focus and recognition of significance.³⁶⁶

Pilots have been used both as a form of experimentation to identify potential new approaches, and as a test to ensure the success of a broader deployment. From rates, technologies, and business models, utilities continue to leverage pilots to experiment and understand the potential of new technologies. Pilots are a critical step in the innovation adoption curve, as they demonstrate the technical and economic viability of a solution and demonstrate a solution’s potential and scalability. However, pilot programs are often siloed within the utility, both culturally and programmatically. Innovation programs need to evolve to not only engage new technologies directly with the technology teams at the utility, but also to incorporate processes to efficiently scale successfully demonstrated technologies. This section

Innovation programs need to evolve to not only engage new technologies directly with the technology teams at the utility, but also to incorporate processes to efficiently scale successfully demonstrated technologies.

³⁶⁵ Costello (2016).

³⁶⁶ National Academies of Sciences, Engineering, and Medicine (2021).

examines pilot and innovation programs operated by U.S. utilities and local governments in New York, California, Massachusetts, Vermont, and Connecticut.

5.4.1 Current Energy Innovation Programs

While most utility regulators recognize the importance of innovation and the critical role that utilities play in identifying, piloting, and deploying innovative solutions, they have taken different approaches to developing and supporting utility innovation programs around the country. Key differences include the stage of technology they focus on, scale of deployment, and capital available through the program. Through this examination we identify general best practices, as well as principles that might help innovation programs bridge the Valley of Death and ensure more solutions reach broad deployment more efficiently.

5.4.1.1 New York

New York's innovation approach is largely centered around the New York State Energy Research and Development Authority (NYSERDA),³⁶⁷ which has a broad mandate to help reduce energy consumption and greenhouse gas emissions through a large variety of methods. Among its many functions, NYSERDA manages a Clean Energy Fund designed to meet the following objectives: reducing greenhouse gas emissions, energy affordability, penetration and scaling of energy efficiency and clean generation, and growing the state's clean energy economy, in addition to providing programs and resources to scaling innovative energy solutions. The state Public Service Commission approved an impressive \$5.3 billion for the fund from 2016 through 2025, and it supported some of the largest utility innovation programs in the state. NYSERDA also played a leadership role in supporting the state's Climate Leadership and Community Protection Act.

The largest utility innovation program funded is the statewide Reforming the Energy Vision (REV) program.³⁶⁸ The goal of REV was to reshape utility business practices to encourage new roles and business models for electric utilities, and REV was largely successful in those terms. According to a former policy advisor from the New York state team in our interviews: "The role of the utility can no longer focus on one-way directional relationships with their customers, just sending electricity out and ensuring grid reliability. They need to see their role as a bidirectional force within the market and consider consumer behaviors that might send electricity back onto the grid through distributed generation, consider the new types of technologies that are occurring around the customer like energy efficiency and demand response, as well as customer expectations around what a new smart energy efficient home looks like in the 21st century."

In this vein, REV has advanced the concept of the utility as a distribution platform company, which through incentives and price signals encourages technological innovation. The former policy advisor explains: "When it came to grid investment, REV worked to understand the business-as-usual case—say it was a new substation—and ask, 'Is there an opportunity to replace that BAU [Business as Usual] case with something cleaner?' Instead of a substation, can we look at energy efficiency, can we look at more clean energy generation? You cannot make these decisions without utility data and utility perspective. REV tried to create both new incentives for utilities to invest in and explore new business models, as well as clear expectations around the role of the utility."

³⁶⁷ New York State. NYSERDA. 2022. Research & Innovation Centers. <https://www.nyserda.ny.gov/Researchers-and-Policymakers/Research-and-Innovation-Centers>.

³⁶⁸ New York State. NYSERDA. 2022. DPS – Reforming the Energy Vision. About the Initiative. <https://www3.dps.ny.gov/w/pscweb.nsf/all/cc4f2efa3a23551585257dea007dcfe2>.

REV was successful in many areas, particularly around collaboration and leveraging experts to understand specific technology challenges and identify potential solutions to address them.^{369, 370} REV demonstrations led to valuable outcomes such as piloting innovative solutions for grid operational environments and an improved understanding of the challenges and opportunities for DER integration. That said, REV has largely resulted in a focus on pilots and demonstration projects, with insufficient scaled deployment and unclear strategies for scaling successful pilots. Furthermore, with NYSERDA having primary responsibility for innovation rather than the utilities, utility R&D budgets have been reduced. While the focus on pilots and demonstrations in New York is extremely promising, proven solutions still lack a clear path to scaling. This pathway needs to be a critical component of any state or utility innovation program.

5.4.1.2 California

California has several programs to support clean energy innovation in the state. One central effort is the Electric Program Investment Charge (EPIC) Program. The EPIC program is enabling California IOUs, the California Energy Commission, and other entities to deploy pilots and demonstration projects for emerging technologies to address evolving grid needs. The program has been allocated over \$130 million annually.³⁷¹ The stated goals include expanding the use of renewable energy; building a safe and resilient electricity system; advancing electric technologies for buildings, businesses, and transportation; and enabling a more decentralized grid.³⁷²

Through EPIC, California has launched programs such as CalTestBed, which supports early-stage clean energy innovation. The program leverages assets, facilities, infrastructure, and resources from the state, the University of California Office of the President, and Berkeley Lab to develop over 30 test beds, mostly in partnership with University of California facilities.³⁷³ The program distributes \$9 million in vouchers to up to 60 companies with a qualifying technology readiness level. The companies can use these vouchers to test and develop their solutions at any of the program test beds.³⁷⁴

Another program under EPIC is the California Energy Innovation Ecosystem, which supports innovative solutions that do not meet the investment requirements of the private sector. The program provides access to networks, funding, mentoring, facilities, and expertise necessary to successfully continue to scale their solutions.³⁷⁵

The EPIC program has strong goals and the capital to achieve them, and emphasizes development and commercialization of solutions through a broad array of grant programs and funding opportunities. However, most of the programs are focused on R&D and do not appear to have a scaling component. Instead, they rely on scaled utility integration for successfully piloted technologies.

³⁶⁹ Bradley and Richards (2019).

³⁷⁰ REV Connect. 2022. Innovation Opportunities. <https://nyrevconnect.com/innovation-opportunities/>.

³⁷¹ California Energy Commission. 2022. Electric Program Investment Charge Program – EPIC.

<https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program>.

³⁷² Id.

³⁷³ CalTestBed. 2020. About the CalTestBed Program. <https://www.caltestbed.com/about/>.

³⁷⁴ Id.

³⁷⁵ California Energy Commission. 2022. Energy Innovation Ecosystem. <https://www.energy.ca.gov/programs-and-topics/topics/research-and-development/energy-innovation-ecosystem>.

5.4.1.3 Massachusetts

In a state with a reputation for innovation and startups, the Massachusetts Clean Energy Center represents a different approach and a broader mandate to supporting energy innovation, with a focus that is not limited to utilities. Funded through the Massachusetts Renewable Energy Trust Fund, innovation is supported by a system benefits charge of approximately 29 cents per month on the average residential electric utility bill. The Clean Energy Center provides funding for seed grants and technology as well as direct equity and venture-capital debt investment in Massachusetts-based early stage cleantech companies.³⁷⁶ This approach to innovation represents a policy decision by the state government to foster clean technology innovation at an early stage, and to use utility bills as the funding mechanism this public good.

The interest in innovation in Massachusetts also is evident in a series of grid modernization dockets that began in 2012. In 2018, the Department of Public Utilities (DPU) approved a grid modernization plan for each Massachusetts electric company, including a three-year investment plan and a five-year strategic plan. The DPU pre-authorized five grid-facing investment categories subject to company-specific budget caps for 2018–2020, which was extended through 2021 due to the COVID-19 pandemic. The investment categories include monitoring/control, distribution automation, advanced distribution management systems, and advanced communications infrastructure. As part of its oversight, the DPU requires the electric companies to report on metrics related to infrastructure technology and performance.

In addition, in a recent Eversource rate case, the DPU approved a \$55 million budget for a battery energy demonstration program and a \$45 million electric vehicle charging program, with cost recovery to be addressed in grid modernization proceedings.³⁷⁷

The Massachusetts regulatory approach to innovation represents a strongly prescribed approach within a framework of preapproval and budget caps with early-stage innovation funded through customers' electricity bills.

5.4.1.4 Vermont

Vermont has taken a strongly supportive and deliberative approach to innovation, with the Public Service Commission directly sanctioning innovation in 2019 in the Green Mountain Power (GMP) rate case, linking utility innovation with the state's clean energy goals.³⁷⁸ The Commission approved the utility's New Initiative Program, a series of pilots to be reviewed and evaluated apart from the utility's base rates. Under this program, the utility offers incentives for customers to buy batteries through a 10-year lease in exchange for agreeing to participate in demand response when the utility needs it, an approach that reduced energy costs during a heatwave by providing demand response capacity from 8,000 homes. GMP also is the first utility to successfully deploy a vehicle-to-grid electric fleet battery program.³⁷⁹ The value of this project is lower costs for all GMP customers. This approach serves as an example of a small utility that can operate niche technology programs, demonstrating reduced costs for all utility customers as a result of clear regulatory goals. With this type of regulatory environment, GMP was listed by Fast

³⁷⁶ Massachusetts Clean Energy Center. 2022. Innovate Clean Energy. Funding Opportunities.

<https://www.masscec.com/innovate-clean-energy/funding-opportunities>.

³⁷⁷ NStar Electric Company and Western Electric Company, DPU-17-05 at 470-471,501-502 (2017) and DPU 15-120/D.P.U. 15-122 at 186–187.

³⁷⁸ Vermont Public Utility Commission (2019).

³⁷⁹ GMP news release, December 3, 2020. <https://greenmountainpower.com/gmp-saves-money-for-customers-with-v2g/>

Company as among the most innovative companies for pioneering a battery storage solution to cut carbon emissions.³⁸⁰

5.4.1.5 Connecticut

Connecticut’s Public Utility Regulatory Authority (PURA) has championed one of the most complete innovation program solutions through its Framework for an Equitable Modern Grid proceeding. The idea is to enable pilots to scale and identify solutions that might not be possible under traditional regulatory frameworks. Specifically, the Innovation Pilots Straw Proposal addresses risk broadly as well as issues associated with cost recovery that in the past have limited research and development. Proposed projects must be both “reasonable in cost and prudent” to move forward from the start, and there are multiple avenues for cost recovery.³⁸¹ Furthermore, the PURA Innovations Pilots Framework was designed with specific processes and methodologies for assessing pilot success and scaling successful pilots to broader deployment.

