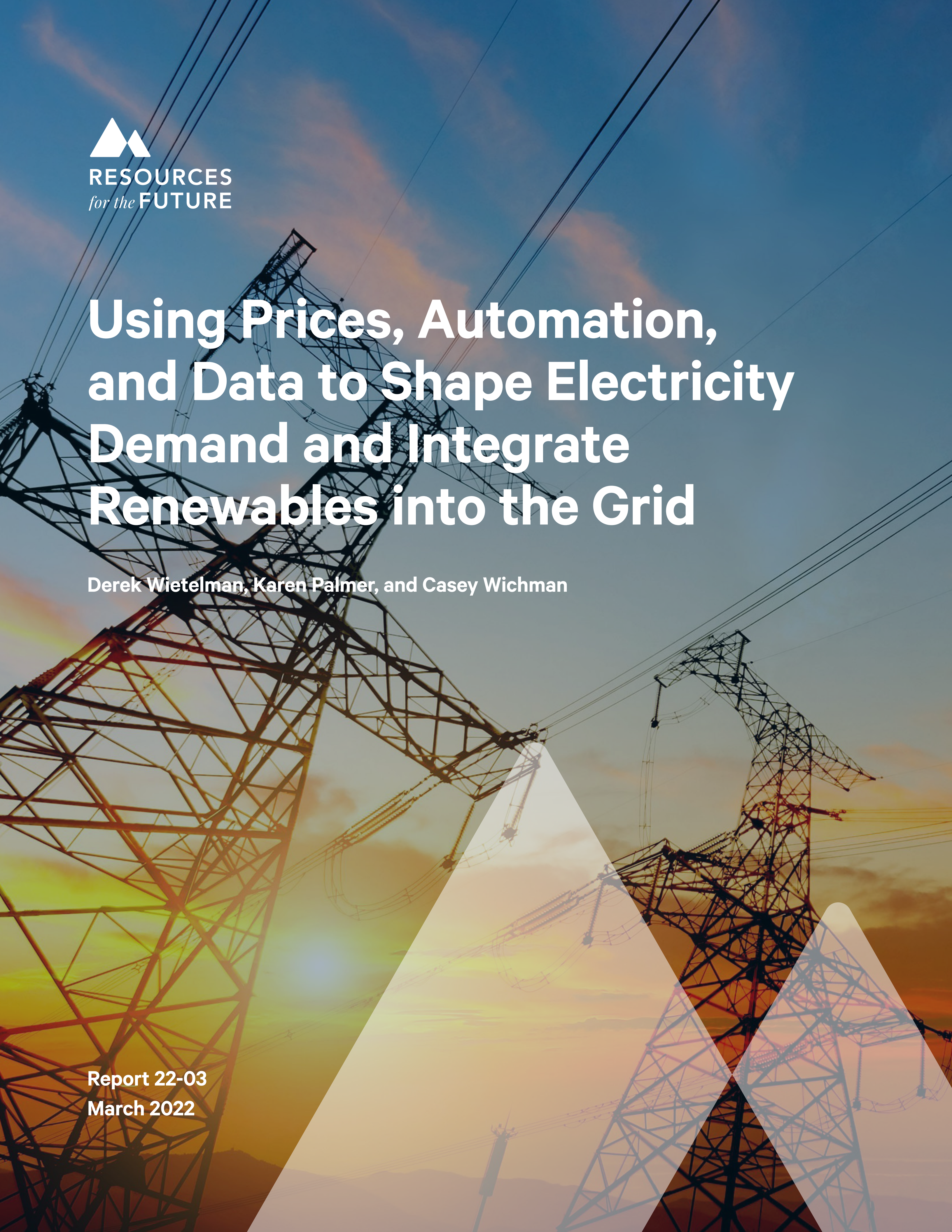

RESOURCES *for the* FUTURE

Using Prices, Automation, and Data to Shape Electricity Demand and Integrate Renewables into the Grid

Derek Wietelman, Karen Palmer, and Casey Wichman

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About the Authors

Derek Wietelman is a PhD student in the Department of Agricultural and Resource Economics at the University of Maryland, College Park. His current work focuses on estimating causal effects of price and non-price policy interventions on water and electricity demand.

Karen Palmer is a senior fellow at Resources for the Future and an expert on the economics of environmental, climate, and public utility regulation of the electric power sector. Her work seeks to improve the design of environmental and technology regulations in the sector and the development of new institutions to help guide the ongoing transition of the electricity sector.

Casey Wichman is an assistant professor in the School of Economics at the Georgia Institute of Technology and a university fellow at Resources for the Future. His research spans water demand management, valuation of environmental resources and infrastructure, urban transportation, public goods provision, demand for outdoor recreation, climate policy, and assessing informational constraints in decision-making.

Acknowledgements

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About RFF

Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.