This program considers innovation from all sides and advances methods of identifying, prioritizing, developing, and scaling innovation investments. It also supports developing and identifying cost recovery mechanisms: “Cost recovery could occur through multiple mechanisms, including annual reconciliation processes or riders and general rate cases. The new framework addresses methods to scale from demonstrations to broad deployment, with funding mechanisms including cost recovery for utilities and funding for developer-led projects. It operates under the following principles: economic viability and equity, diversification and market gaps, scalability, and continuous learning.”³⁸²

This innovation program is extremely promising and could be a model for widespread adoption. Connecticut Electric Distribution Companies submitted their plans to PURA in fall 2021. The proposal recognizes the importance of project developers as well as the utilities. It is broadly conceived to provide metrics, a process, customer protections, and cost recovery for project innovator costs. Its guiding principles of economic viability and equity, transparency in decision-making, equity, scalability, and continuous learning are congruent with the steps identified by Berkeley Lab for successful pilots. Elements and outcomes are clearly defined, and there are safeguards, time frames for deployment, and opportunity for assessment and improvement—all of which will foster a willingness to experiment and ultimately deploy successful innovations.

5.4.2 Next-Generation Innovation Programs

Our analysis of innovation programs across states finds numerous opportunities to pilot technologies, but limited support to scale successful technologies to broad adoption. Pilot programs are the first step that utilities, regulators, and other government agencies can take towards advancing energy technologies to achieve state energy goals. Their main purpose is to identify viable energy infrastructure solutions and de-risk, from technical, operational, and economic perspectives, their scaled deployment. That is why scaling solutions need to become a core pillar of innovation programs and should be included in planning from the start.

³⁸⁰ GMP news release, March 10, 2020. <https://greenmountainpower.com/gmp-earns-spot-on-fast-companys-most-innovative-companies-list-for-pioneering-cost-effective-solutions-including-battery-storage-to-cut-carbon-emissions/>

³⁸¹ Ct.gov. Innovation Pilots Framework: Straw Proposal. <https://portal.ct.gov/-/media/PURA/electric/Innovation-Pilots-Framework---Straw-Proposal.pdf>.

³⁸² Ct.gov. Innovation Pilots Framework: Straw Proposal. <https://portal.ct.gov/-/media/PURA/electric/Innovation-Pilots-Framework---Straw-Proposal.pdf>.

All too often, once solutions are piloted and evaluated, the pilot program ends. There are no predefined steps and channels to scale successful pilots. Instead, the goal of every energy infrastructure pilot program should be to identify which technology solutions ought to be scaled quickly to support the utility's efforts towards meeting state energy and climate goals. As such, scaling and next steps for successful pilots, and identifying utility and government resources that can be leveraged to scale successful solutions in advance, should be required components of pilot program design.

[T]he goal of every energy infrastructure pilot program should be to identify which technology solutions ought to be scaled quickly to support the utility's efforts towards meeting state energy and climate goals.

Further, a central reason for the gap between pilot programs and scaling efforts lies in the fundamentals of utility culture. Pilot programs and scaling are separated within utilities, often by design. As a grid-technology cleantech founder who went through the piloting and scaling process puts it: "The issue that is consistent across different countries and different states is that innovation is often conducted separately from the core business of the utility. For example, if you want to build a new type of control system, the people who are running the control systems don't have the time or capacity to engage with the innovation project. This means you are working with an innovation team or an R&D team who are acting as proxies, attempting to represent what the utility needs. As a result, technologies can get stuck in this 'innovation' world, while not actually engaging with the ultimate end customer of the utility. Solutions going through pilots might think they successful, but once they move beyond pilots to the core utility teams, they often find out that in reality they are not making the progress towards deployment that they thought."

Utilities can evolve internally to overcome this challenge and bridge the gap between innovative solutions and the core operations of the business by bringing experts and diverse problem solvers to the table who integrate across divisions and departments. According to the cleantech founder, "This siloing of innovation is the result of a long history of regulation focused around minimizing costs and risks. Utilities have not been rewarded for spending time and capital evaluating new concepts and new business models; they have been rewarded based on a return on capital expenditure. In this environment there is not much tolerance in utilities or regulators for failure, and this risk aversion impacts the approach to innovation (where failure is normally viewed as learning rather than something to avoid)." Rather than focusing on minimizing costs as they have historically, utilities need to begin thinking about the best way to build teams and competence around identifying and testing technologies, scaling them up, and operating them all as a part of one process. "In developing complicated products or services—for example, medical devices—there are a variety of experts, on medicine, on data privacy, on hardware, and so on, all of whom collaborate to develop a product," the cleantech founder added. "Utilities at the moment tend to do things in a sequential and siloed manner as part of business as usual, but need to more effectively collaborate across siloes with interdisciplinary teams to enable and adopt innovation."

5.5 Conclusion

As energy challenges continue to mount, efficiently identifying, scaling, and deploying innovative solutions are key to meeting these challenges. Utilities are foundational to our electrical infrastructure and will play a central role in managing and deploying much of this innovation. While the importance of innovation and utilities in solving this challenge are broadly recognized, there is a Valley of Death in the innovation adoption process. This gap between demonstrations and broad deployment delays the installation of critical infrastructure designed to achieve energy goals and secure electrical infrastructure for the future. Furthermore, solving this challenge and scaling solutions will have a multiplicative effect. De-risking projects from technical, operational, and economic standpoints through regulatory support, and

providing more consistency and transparency for the scaling process, directly benefit the development of technology solutions, allow investors to commit capital more confidently, and enable developers to be more involved with deploying and scaling projects.

This report focuses on two challenges central to the gap in innovation deployment:

1. Utility funding mechanisms are not designed to allow for the inherent risk of investments to scale innovative solutions, presenting serious challenges for funding. In addition, regulators broadly are not comfortable with “failed” projects and disincentivize utilities from making innovation investments. However, to meet state energy and climate goals, utilities need to be able to recoup the capital investments necessary to scale successfully tested solutions.
2. Innovation programs offer a unique platform to identify and test potential new solutions, but often fail to efficiently scale successful pilots. This is partially a result of a utility culture that siloes innovation and separates it from the core functions of the utility. It has often led to an environment where solutions are piloted over and over but never scaled.

We make several recommendations to help overcome these challenges and bridge the Valley of Death for needed clean energy innovations. With respect to the rate case process, utilities must be able to recoup their investments in innovative solutions. To achieve this, regulators should consider the value of successful innovation projects, as well as the value of learning even from unsuccessful pilots. There is value in scaling innovative solutions not just for the grid and customers of today, but also for the customers of the future, when more energy usage is electrified, electric vehicles are commonplace, and distributed variable energy sources account for a substantial percentage of total generation, and this should be reflected in rate cases.

The efficient scaling of successful demonstrations needs to be a central focus for innovation and pilot programs. Methodologies for identifying capital and scaling successful pilots should be fundamental elements incorporated into pilot program design. Furthermore, utilities should work internally to bridge the gap between innovation teams and technical teams, ensuring that pilots are addressing real challenges for the utility, and successful technologies have the expertise and relationships to scale projects through existing utility processes.

[U]tilities should work internally to bridge the gap between innovation teams and technical teams, ensuring that pilots are addressing real challenges for the utility, and successful technologies have the expertise and relationships to scale projects through existing utility processes.

Enabling innovative infrastructure solutions to reach broad deployment more efficiently and equitably is a critical challenge in achieving energy and climate goals. A global energy transition is underway, and it is critical to our collective future. It should be no surprise that as our climate goals evolve, regulators and utilities must evolve alongside them, recognizing the ways that the future is not the past. The U.S. failing to rise to these challenges risks citizens losing opportunities, the nation losing competitiveness, and the consequences of ever greater climate disasters.

6.0 References

Executive Summary

Farley, C., J. Howat, J. Bosco, N. Thakar, J. Wise, J. Su, and L. Schwartz (technical editor). 2021. *Advancing Equity in Utility Regulation*. Future Electric Utility Regulation report no. 12. Berkeley Lab. <https://emp.lbl.gov/publications/advancing-equity-utility-regulation>.

McKinsey & Co. 2020. “Building an R&D strategy for modern times.” November 3, 2020. <https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/building-an-r-and-d-strategy-for-modern-times>.

National Academies of Sciences, Engineering, and Medicine. 2021. *The Future of Electric Power in the United States*. The National Academies Press. <https://doi.org/10.17226/25968>.

National Regulatory Research Institute (NRRI). 2016. *A Primer on R&D in the Energy Utility Sector*. <https://pubs.naruc.org/pub/FA85BA08-D94D-E40F-B7E1-98F834372877>.

Waite, Marilyn. 2017. Why US utilities should invest in innovation. <https://www.utilitydive.com/news/why-us-utilities-should-invest-in-innovation/441114/>.

Chapter 1. Protecting Consumers in a Period of Rapid Transformation

Barbose, Galen. 2017. Net Metering and Rate Reforms for Distributed Solar. NCSL “Soaking up the Sun” Webinar. (September 28). https://www.ncsl.org/Portals/1/Documents/energy/webinar_G_Barboose_9_2017_31661.pdf.

Bolinger, Mark, Will Gorman, Joseph Rand, Ryan H. Wiser, Seongeun Jeong, Joachim Seel, Cody Warner, and Bentham Paulos. 2021. *Hybrid Power Plants: Status of Installed and Proposed Projects*. Lawrence Berkeley National Laboratory. <https://emp.lbl.gov/publications/hybrid-power-plants-status-0>.

Critical Consumer Issues Forum. 2021. Supporting Electricity Customers Through Times of Crisis: Being There When it Matters Most. <http://www.cciforum.com/wp-content/uploads/CCIF-Supporting-Customers-Report-July-2021.pdf>.

EIA. 2021a. Annual Energy Outlook 2021. Reference case, Table 8. https://www.eia.gov/outlooks/aeo/excel/aeotab_8.xlsx.

EIA. 2021b. Annual Energy Outlook 2021. <https://www.eia.gov/outlooks/aeo/>.

EIA. Table ES1.A. Total Electric Power Industry Summary Statistics, 2021 and 2021. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_es1a.

Farley et al. 2021. *Advancing Equity in Utility Regulation*. Future Electric Utility Regulation report no. 12. Berkeley Lab. <https://emp.lbl.gov/publications/advancing-equity-utility-regulation>.

Fekete, Emily. 2020. States with Community Solar Policy Updates and Capacity Growth Potential. NREL. <https://www.nrel.gov/docs/fy21osti/78174.pdf>.

Frick, N. et al. 2021. *Locational Value of Distributed Energy Resources*. Berkeley Lab. <https://emp.lbl.gov/publications/locational-value-distributed-energy>.

Internal Revenue Service. 2021. Plug-In Electric Drive Vehicle Credit (IRC 30D). <https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d>.

Lowry, M., T. Woolf, and L. Schwartz (technical editor). 2016. *Performance-Based Ratemaking in a High Distributed Energy Resources*. Future Electric Utility Regulation report no. 3. Berkeley Lab. https://emp.lbl.gov/sites/all/files/lbnl-1004130_0.pdf.

Lowry, M., M. Makos, J. Deason, and L. Schwartz. 2017. *State Performance-Based Regulation Using Multiyear Rate Plans for U.S. Electric Utilities*. Berkeley Lab. https://eta.lbl.gov/sites/default/files/publications/multiyear_rate_plan_gmlc_1.4.29_final_report071217.pdf.

National Conference of State Legislatures. 2019. *Modernizing the Electric Grid: State Role and Policy Options*. https://www.ncsl.org/Portals/1/Documents/energy/Modernizing-the-Electric-Grid_112519_34226.pdf.

National Conference of State Legislatures. 2021. State Renewable Portfolio Standards and Goals. <https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx>.

The National Energy Screening Project. 2020. *National Standards Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources*. (August). <https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/>.

North Carolina Clean Energy Technology Center. 2021a. *The 50 States of Grid Modernization: Energy Storage and Utility Business Model Reforms Take Focus in 2020*. <https://nccleantech.ncsu.edu/2021/02/03/the-50-states-of-grid-modernization-energy-storage-and-utility-business-model-reforms-take-focus-in-2020/>.

North Carolina Clean Energy Technology Center. 2021b. *50 States of Solar: Q4 2020 Quarterly Report & 2020 Annual Review Executive Summary*. <https://nccleantech.ncsu.edu/wp-content/uploads/2021/01/Q4-20-Solar-Exec-Summary-Final.pdf>.

Ramasamy, Vignesh, David Feldman, Jal Desai, and Robert Margolis. 2021. *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021*. NREL. NREL/TP-7A40-80694. (November).

Regulatory Assistance Project. 2015. *Smart Rate Designs for a Smart Future*.

United States. 2021. Nationally Determined Contribution. Reducing Greenhouse Gases in the United States: A 2030 Emissions Target. <https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20States%20of%20America%20First/United%20States%20NDC%20April%2021%202021%20Final.pdf>.

Woolf, T. 2021. *Benefit-Cost Analysis for Utility-Facing Grid Modernization Investments: Trends, Challenges, and Considerations*. Berkeley Lab. <https://emp.lbl.gov/publications/benefit-cost-analysis-utility-facing>.

Chapter 2. A Labor Perspective on Innovation to Meet Climate Goals for the Electricity Sector

Andrews, Caitlin. 2021. What You Need to Know Before You Cast Your Vote on CMP Corridor Referendum. Maine Public Radio. (Sept. 27). <https://www.mainepublic.org/politics/2021-09-27/what-you-need-to-know-before-you-cast-your-vote-on-cmp-corridor-referendum>.

Associated Press (AP). 2018. “\$950M Maine Power Grid Project Now the Frontrunner for Mass. Deal.” *Bangor Daily News* (March 28).

AP. 2021. “Plans for largest US solar field north of Vegas scrapped.” (July 23). <https://apnews.com/article/technology-government-and-politics-environment-and-nature-las-vegas-nevada-9bf3640dfefbc6f7f45a97c6810f5ff7>.

Aragon, Fernando, Punam Chuhan-Pole, and Bryan Land. 2015. The Local Economic Impacts of Resource Abundance: What Have We Learned? World Bank Office of the Chief Economist. May. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/05/12/090224b082e6d1ff/1_0/Rendered/PDF/The0local0econ0at0have0we0learned00.pdf.

Baker, David R., and Millicent Dent. 2019. “NIMBYs Shoot Down Green Projects Next Door While Planet Burns.” *Bloomberg Green* (September 17). <https://www.bloomberg.com/news/features/2019-09-17/nimbys-shoot-down-green-projects-next-door-while-planet-burns>.

Blonsky, Michael et al. 2019. “Potential Implications of Transportation and Building Electrification on the Grid: A Review of Electrification Projections and their Effects on Grid Infrastructure, Operation, and Planning.” *Current Sustainable/Renewable Energy Reports* 6: 169–176.

BlueGreen Alliance. 2020. State Based Policies to Build a Cleaner, Safer, More Equitable Economy: A Policy Toolkit. (July 24). <https://www.bluegreenalliance.org/resources/state-based-policies-to-build-a-cleaner-safer-more-equitable-economy-a-policy-toolkit/>.

Blunt, Katherine, and Russell Gold. 2019. “PG&E Knew for Years Its Lines Could Spark Wildfires, and Didn’t Fix Them.” *Wall Street Journal* (July 10). https://www.wsj.com/articles/pg-e-knew-for-years-its-lines-could-spark-wildfires-and-didnt-fix-them-11562768885?mod=hp_lead_pos4.

Booth, Michael. 2021. “How Workers at Colorado Springs’ Shuttered Power Plant Are Transitioning to New Careers.” *The Colorado Sun* (Sept. 13). <https://energynews.us/2021/09/13/how-workers-at-colorado-springs-shuttered-power-plant-are-transitioning-to-new-careers/>.

Botero, Julia. 2016. Jefferson County Lawmakers Deny Tax Breaks for Green Energy Projects. North Country Public Radio. (July 7). <https://www.northcountrypublicradio.org/news/story/32180/20160707/jefferson-county-lawmakers-deny-tax-breaks-for-green-energy-projects>

Brasch, Sam. 2021 How a Colorado Coal Plant Could Become a Massive Battery for Renewable Energy. Colorado Public Radio. (Sept. 7). <https://www.cpr.org/2021/09/07/hayden-generating-station-coal-plant-could-become-a-massive-battery-for-renewable-energy/>.

Brunner, Eric, Ben Hoen, and Joshua Hyman 2021. *School District Revenue Shocks, Resource Allocations, and Student Achievement: Evidence from the Universe of U.S. Wind Energy Installations*. LBNL Report. (March). <https://emp.lbl.gov/publications/school-district-revenue-shocks>

California Energy Commission. 2021. SB 100 Starting Point for the CAISO 20-Year Transmission Outlook. Docket No. 21-SIT-01. Sept. 13, 2021. file:///C:/Users/Mark/AppData/Local/Temp/TN239685_20210913T160327_SB%20100%20Starting%20Point%20for%20the%20CAISO%2020-year%20Transmission%20Outlook.pdf.

Carbon Brief. 2020. Mapped: The World's Coal Power Plants. (March 26). <https://www.carbonbrief.org/mapped-worlds-coal-power-plants>.

Carley, Sanya, David M. Konisky, Zoya Atiq, and Nick Land. 2020. "Energy infrastructure, NIMBYism, and public opinion: A systematic literature review of three decades of empirical survey literature." *Environ. Res. Lett.* 15 093007. <https://iopscience.iop.org/article/10.1088/1748-9326/ab875d/pdf>.

Chaudry, Nidhi. 2018. "Recruit Local: The Next Generation in the Utility Workforce." American Public Power Association. (March 12). <https://www.publicpower.org/periodical/article/recruit-local-next-generation-utility-workforce>.

Consolidated Edison Co. of New York. 2013. *Post Sandy Enhancement Plan*. (June 20). https://www.coned.com/-/media/files/coned/documents/services-outages/post_sandy_enhancement_plan.pdf.

Crisos, Jon. 2019. "CMP Ranks Last Nationwide in Customer Satisfaction, According to New Survey." WGME. (Nov. 14). <https://wgme.com/news/i-team/cmp-ranks-last-nationwide-in-customer-satisfaction-according-to-new-survey>.

Davis, S. J. et al. 2018. "Net zero emissions energy systems." *Science* 360, eaas9793. DOI: 10.1126/science.aas9793.

EEI. 2016. "Understanding the Electric Power Industry's Response and Restoration Process." October. https://www.eei.org/issuesandpolicy/electricreliability/mutualassistance/Documents/MA_101FINAL.pdf.

Energywire. 2020. "Thousands of Coal Workers Lost Jobs. Where Will They Go?" (June 25). <https://energynews.us/2020/06/25/thousands-of-coal-workers-lost-jobs-where-will-they-go/>.

FEMA. 2013. *Hurricane Sandy FEMA After-Action Report*. (July 1). https://s3-us-gov-west-1.amazonaws.com/dam-production/uploads/20130726-1923-25045-7442/sandy_fema_aar.pdf.

Ferris, David. 2021. "Why Coal Plant Workers Aren't Going Green." *E&E News* (June 22). <https://www.eenews.net/articles/why-coal-plant-workers-arent-going-green/>.

Firestone, Jeremy, Ben Hoen, Joseph Rand, Debi Elliott, Gundula Hübner, and Johannes Pohl. 2017. "Reconsidering Barriers to Wind Power Projects: Community Engagement, Developer Transparency and Place." *Journal of Environmental Policy & Planning* (December). <https://emp.lbl.gov/publications/reconsidering-barriers-wind-power>.

Gelazanskas, L., and K. A. A. Gamage. 2016. "Distributed energy storage using residential hot water heaters." *Energies* 9: 127.

- Gross, S. 2020. *Renewables, Land Use, and Local Opposition in the United States*. (January). <https://www.brookings.edu/research/renewables-land-use-and-local-opposition-in-the-united-states/>.
- Hamilton, L. C., E. Bell, J. Hartter, and J. D. Salerno. 2018. “A change in the wind? US public views on renewable energy and climate compared.” *Energ Sustain Soc* 8: 11. <https://energysustainsoc.biomedcentral.com/articles/10.1186/s13705-018-0152-5>.
- Headwaters Economics. 2017. *Communities at Risk from Closing Coal Plants*. (March). <https://headwaterseconomics.org/energy/coal/communities-coal-plant-closures/>.
- Hu, W., C. Su, Z. Chen, and B. Bak-Jensen. 2013. “Optimal operation of plug-in electric vehicles in power systems with high wind power penetrations.” *IEEE Trans. Sustain. Energy* 4: 577–585.
- IRENA. 2021. *Renewable capacity statistics 2021*. International Renewable Energy Agency.
- Jeromin, Kerrin. 2021. “Already, 18 Weather Disasters Costing at least \$1 Billion Each Have Hit the U.S. this Year.” *The Washington Post* (Oct. 11). <https://www.washingtonpost.com/weather/2021/10/11/billion-dollar-disasters-2021-climate/>.
- Jones, Betony, Peter Philips, and Carol Zabin. 2016. *The Link Between Good Jobs and a Low Carbon Future*. UC Berkeley Labor Center. (July 12). <https://laborcenter.berkeley.edu/the-link-between-good-jobs-and-a-low-carbon-future/>.
- Keefe, Josh. 2019. *How Central Maine Power Failed Its Customers and Still Increased Profits*. Bangor Daily News. (May 1). <https://bangordailynews.com/2019/05/01/business/how-central-maine-power-failed-its-customers-and-still-increased-profits-2/>.
- Kitterman, Brad, and Jack Dugan. 2006. *The Disappearing Utility Workforce*. *Electric Energy T&D Magazine* (March/April). <https://electricenergyonline.com/energy/magazine/261/article/The-Disappearing-Utility-Workforce.htm>.
- Larson, E., C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, E. J. Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan. 2021. *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*. Final report. Princeton University. (October 29). <https://netzeroamerica.princeton.edu/?explorer=year&state=national&table=2020&limit=200>.
- Larson, Eric, Chris Greig, Jesse Jenkins, Erin Mayfield, Andrew Pascale, Chuan Zhang, Joshua Drossman, Robert Williams, Steve Pacala, Robert Socolow, Ejeong Baik, Rich Birdsey, Rick Duke, Ryan Jones, Ben Haley, Emily Leslie, Keith Paustian, Amy Swan. 2020. *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*. Princeton University, Andlinger Center For Energy and Environment, High Meadows Environmental Institute, Carbon Mitigation Initiative. (December 15).
- Leiserowitz, A., E. Maibach, S. Rosenthal, J. Kotcher, J. Carman, X. Wang, J. Marlon, K. Lacroix, and M. Goldberg. 2021. *Climate Change in the American Mind*. Yale University and George Mason University. New Haven, CT: Yale Program on Climate Change Communication. (March). <https://climatecommunication.yale.edu/publications/climate-change-in-the-american-mind-march-2021/>.
- Li, Furong. 2020. “The Future Structure of the Electrical Supply System – From Economies of Scale to Economies of Flexibility.” *Oxford Energy Forum* 124. (Sept.).

- Liu, Z., Q. Wu, A. H. Hielsen, and Y. Wang. 2014. “Day-ahead energy planning with 100% electric vehicle penetration in the Nordic region by 2050.” *Energies* 7: 1733–1749.
- Macgillis, Alec. 2018. “Forced to Choose Between a Job – and a Community.” *ProPublica* (May 23). <https://www.propublica.org/article/adams-county-ohio-coal-forced-to-choose-between-a-job-and-a-community>.
- MacMillan, Douglas, and Will Englund. 2021. “Longer, more frequent outages afflict the U.S. power grid as states fail to prepare for climate change.” *The Washington Post* (October 24). <https://www.washingtonpost.com/business/2021/10/24/climate-change-power-outages/>.
- Mancarella, Pierluigi. 2020. “Electricity Grid Fragility and Resilience in a Future Net-Zero Carbon Economy.” *Oxford Energy Forum* 124 (September).
- Manzo, Frank, Jill Gigstad, Robert Bruno, and Kevin Duncan. 2021. *Building a Strong Minnesota: An Analysis of Minnesota’s Union Construction Industry*. (July 1). <https://illinoisepi.files.wordpress.com/2021/05/mepi-minnesota-union-construction-report-final.pdf>.
- Marsh, Kate, Neely McKee, and Maris Welch. 2021. *Opposition to Renewable Energy Facilities in the United States*. Columbia Law School Sabin Center for Climate Change Law. (September). <https://climate.law.columbia.edu/content/opposition-renewable-energy-facilities-united-states>.
- Massachusetts Institute of Technology. 2016. *Utility of the Future: An MIT Energy Initiative Response to an Industry in Transition*. <https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Full-Report.pdf>.
- Masuta, T., and A. Yokoyama. 2012. “Supplementary load frequency control by use of a number of both electric vehicles and heat pump water heaters.” *IEEE Trans. on Smart Grid* 3: 1253–1262.
- Motavelli, Jim. 2021. “The NIMBY Threat to Renewable Energy.” *Sierra* (Sept. 20). <https://www.sierraclub.org/sierra/2021-4-fall/feature/nimby-threat-renewable-energy>.
- National Association of State Energy Officials, Energy Futures Initiative, and BW Research Partnership. 2020. *Wages, Benefits, and Change, A Supplemental Report to the Annual U.S. Energy & Employment Report* <https://www.usenergyjobs.org/>.
- New York State. 2013. Moreland Commission on Utility Storm Preparation and Response, Final Report. (June 22). <https://utilitystormmanagement.moreland.ny.gov/>.
- New York State. 2021. Governor Cuomo Announces \$86.2 Million In Settlements With 4 Utilities for Failures Related to Power Outages and Emergency Response Including Tropical Storm Isaias. Press Release. (July 15). https://www.dfs.ny.gov/reports_and_publications/press_releases/pr202107151.
- Nir, Sarah Maslin. 2020. “He Set Up a Big Solar Farm. His Neighbors Hated It.” *The New York Times* (March 18). <https://www.nytimes.com/2020/03/18/nyregion/solar-energy-farms-ny.html>.
- NOAA. 2021. Record Number of Billion-Dollar Disasters Struck U.S. in 2020. (Jan. 8). <https://www.noaa.gov/stories/record-number-of-billion-dollar-disasters-struck-us-in-2020>.
- NOAA. 2022. Billion Dollar Weather and Climate Disasters: Overview. <https://www.ncdc.noaa.gov/billions/>.

- OECD. 2012. *Linking Renewable Energy to Rural Development*. (Nov. 10). <https://www.oecd.org/regional/linkingrenewableenergytoruraldevelopment.htm>.
- Pakka, V. H., and M. Rylatt. 2016. "Design and analysis of electrical distribution networks and balancing markets in the UK: A new framework with applications." *Energies* 9: 101.
- Patridge, A., and Brady Steigauf. 2020. Minnesota's Power Plant Communities: An Uncertain Future. Center for Energy and Environment. <https://www.mncee.org/minnesotas-power-plant-communities-uncertain-future>.
- Penrod, Emma. 2021a. "Democrats' Clean Electricity Plan to Require 85 GW of Renewable Energy Additions a Year: S&P." *Utility Dive* (Sept. 30). <https://www.utilitydive.com/news/democrats-clean-electricity-plan-to-require-85-gw-of-renewable-energy-addi/607338/>.
- Penrod, Emma. 2021b. "Unlocking the Transition: Politicians Tout Renewable Energy Jobs for Ex-Fossil Fuel Workers, But It's Not So Simple." *Utility Dive* (Nov. 5). <https://www.utilitydive.com/news/unlocking-the-transition-politicians-tout-renewable-energy-jobs-for-ex-fos/609335/>.
- Perkins, Tom. 2021. "How decades of neglect left Detroit's grid vulnerable to powerful storms." *Energy News Network* <https://energynews.us/2021/09/16/how-decades-of-neglect-left-detroits-grid-vulnerable-to-powerful-storms/>.
- Pillai, J. R., and B. Bak-Jensen. 2011. "Integration of vehicle-to-grid in western Danish power system." *IEEE Trans. Sustain. Energy* 2: 12–19.
- Polson, Jim. 2013. "Utility Line Worker Cuts Hobble Emergency Storm Response." *Bloomberg News* (July 4). <https://www.bloomberg.com/news/articles/2013-07-04/utility-line-worker-cuts-hobble-emergency-storm-response>.
- Princeton University. 2020. Net Zero America. Interim report. https://netzeroamerica.princeton.edu/img/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf.
- Quadrennial Energy Review. 2017. *Transforming the Nation's Electricity System: The Second Installment of the QER* (January).
- Rand, Joseph, and Ben Hoen. 2017. *Thirty years of North American wind energy acceptance research: What have we learned?* Berkeley Lab. <https://emp.lbl.gov/publications/thirty-years-north-american-wind>.
- Robson, L. S., V. Landsman, D. Latour-Villamil, H. Lee, and C. Mustard. 2021. *Updating a Study of the Union Effect on Safety in the ICI Construction Sector: A Report Prepared by the Institute for Work and Health for the Ontario Construction Secretariat*. Institute for Work and Health. (January). <https://www.iwh.on.ca/scientific-reports/updates-study-on-union-effect-on-safety-in-ici-construction-sector>.
- S&P Global. 2021. "US Power Outages Jumped 73% in 2020 Amid Extreme Weather Events." (Jan. 19). <https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/us-power-outages-jumped-73-in-2020-amid-extreme-weather-events-62181994>.

Saha, Devashree, Tom Cyrs, Jillian Neuberger and Katrina McLaughlin. 2021. “US Infrastructure Bill Is Good, but Not Enough to Transform the Electricity Grid.” World Resources Institute. (August 9). <https://www.wri.org/insights/us-infrastructure-bill-good-not-enough-transform-electricity-grid>.

Sandia National Laboratories. 2021. *The Resilience Planning Landscape for Communities and Electric Utilities*. SAND2021-417.

Sandia National Laboratories. 2021. *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*. SAND2021-5627.

Sandia National Laboratories. 2021. *Performance Metrics to Evaluate Utility Resilience Investments*. SAND2021-5919.

Sandia National Laboratories. 2021. *Regulatory Mechanisms to Enable Investments in Electric Utility Resilience*. SAND2021-6781.

Sandia National Laboratories. 2021. *The Quest for Public Purpose Microgrids for Resilience: Considerations for Regulatory Approval*. SAND2021-8207.

Schaefer, Christian. 2020. “Why Decarbonizing the Electricity Sector Will Require More Than Just Building Renewable Energy Sources.” *Oxford Energy Forum* 124 (September).

Schwartz, Lisa. 2020. “Distribution Planning Regulatory Practices in Other States.” Presentation to Oregon Public Utility Commission. (May 21). https://eta-publications.lbl.gov/sites/default/files/schwartz_puc_regulatory_practices_opuc_20200521.pdf.

Segreto, Marco, Lucas Principe, Alexandra Desormeaux, Marco Torre, Laura Tomassetti, Patrizio Tratzi, Valerio Paolini, and Francesco Petracchini. 2020. Trends in Social Acceptance of Renewable Energy Across Europe—A Literature Review. *Int J Environ Res Public Health*. 17(24) (December): 9161. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7764547/>.

Sepulveda, N. A., J. D. Jenkins, F. J. de Sisternes, and R. K. Lester. 2018. “The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation.” *Joule* 2(11): 2403–2420. (November 21).

Sharp, David. 2021. “Maine Voters Reject CMP Corridor Project But Fight Is Far From Over.” WGME. (Nov. 3). <https://wgme.com/news/local/maine-voters-reject-cmp-corridor-project-but-fight-is-far-from-over>.

Sosa, David, and Virginia Perry-Failor. 2012. “Labor Costs and the Rate Case.” *Public Utilities Fortnightly* (March). <https://www.analysisgroup.com/link/32b793f530984893babf505018fbdab6.aspx>.

Su, Jean. 2021. “Climate, Environmental, and Energy Justice: Integrating Justice into Electricity System Design and Decision-Making,” in Farley, C., J. Howat, J. Bosco, N. Thakar, J. Wise, J. Su, and L. Schwartz (technical editor). 2021. *Advancing Equity in Utility Regulation*. Future Electric Utility Regulation report no. 12. Berkeley Lab. <https://emp.lbl.gov/publications/advancing-equity-utility-regulation>.

Tarekegne, Bethel W., Kamila Kazimierczuk, and Rebecca S. O’Neil. 2021. Coal-Dependent Communities in Transition: Identifying Best Practices to Ensure Equitable Outcomes. Pacific Northwest National Laboratory. (Sept. 2021).

Tegen, S. 2005. Comparing Statewide Economic Impacts of New Generation from Wind, Coal, and Natural Gas in Arizona, Colorado, and Michigan. NREL Conference Paper CP-500-38154. (August).

The White House. 2021. Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies. (April 22). <https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/>.

University of California (UC) Berkeley. 2020. *2035: The Report*. (June). <https://www.2035report.com/electricity/>.

California Energy Commission. 2021. SB 100 Starting Point for the CAISO 20-Year Transmission Outlook. Sept. 13, 2021. Docket No. 21-SIT-01. file:///C:/Users/Mark/AppData/Local/Temp/TN239685_20210913T160327_SB%20100%20Starting%20Point%20for%20the%20CAISO%2020-year%20Transmission%20Outlook.pdf.

U.S. Bureau of Labor Statistics. 2021. Employment for Utilities: Electric Power Generation, Transmission and Distribution (NAICS 2211) in the United States. <https://fred.stlouisfed.org/series/IPUCN2211W200000000>.

U.S. Dept. of Energy. 2004. *U.S. Transmission Capacity: Present Status and Future Prospects*. (June). https://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/transmission_capacity.pdf.

U.S. Dept. of Energy. 2012. Operations and Maintenance Savings from Advanced Metering Infrastructure – Initial Results. (December).

Utility Workers Union of America. 2013. *Shaping Michigan's Energy Future: A Report by the Utility Workers Union of America to the Michigan Senate Energy and Technology Committee*. (June 4). [https://legislature.mi.gov/documents/2013-2014/CommitteeDocuments/Senate/Energy%20and%20Technology/Testimony/2013-SCT-ENERGY-06-04-1-02-Utility%20Workers%20Union%20of%20America,%20George%20Mano%20%20\(Neutral\).PDF](https://legislature.mi.gov/documents/2013-2014/CommitteeDocuments/Senate/Energy%20and%20Technology/Testimony/2013-SCT-ENERGY-06-04-1-02-Utility%20Workers%20Union%20of%20America,%20George%20Mano%20%20(Neutral).PDF).

Williams, James H., Ryan A. Jones, Ben Haley, Gabe Kwok, Jeremy Hargreaves, Jamil Farbes, and Margaret S. Torn. 2021. “Carbon Neutral Pathways for the United States.” *AGU Advances* 2. <https://doi.org/10.1029/2020AV000284>.

Xcel Energy. 2019. Integrated Distribution Plan (2020–2029). Docket No. E002/M-19-666. (Nov. 1).

Zhou, L., Y. Li, B. Wang, Z. Wang, and X. Hu. 2015. “Provision of supplementary load frequency control via aggregation of air conditioning loads.” *Energies* 8: 14098–14117.

Zitelman, Kiera, and Jasmine McAdams. 2021. The Role of State Utility Regulators in a Just and Reasonable Energy Transition: Examining Regulatory Approaches to the Economic Impacts of Coal Retirements. NARUC. (September). <https://pubs.naruc.org/pub/952CF0F2-1866-DAAC-99FB-0C6352BF7CB0>.

Chapter 3. U.S. Electric Companies Are Innovating to Provide the Solutions and Options that Customers Want

AES Corporation. 2021. “AES Announces First-of-Its-Kind Agreement to Supply 24/7 Carbon-Free Energy for Google Data Centers in Virginia” (press release). (May 4). <https://aescorp2020cr.q4web.com/press-releases/news-details/2021/AES-Announces-First-of-Its-KindAgreement-to-Supply-247-Carbon-Free-Energy-for-Google-Data-Centers-inVirginia/default.aspx>.

Byrd, Lori, Eric O’Shaughnessy, and Norma Hutchinson. 2021. Actions Large Energy Buyers Can Take to Transform and Decarbonize the Grid. WRI Issue Brief. (August). <https://www.wri.org/research/actions-large-energy-buyers-can-take-transform-and-decarbonize-grid>.

California Public Utilities Commission. 2021. CPUC Better Aligns Energy Efficiency Programs to Reduce GHG Emissions, Support Equity, and Increase Grid Stability (press release). Docket # R.13-11-005. (May). <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M385/K242/385242131.PDF>.

DTE Energy. 2022. MIGreenPower Wind & Solar Clean Energy Programs. <https://newlook.dteenergy.com/wps/wcm/connect/dte-web/quicklinks/migreenpower>.

Florida Public Service Commission. 2021. Docket No: 20210015-EL. *Petition by FPL for Base Rate Increase and Rate Unification*. Filed August 10, 2021. <https://www.floridapsc.com/library/filings/2021/09057-2021/09057-2021.pdf>.

Google. 2020. “24/7 by 2030: Realizing a Carbon-free Future.” (September). <https://www.gstatic.com/gumdrop/sustainability/247-carbon-free-energy.pdf>.

Institute for Electric Innovation (IEI). 2020. Electric Company Green Tariff Programs Update. Issue Brief. (October). https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Green-Tariffs-Update_October-2020.ashx.

IEI. 2021a. *Electric Company Smart Meter Deployments: Foundation for a Smart Grid*. (2021 Update). April. https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Smart_Meter_Report_April_2021.ashx.

IEI. 2021b. Energy Efficiency Trends in the Electric Power Industry: Top 10 Things You Should Know. (December). https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Energy-Efficiency-Top-10_Mar2020.ashx.

IEI. 2021c. Electric Companies Are Committed to a Clean Energy Future: 10 Things You Should Know (2021 Update). https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI-Clean-Energy-Top-10_April-2021.ashx

NESP. 2021. *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources*. (August). <https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/>.

Oregon PUC. October 9, 2017. Order 17-386. In the Matter of Portland General Electric Company, 2016 Integrated Resource Plan. <https://apps.puc.state.or.us/orders/2017ords/17-386.pdf>.

Parks Associates. 2020. Twenty-nine Percent of U.S. Broadband Households Plan to Purchase a Smart Thermostat in 2020. (February). <http://www.parksassociates.com/blog/article/pr-02042020>.

Powerley. 2021. “Powerley Turns 100 Million Customer Interactions into Utility Impacts.” Blog Post. (Feb. 4). <https://powerley.com/powerley-turns-100-million-customer-interactions-utility-impacts/>.

Southern California Edison. 2020. Clean Energy Optimization Pilot Year 1 Annual Report. (December). https://library.sce.com/content/dam/sce-doclib/public/regulatory/filings/pending/electric/ELECTRIC_4383-E.pdf.

The White House. 2021a. Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability. (December). <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/>.

The White House. 2021b. Executive Order on Tackling the Climate Crisis at Home and Abroad. (January) 27. <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/>.

Uplight. 2021. *Consumers Energy Provides 100,000 Pre-Enrolled Smart Thermostats to Save Money and Energy*. Case Study. https://uplight.com/wp-content/uploads/2021/03/U_CaseStudy_ConsumersEnergy_Thermostat_2021.pdf.

Chapter 4. Innovating the Electricity System from the Hearing Room to the Edge of the Grid

American Society of Civil Engineers (ASCE). 2021. *2021 Report Card for America’s Infrastructure: A Comprehensive Assessment of America’s Infrastructure*. https://infrastructurereportcard.org/wp-content/uploads/2020/12/National_IRC_2021-report.pdf.

Barbose, Galen L., Sydney Forrester, Eric O’Shaughnessy, and Naïm R Darghouth. 2021. *Residential Solar-Adopter Income and Demographic Trends: 2021 Update*. Berkeley Lab. <https://emp.lbl.gov/publications/residential-solar-adopter-income-and>.

Bhusal, N., M. Abdelmalak, M. Kamruzzaman, and M. Benidris. 2020. “Power system resilience: Current practices, challenges, and future directions.” *IEEE Access* 8: 18064–18086. doi:10.1109/access.2020.2968586.

Bronski, P., M. Dyson, M. Lehrman, J. Mandel, J. Morris, T. Palazzi, S. Ramirez, and H. Touati. 2015a. *The Economics of Demand Flexibility: How ‘Flexiwatts’ Create Quantifiable Value for Customers and the Grid*. Rocky Mountain Institute (RMI). (August). <https://rmi.org/insight/the-economics-of-demand-flexibility-how-flexiwatts-create-quantifiable-value-for-customers-and-the-grid/>.

Bronski, P., J. Creyts, M. Crowdis, S. Doig, J. Glassmire, L. Guccione, J. Mandel, B. Rader . . . and H. Touati. 2015b. *The Economics of Load Defection: How Grid-Connected Solar-Plus-Battery Systems Will Compete with Traditional Electric Service, Why it Matters, and Possible Paths Forward*. Rocky Mountain Institute (RMI). (April). <https://rmi.org/insight/the-economics-of-load-defection-how-grid-connected-solar-plus-battery-systems-will-compete-with-traditional-electric-service-why-it-matters-and-possible-paths-forward/>.

CAISO, PG&E, SCE, and SDG&E. 2017. *Coordination of Transmission and Distribution Operations in a High Distributed Energy Resource Electric Grid*. More Than Smart. https://gridworks.org/wp-content/uploads/2018/11/MoreThanSmartReport-CoordinatingTransmission_DistributionGridOperations.pdf.

California Public Utilities Commission (PUC). 2020. *Appendix B — An Overview of Distribution System Operator Models*. (Issue brief R.21-06-017). (February). <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M392/K348/392348813.pdf>.

Cawley, James H., and Norman J. Kennard. 2018. *A Guide to Utility Ratemaking*. Pennsylvania Public Utilities Commission. https://www.puc.pa.gov/General/publications_reports/pdf/Ratemaking_Guide2018.pdf.

Clack, C., A. Choukulkar, B. Cote, and S. McKee. 2020. *Why Local Solar For All Costs Less: A New Roadmap for the Lowest Cost Grid*. Vibrant Clean Energy, LLC. https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf.

Cleary, Kathryn, and Karen Palmer. 2020. *Renewables 101: Integrating Renewable Energy Resources into the Grid*. Resources for the Future. https://media.rff.org/documents/Renewables_101.pdf.

Coalition for Community Solar Access. 2020. Local Solar for All. <https://www.localsolarforall.org/>.

Connecticut Public Utilities Regulatory Authority (PURA). 2021. *17-12-03RE05 Innovation Pilots Framework - Final Proposal*. [http://www.dpuc.state.ct.us/2nddockcurr.nsf/8e6fc37a54110e3e852576190052b64d/146129694f23886085258752007994e2/\\$FILE/17-12-03RE05%20Innovation%20Pilots%20Framework%20-%20Final%20Proposal.pdf](http://www.dpuc.state.ct.us/2nddockcurr.nsf/8e6fc37a54110e3e852576190052b64d/146129694f23886085258752007994e2/$FILE/17-12-03RE05%20Innovation%20Pilots%20Framework%20-%20Final%20Proposal.pdf).

Creyts, J., and L. Guccione. 2014. *The Economics of Grid Defection: When and Where Distributed Solar Generation Plus Storage Competes with Traditional Utility Service*. Rocky Mountain Institute (RMI). <https://rmi.org/insight/the-economics-of-grid-defection-when-and-where-distributed-solar-generation-plus-storage-competes-with-traditional-utility-service/>.

De Martini, Paul, and Lorenzo Kristov. 2015. *Distribution Systems in a High Distributed Energy Resources Future*. LBNL-1003797. <https://emp.lbl.gov/publications/distribution-systems-high-distributed>.

EIA (U.S. Energy Information Administration). 2018a. “Utilities continue to increase spending on transmission infrastructure.” *Today in Energy* (February 9). <https://www.eia.gov/todayinenergy/detail.php?id=34892>.

EIA. 2018b. “Major utilities continue to increase spending on U.S. electric distribution systems.” *Today in Energy* (July 20). <https://www.eia.gov/todayinenergy/detail.php?id=36675>.

EIA. 2021a. *Annual Energy Outlook 2021*. (February). <https://www.eia.gov/outlooks/aeo/electricity/sub-topic-01.php>.

EIA. 2021b. *Short-Term Annual Energy Outlook*. (December). <https://www.eia.gov/outlooks/steo/archives/dec21.pdf>.

Energy Policy Act of 2005, Pub. L. No. 109–58, § 2, 119 Stat. 941 (2005).

Entergy Corporation. 2021a. *Entergy System Hurricane Ida Update – 9/2/21 @ 5 p.m.* Press release. *Entergy Newsroom* (September 2). <https://www.energynewsroom.com/article/entergy-system-hurricane-ida-update-9-2-21-5-p-m/>.

Entergy Corporation. 2021b. *Ida damage greater than Katrina, Ike, Delta, Zeta combined* Press release. *Entergy Newsroom* (September 5). <https://www.energynewsroom.com/article/ida-damage-greater-than-katrina-ike-delta-zeta-combined/>.

Entergy Corporation. 2021c. *Entergy Provides Update on Hurricane Ida.* (Press release) (September 21) <https://www.energynewsroom.com/news/entergy-provides-update-on-hurricane-ida/>.

Farley, C., J. Howat, J. Bosco, N. Thakar, J. Wise, J. Su, and L. Schwartz (technical editor). 2021. *Advancing Equity in Utility Regulation.* Future Electric Utility Regulation report no. 12, Lawrence Berkeley National Laboratory. <https://emp.lbl.gov/publications/advancing-equity-utility-regulation>.

Foehringer Merchant, Emma. 2019. "Hawaii's Trailblazing Solar Market Continues to Struggle Without Net Metering." *GTM*. <https://www.greentechmedia.com/articles/read/hawaiis-solar-market-continues-to-struggle-without-net-metering>.

Fox-Penner, Peter. 2020. *Power after Carbon: Building a Clean, Resilient Grid.* Harvard University.

Frick, Natalie M., J. P. Carvallo, and L. C. Schwartz. 2021. *Quantifying grid reliability and resilience impacts of energy efficiency: Examples and opportunities.* Lawrence Berkeley National Laboratory. <https://emp.lbl.gov/publications/quantifying-grid-reliability-and>.

Glick, D., and M. Lehrman. 2014. *Rate Design for the Distribution Edge: Electricity Pricing for a Distributed Resource Future.* Rocky Mountain Institute (RMI). <https://rmi.org/insight/rate-design-for-the-distribution-edge-electricity-pricing-for-a-distributed-resource-future/>.

Green Mountain Power (GMP). 2014. *2014 Integrated Resource Plan* (Working paper). <https://greenmountainpower.com/wp-content/uploads/2019/02/2014-Integrated-Resource-Plan.pdf>.

Green Mountain Power (GMP). 2017. *Green Mountain Power Recertified as B Corp, A Force for Good.* (August 21). <https://greenmountainpower.com/green-mountain-power-recertified-b-corp-force-good/>.

Green Mountain Power (GMP). 2019. *Vermont Public Utilities Commission Case No. 19-3537-TF, Exhibit GMP-JC-2: BYOD Tariff filing 9-20-19.* <https://epuc.vermont.gov/?q=node/64/144549/FV-PFEXAFF-PTL>.

Green Mountain Power (GMP). 2020a. *Multi-Year Regulation Plan 2020–2022* (Publication No. Per PUC August 27, 2020 order in Case No. 20-1401-PET). https://puc.vermont.gov/sites/psbnew/files/doc_library/green-mountain-power-multi-year-regulation-plan.pdf.

Green Mountain Power (GMP). 2020b. *Vermont Regulators Approve Pioneering GMP Energy Storage Programs to Save Customers Money and Increase Reliability* Press release. (May). <https://greenmountainpower.com/vermont-regulators-approve-pioneering-gmp-energy-storage-programs/>.

Green Mountain Power. 2020c. "GMP's Energy Storage Programs Deliver \$3 Million In Savings for All Customers During 2020 Energy Peaks" (press release). (September 29). <https://greenmountainpower.com/news/gmps-energy-storage-programs-deliver-3-million-in-savings/>

Green Mountain Power (GMP), & Renewable Energy Vermont (REV). 2019. *Memorandum of Understanding Between Green Mountain Power and Renewable Energy Vermont* (Case No. 18-1633-PET). (March). <https://greenmountainpower.com/wp-content/uploads/2019/04/2019-03-26-GMP-REV-MOU.pdf>.

Hawaii State Energy Office (HSEO) 2019. *Hawaii Energy Facts & Figures*. (July). https://energy.hawaii.gov/wp-content/uploads/2019/07/2019-FF_Final.pdf.

Hawaii State Energy Office (HSEO). 2020. *Annual Report 2020*. https://energy.hawaii.gov/wp-content/uploads/2021/01/HSEO_2020_Annual_Report.pdf.

Hawaiian Electric Industries, Inc. 2021. *Proposed Emergency Demand Response / Scheduled Dispatch Program Implementation Plan* (Docket No. 2019-0323). (June 18). <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21F21A90122E00962>.

Hawaiian Electric, Maui Electric, and Hawai'i Electric Light. 2018a. *Planning Hawaii's Grid for Future Generations: Integrated Grid Planning Report*. (March). https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/20180301_IGP_final_report.pdf.

Hawaiian Electric, Maui Electric, and Hawai'i Electric Light. 2018b. *Planning Hawaii's Grid for Future Generations Integrated Grid Planning Workplan*. (December). <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A18L17B01449I00681>.

Hawaii Public Utilities Commission (PUC). 2021a. *Guidance for Development of an Emergency Demand Response Program and Notification of Additional Status Update Meetings* (Docket No. 2019-0323). March 19. <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21C19B50237H02575>.

Hawaii Public Utilities Commission (PUC). 2021b. Performance Based Regulation (PBR). <https://puc.hawaii.gov/energy/pbr/>.

Hiller, J. 2022, February 19. "Wary of Being Left in the Dark, Americans Produce Their Own Power." Wall Street Journal. <https://www.wsj.com/articles/amid-power-outages-americans-buying-generators-solar-plus-battery-microgrids-11645207261>.

IEEE Std 1547-2018 – IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, Institute of Electrical and Electronics Engineers <https://ieeexplore-ieee-org.libproxy.berkeley.edu/stamp/stamp.jsp?tp=&arnumber=8332112> § 3.1 Definitions (2018).

Instituting a Proceeding to Investigate Distributed Energy Resource Policies Pertaining To The Hawaiian Electric Companies, Docket No. 2019-0323, Order No. 37816, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21F08B30537B01373> 1–34 (The Public Utilities Commission of the State of Hawaii June 8, 2021).

Instituting a Proceeding to Investigate Distributed Energy Resource Policies Pertaining To The Hawaiian Electric Companies, Docket No. 2019-0323, Order No. 37853, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21F30B61709E01491> 1–25 (The Public Utilities Commission of the State of Hawaii June 30, 2021).

Instituting a Proceeding To Investigate Performance-Based Regulation, Docket No. 2018-0088, Order No. 35411, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A18D18B60624J02464> 1–60 (The Public Utilities Commission of the State of Hawaii April 18, 2018).

Instituting a Proceeding To Investigate Performance-Based Regulation (Final Details), Docket No. 2018-0088, Decision and Order No. 37787, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21E17B53226E00118> 1–159 (The Public Utilities Commission of the State of Hawaii May 17, 2021).

Instituting a Proceeding To Investigate Performance-Based Regulation (Phase 1), Docket No. 2018-0088, Decision and Order No. 36326, <https://puc.hawaii.gov/wp-content/uploads/2019/05/DO-36326.05-23-2019.pdf> 1–54 (The Public Utilities Commission of the State of Hawaii May 23, 2019).

Instituting a Proceeding To Investigate Performance-Based Regulation (Phase 2), Docket No. 2018-0088, Decision and Order No. 37507, https://puc.hawaii.gov/wp-content/uploads/2020/12/2018-0088.PBR_Phase-2-DO.Final_mk_12-22-2020.E-FILED.pdf 1-226 (The Public Utilities Commission of the State of Hawaii December 23, 2020).

Instituting Proceeding to Investigate Distributed Energy Resource Policies Pertaining To The Hawaiian Electric Companies, Docket No. 2019-0323, Order No. 36538, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A19I25A84705I00380> 1–14 (The Public Utilities Commission of the State of Hawaii September 24, 2019).

Instituting Proceeding to Investigate Integrated Grid Planning, Docket No. 2018-0165, Order No. 35569, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A18G12B05711C00464> 1–32 (The Public Utilities Commission of the State of Hawaii July 12, 2018).

Instituting Proceeding to Investigate Integrated Grid Planning, Docket No. 2018-0165, Order No. 36725, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A19K05A82455F00010> 1–16 (The Public Utilities Commission of the State of Hawaii November 4, 2019).

Instituting Proceeding to Investigate Integrated Grid Planning, Docket No. 2018-0165, Order No. 37419, <https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A20K05B61158J00380> 1–19 (The Public Utilities Commission of the State of Hawaii November 5, 2020).

IREC. 2021. “Key Decisions for Hosting Capacity Analyses.” <https://irecusa.org/resources/key-decisions-for-hosting-capacity-analyses/>.

Jacobson, Mark Z., Anna-Katharinavon Krauland, Stephen J. Coughlin, Frances C. Palmer, and Miles M. Smith. 2022. “Zero air pollution and zero carbon from all energy at low cost and without blackouts in variable weather throughout the U.S. with 100% wind-water-solar and storage.” *Renewable Energy* 184 (January): 430–442. <https://www.sciencedirect.com/science/article/abs/pii/S0960148121016499?via%3Dihub>.

Jessel, S., S. Sawyer, and D. Hernández. 2019. “Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature.” *Frontiers in Public Health* 7(357). doi:10.3389/fpubh.2019.00357.

Kihm, Steve, Andrew Satchwell, and Peter Cappers. 2015. *The Effects of Rising Interest Rates on Electric Utility Stock Prices: Regulatory Considerations and Approaches*. LBNL-1003952. <https://emp.lbl.gov/publications/effects-rising-interest-rates>.

Kristov, L. 2021. “Valuing and Compensating Distributed Energy Resources.” *Energy Systems Integration Group*. (June 28). <https://www.esig.energy/valuing-and-compensating-distributed-energy-resources/>.

Kristov, L., and P. De Martini. 2014. *21st Century Electric Distribution System Operations*. (May). <http://smart.caltech.edu/papers/21stCElectricSystemOperations050714.pdf>.

Kristov, L., and P. De Martini. 2015. *Distribution Systems in a High Distributed Energy Resources Future: Planning, Market Design, Operation and Oversight* (Rep. No. 2). Lawrence Berkeley National Laboratory. (October). <https://escholarship.org/uc/item/6689n6x1>.

Lazar, J. 2016. *Electricity Regulation in the US: A Guide. Second Edition*. Regulatory Assistance Project (RAP). <http://www.raponline.org/wp-content/uploads/2016/07/rap-lazar-electricity-regulation-US-june-2016.pdf>.

LeBel, Mark, Jessica Shipley, Carl Linvill, and Camille Kadoch. 2021. “Smart Rate Design for Distributed Energy Resources.” Regulatory Assistance Project.

Lee, Taedong, Mark B. Glick, and Jae Hyup Lee. 2020. “Island energy transition: Assessing Hawaii’s multi-level, policy-driven approach.” *Renewable and Sustainable Energy Reviews* 118. <https://yonsei.pure.elsevier.com/en/publications/island-energy-transition-assessing-hawaiis-multi-level-policy-dri>.

Lowder, Travis, and Kaifeng Xu. 2020. *The Evolving U.S. Distribution System: Technologies, Architectures, and Regulations for Realizing a Transactive Energy Marketplace*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-74412. <https://www.nrel.gov/docs/fy20osti/74412.pdf>.

Martinot, E., L. Kristov, and J. D. Erickson. 2015. “Distribution System Planning and Innovation for Distributed Energy Futures.” *Current Sustainable/Renewable Energy Reports* 2(2): 47–54. doi:10.1007/s40518-015-0027-8.

Maryland Department of Environment. 2021. *The 2030 Greenhouse Gas Emissions Reduction Act 2030 GGRA Plan*. [https://mde.maryland.gov/programs/Air/ClimateChange/Pages/Greenhouse-Gas-Emissions-Reduction-Act-\(GGRA\)-Plan.aspx](https://mde.maryland.gov/programs/Air/ClimateChange/Pages/Greenhouse-Gas-Emissions-Reduction-Act-(GGRA)-Plan.aspx).

National Association of Regulatory Utility Commissioners (NARUC). 2020. *State Commission Staff Surge Call: Distribution System Data* (Issue brief No. DEOE0000818). <https://pubs.naruc.org/pub/B3E77DDD-155D-0A36-3126-315B34904383>.

National Energy Screening Project (NESP). 2020. *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources*. <https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/>.

National Renewable Energy Lab (NREL). 2021. *Electrification Futures Study*. (May). <https://www.nrel.gov/analysis/electrification-futures.html>.

Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future, R.21-06-017, <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M390/K664/390664433.PDF> 1–37 (The Public Utilities Commission of the State of California July 2, 2021).

Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, 18 CFR Part 35, Docket No. RM18-9-000, Order No. 2222, Department of Energy Federal Energy Regulatory Commission (FERC) https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf § C (2020).

Penn, I. 2022, March 13. “Frustrated With Utilities, Some Californians Are Leaving the Grid.” The New York Times. <https://www.nytimes.com/2022/03/13/business/energy-environment/california-off-grid.html>.

Petition of Green Mountain Power for approval of a multi-year regulation plan pursuant to 30 V.S.A. §§ 209, 218, and 218d, Case No. 18-1633-PET, <https://epuc.vermont.gov/?q=node/64/132296/FV-ALLOTDOX-PTL> 1-4 (State of Vermont Public Utilities Commission June, 2019).

Polson, Jim. 2013. “Utility Line Worker Cuts Hobble Emergency Storm Response.” Bloomberg Business. <https://www.bloomberg.com/news/articles/2013-07-04/utility-line-worker-cuts-hobble-emergency-storm-response>.

Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Case No. 14-M-0101, Order Adopting Regulatory Policy Framework and Implementation Plan, <https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=14-m-0101> 1-133 (State of New York Public Service Commission February 25, 2015).

PURA Investigation into Distribution System Planning of the Electric Distribution Companies – Innovative Technology Applications and Programs (Innovation Pilots), Docket No. 17-12-03RE05, <http://www.dpuc.state.ct.us/2ndDOCKCURR.NSF/60903cc7b9de44728525746b006e8ffb/d779ca825fe99a368525875200798b51?OpenDocument&scrollTop=1098> 1-3 (The State of Connecticut Public Utilities Regulatory Authority October 04, 2019).

Rickerson, W., and K. Zitelman. 2022. Valuing Resilience for Microgrids: Challenges, Innovative Approaches, and State Needs. National Association of Regulatory Utility Commissioners. <https://pubs.naruc.org/pub/1B571AB6-1866-DAAC-99FB-2509F05E4A67>

Schwartz, L. (Ed.). 2017. *Value-Added Electricity Services: New Roles for Utilities and Third-Party Providers*. Future Electric Utility Regulation report No. 9. Lawrence Berkeley National Laboratory. (October). https://eta-publications.lbl.gov/sites/default/files/feur_9_value-added_electricity_services_20171029_fin.pdf.

Shreve, D., and W. Schauer. 2019. *Deep decarbonisation requires deep pockets: Trillions required to make the transition*. Wood MacKenzie. (June). <http://www.decarbonisation.think.woodmac.com/>.

Silicon Valley Clean Energy, and Gridworks. 2019. *Silicon Valley Clean Energy Virtual Power Plant Options Analysis*. https://gridworks.org/wp-content/uploads/2019/08/GW_Silicon-Valley-Clean-Energy-report.pdf.

Sin, Y., P. Jadun, B. Nelson, M. Muratori, C. Murphy, J. Logan, and T. Mai. 2020. *Electrification Futures Study: Methodological Approaches for Assessing Long-Term Power System Impacts of End-Use Electrification*. doi:NREL/TP-6A20-73336.

Solar Alternatives. 2020. SBP Creates Louisiana’s First Commercial Solar Microgrid. Press release. *Solar Alternatives, Inc.* (September 4). <https://www.solalt.com/sbp-creates-louisianas-first-commercial-solar-microgrid/>.

Spector, J. 2022, February 14. “People power: Hawaii utility wants to pay households to share clean energy.” Canary Media. <https://www.canarymedia.com/articles/batteries/people-power-hawaii-utility-wants-to-pay-households-to-share-clean-energy>

St. John, J. 2021. “Hurricane-driven blackouts in New Orleans send a dire warning about the need for distributed energy.” *Canary Media* (September 1). <https://www.canarymedia.com/articles/climate-crisis/hurricane-driven-blackouts-in-new-orleans-send-a-dire-warning-about-the-need-for-distributed-energy>.

Stanton, Tom. 2020. “Solar Energy that Pays for Low-Income Customers and Communities.” *NRRI Insights* (December). <https://pubs.naruc.org/pub/46965D7D-155D-0A36-315D-58319B591EB8>.

State of Vermont Public Utilities Commission. 2021. Electric Alternative Regulation. <https://puc.vermont.gov/electric/electric-alternative-regulation>.

Sturmer, J. M., A. Plietzsch, and M. Anvari. 2021. *The Risk of Cascading Failures in Electrical Grids Triggered by Extreme Weather Events* (Rep. No. ArXiv:2107.00829v1 [physics.soc-ph]). Cornell University. (July). <https://arxiv.org/abs/2107.00829v1>.

Sunrun. 2019. *Building a More Resilient Grid*. <https://www.sunrun.com/sites/default/files/wildfire-mitigation-sunrun.pdf>.

Synapse Energy Economics and Sandia National Laboratories. 2021. *The Quest for Public Purpose Microgrids for Resilience: Considerations for Regulatory Approval*. Synapse Energy Economics and Sandia National Laboratories.

Tariff filing of Green Mountain Power Corporation for approval of a Bring Your Own Device tariff to be effective October 31, 2019, Case No. 19-3537-TF, Final Order, 1–33 (State of Vermont Public Utilities Commission May 20, 2020). <https://epuc.vermont.gov/?q=node/64/144549/FV-BDIssued-PTL>.

Vermont Energy Investment Corporation (VEIC). 2018. *Solar and Distributed Generation as Key Elements in Meeting Vermont’s Comprehensive Energy Plan Goals* (Tech. No. DE-EE0006911). (March). <https://www.osti.gov/servlets/purl/1434651>.

Zibelman, Audrey. 2021. “Decarbonization: Australia’s Journey of Energy Transition.” *IEEE Power & Energy* (September/October). <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9520140>.

Chapter 5. Scaling Utility Innovation: Identifying a Path to Action

Acadia Center. 2021. “PUC and State Energy Mandate Reform: Prioritizing Climate and Equity in the Northeast. (July).

Baker, David R. 2021. California to Test Whether Big Batteries Can Stop Summer Blackouts. Bloomberg Green. (April 1). <https://www.bloomberg.com/news/articles/2021-04-01/to-avoid-blackouts-california-s-installing-more-big-batteries-than-all-of-china>.

Bonbright, James C. 1961. *Principles of Public Utility Rates*, Columbia University Press.
Center for Sustainable Systems, University of Michigan. 2021. “U.S. Grid Energy Storage Factsheet.” Pub. No. CSS15-17. <https://css.umich.edu/factsheets/us-grid-energy-storage-factsheet>.

- Bradley, Dan, and H. Christine Richards. 2019. “How REV Connect’s Innovation Sprints Redefine Utility Procurement.” *Public Utilities Fortnightly* (February). <https://guidehouse.com/-/media/www/site/insights/energy/2019/rev-connect-innovation-under-deadline.pdf>.
- Cappers, P. A., and C. A. Spurlock. 2020. *A handbook for designing, implementing, and evaluating successful electric utility pilots*. Berkeley Lab. https://eta-publications.lbl.gov/sites/default/files/pilot_best_practices_final_20200904.pdf.
- Christiansen, Clayton, Michael E. Raynor, and Rory MacDonald. 2015. “What is Disruptive Innovation?” *Harvard Business Review* (December).
- Commonwealth of Massachusetts. 2021. Chapter 8: An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy. <https://malegislature.gov/Laws/SessionLaws/Acts/2021/Chapter8>.
- Cooper, Adam and Mike Shuster. 2021. *Electric Company Smart Meter Deployments: Foundation for a Smart Grid (2021 Update)*. (April). https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Smart_Meter_Report_April_2021.ashx#:~:text=As%20of%20year%2D%20end%202019,expected%20by%20year%2Dend%202021.
- Costello, Ken. 2016. “Primer on R&D in the Energy Utility Sector.” NRRI Report. No. 16-05. (May). <https://pubs.naruc.org/pub/FA85BA08-D94D-E40F-B7E1-98F834372877>.
- Doll, Scooter. 2022. “The best (and worst) US states for EV charging.” *electrek* (Jan. 23). <https://electrek.co/2021/11/08/the-best-and-worst-us-states-for-ev-charging/#h-2-california>.
- Edison Electric Institute (EEI). 2017. *Harnessing the Potential of Energy Storage: Storage Technologies, Services, and Policy Recommendations*. (May). https://www.eei.org/issuesandpolicy/generation/documents/eei_harnessingstorage_final.pdf.
- EIA. 2021. “EIA projects renewables share of U.S. electricity generation mix will double by 2050.” <https://www.eia.gov/todayinenergy/detail.php?id=46676>.
- Elliot, Randolph, National Rural Elec Association, Organization of MISO States, Scott Aaronson, Edison Electric Institute, and National Association Advocates. 2019. *Utility Investments in Resilience of Electricity Systems*. Ed. Schwartz, Lisa C. FEUR Report no. 11. https://eta-publications.lbl.gov/sites/default/files/feur_11_resilience_final_20190401v2.pdf.
- Farley, C., J. Howat, J. Bosco, N. Thakar, J. Wise, J. Su, and L. Schwartz (technical editor). 2021. *Advancing Equity in Utility Regulation*. Future Electric Utility Regulation report no. 12, Berkeley Lab. <https://emp.lbl.gov/publications/advancing-equity-utility-regulation>.
- Faruqui, Ahmad. 2020. *Moving From Pilots to Full-Scale Deployments of Time-of-Use Rates: Bridging the Chasm*. The Brattle Group. April 16. https://www.brattle.com/wp-content/uploads/2021/05/18585_moving_from_pilots_to_full-scale_deployments_of_time-of-use_rates_-_bridging_the_chasm.pdf.
- Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. 2015. *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). <https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf>.

Jones, Philip B., Jonathan Levy, Jenifer Bosco, John Howat, and John W. Van Alst. 2018. *The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives*. Future Electric Utility Regulation report No. 10.

https://eta-publications.lbl.gov/sites/default/files/feur_10_transportation_electrification_final_20180813.pdf.

Michigan Public Service Commission. 2022. Energy Programs and Technology Pilots. Final Staff Report. https://www.michigan.gov/mpsc/0,9535,7-395-93307_93312_93593_95590_95594_95685-508663--00.html.

Muller, Joann. 2021. “Biden wants 500,000 EV charging stations. Here’s where they should go.” *Axios* (August 6). <https://www.axios.com/electric-vehicle-charging-stations-equity-1b00f7a6-f87a-4125-9bc0-82399663b345.html>.

National Academies of Sciences, Engineering, and Medicine. 2021. *Enhancing Federal Clean Energy Innovation: Proceedings of a Workshop*. The National Academies Press. <https://doi.org/10.17226/25973>.

National Conference of State Legislators (NCSL). 2021. Modernizing the Electric Grid: State Role and Policy Options. (September 22). <https://www.ncsl.org/research/energy/modernizing-the-electric-grid-state-role-and-policy-options.aspx>.

National Energy Screening Project (NESP). 2021. *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources*. (August). <https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/>.

National Energy Technology Laboratory (NETL). 2008. *Advanced Metering Infrastructure*. (February). https://netl.doe.gov/sites/default/files/Smartgrid/AMI-White-paper-final-021108--2--APPROVED_2008_02_12.pdf.

New York State Senate. 2019. Senate Bill S6599. 2019–2020 Legislative Session. <https://www.nysenate.gov/legislation/bills/2019/s6599>.

Phillips, Jr., C. 1993. *The Regulation of Public Utilities: Theory and Practice*.

Pisano, Gary. 2019. “The Hard Truth about Innovative Cultures.” *Harvard Business Review* (January–February).

Rogers, Everett. M. 2003. *Diffusion of Innovation*. 5th edition. Simon and Shuster. ISBN 978-0-7432-5823-4. <https://www.simonandschuster.com/books/Diffusion-of-Innovations-5th-Edition/Everett-M-Rogers/9780743222099>.

Sergici, Sanem. 2018. Reviewing Grid Modernization Investments: Summary of Recent Methods and Projects. The Brattle Group. (December 4). http://files.brattle.com/files/15440_sergici_nema_grid_mod_report_presentation_12042018.pdf.

Sergici, Sanem. 2019. Grid Modernization: Policy, Market Trends and Directions Forward. The Brattle Group. (May 21). https://www.brattle.com/wp-content/uploads/2021/05/16411_grid_modernization_-_policy_market_trends_and_directions_forward.pdf.

Shattuck, Peter, Abigail Anthony, and Mark LeBel. 2016. "Technology upends the utility business model." *CommonWealth* (March 21). <https://commonwealthmagazine.org/environment/technology-upends-the-utility-business-model/>.

Stevens, Pippa. 2019. "PG&E power outage could cost the California economy more than \$2 billion." CNBC News. (October 10). <https://www.cnbc.com/2019/10/10/pge-power-outage-could-cost-the-california-economy-more-than-2-billion.html>.

Sun, Yinong, Paige Jadun, Brent Nelson, Matteo Muratori, Caitlin Murphy, Jeffrey Logan, and Trieu Mai. 2020. *Electrification Futures Study: Methodological Approaches for Assessing Long-Term Power System Impacts of End-Use Electrification*. Golden, Colorado: National Renewable Energy Laboratory. NREL/TP-6A20-73336. <https://www.nrel.gov/docs/fy20osti/73336.pdf>.

The White House. 2021. *The Path to Achieving Justice40*. (July 20). <https://www.whitehouse.gov/omb/briefing-room/2021/07/20/the-path-to-achieving-justice40/>.

Trabish, Herman K. 2019. "An emerging push for time-of-use rates sparks new debates about customer and grid impacts." *Utility Dive* (Jan. 28). <https://www.utilitydive.com/news/an-emerging-push-for-time-of-use-rates-sparks-new-debates-about-customer-an/545009/#:~:text=New%20programs%20are%20being%20tested,power%20than%20they%20pay%20for>.

Trabish, Herman K. 2020. "Slowed pay-off from billions in AMI investment puts the technology's future in doubts." *Utility Dive* (Feb. 20). <https://www.utilitydive.com/news/slowed-pay-off-from-billions-in-ami-investment-put-the-technologys-future/570274/>.

Twitchell, J. B., J. D. Taft, R. O'Neil, and A. Becker-Dippmann. 2021. *Regulatory Implications of Embedded Grid Energy Storage*. PNNL-30172. (April). <https://energystorage.pnnl.gov/pdf/PNNL-30172.pdf>.

U.S. Department of Energy. n.d. *AMI in Review: Informing the Conversation*. https://www.smartgrid.gov/files/documents/AMI_Report_7_8_20_final_compressed.pdf.

Vermont Public Utility Commission. 2019. May 24, 2019 Order in Case No. 18-1633-PET. <https://epuc.vermont.gov/?q=node/64/132296/FV-BDIssued-PTL>.

Wang, Hara, and Cyril Yee. 2020. "Climate Tech's Four Valleys of Death and Why We Must Build a Bridge." Third Derivative. (June 17). <https://rmi.org/climate-techs-four-valleys-of-death-and-why-we-must-build-a-bridge/>.



Berkeley Lab
1 Cyclotron Rd.
Berkeley, CA 94720

<https://gridmod.labworks.org/>