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Sharing Our Work

Executive Summary

To realize the ambitious clean electricity goals of many states and the Biden administration, variable renewable energy sources will need to be effectively integrated into the electric grid. This report presents a summary of an online workshop convened by Resources for the Future (RFF) in December 2021. RFF convened a group of economists, industry officials, policymakers, data aggregators, and regulators to discuss the role that time-varying pricing, device automation, and high-frequency data can play in shaping electricity demand and aiding renewables integration effort. Existing regulatory, technological, and economic barriers have hindered progress in these efforts. These barriers include regulatory inertia, fears of retail bill volatility, and potentially less-effective rebates for reducing peak consumption. Recent research provides reason for optimism, however, as consumers appear to be cognizant of prices and willing to cede control of some types of electricity consumption to automated processes. Advances in machine learning may also help utilities effectively evaluate the consumption impact of different types of electricity rates. Moving forward, there are ample opportunities for researchers to partner with smart thermostat and other smart device companies, nonprofits, and data aggregators for insights on effective strategies to engage flexible demand from the vast amount of high-frequency consumption data made possible by smart meters.

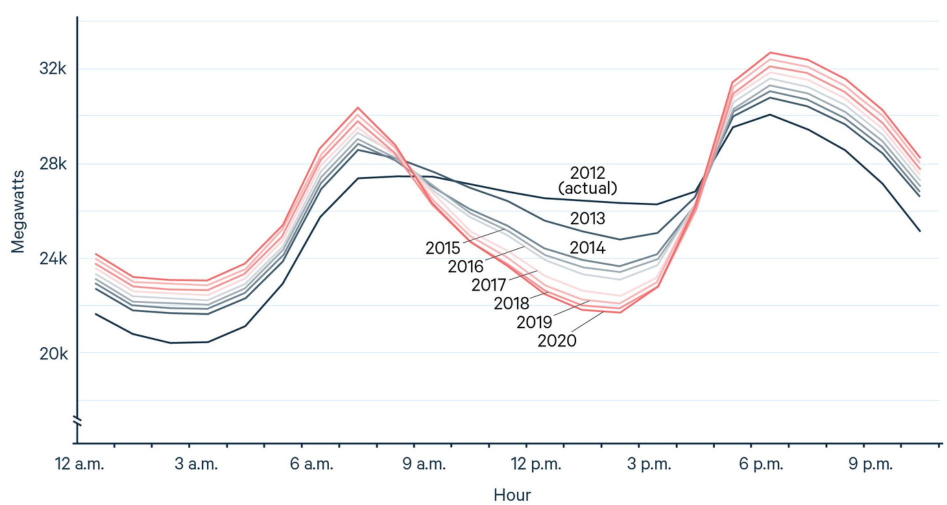
Contents

1. Introduction

To realize the ambitious clean electricity goals of many states and the Biden administration, variable renewable energy sources will need to be effectively integrated into the electric grid. In December 2021, Resources for the Future convened a group of economists, industry officials, policymakers, data aggregators, and regulators to discuss the role that time-varying pricing, device automation, and high-frequency data can play in shaping electricity demand and aiding in the effort to integrate renewables into the grid (i.e., accommodate variable generation from renewables in grid operations and load balancing). To date, existing regulatory, technological, and economic barriers have hindered progress in the efforts to use these tools to effectively shape electricity demand and integrate renewables into the grid. The goals of the RFF workshop were to discuss the nature of these barriers, learn what the latest research has to say about solutions in this space, and identify opportunities for partnerships among academics, utilities, and private-sector companies and data aggregators for future research.

The need for demand-side management and time-varying prices to aid in renewables integration is often illustrated through the classic "duck curve," which charts net electricity load, or demand, that system operators must meet throughout the day (Figure 1). In a system with a relatively large penetration of renewables, the amount of generation from nonrenewables necessary to meet electricity load rises dramatically as the sun sets and intermittent solar generation ceases to produce. This is particularly problematic because this loss of renewable generation coincides with times of peaking electricity demand in the evening as customers return to their homes and fire up electric-hungry appliances. Utilities have historically attempted to turn to time-varying electricity prices that try to discourage electricity use during these peak times and demand-side management programs that offer payments or other incentives to reduce electricity consumption during peak hours.

Figure 1. Duck Curve of Net Electricity Load in California



Notes: Actual and projected net load for a typical winter day in California, 2012-2020. Years after 2012 are projected by the California Independent System Operator and reflect an expectation of increasing solar energy generation.
Source: Cleary and Palmer (2020).

Another challenge posed by the duck curve is that as solar generation grows, the level of net load during hours of abundant renewable generation continues to decline, bringing with it a decline in the value of additional renewable energy, a fall in the daytime wholesale price, and an increased likelihood that renewable generators could be curtailed as a result of insufficient demand for power during certain hours in certain locations. Passing price signals that reflect these variations in cost across the day to consumers could facilitate demand shifting toward periods of lower generation costs, raising the value of renewable generators during hours of operation and helping flatten the ramp up in demand at sunset.

Coincident in time with growth in variable and intermittent renewables is a growing desire to electrify energy end uses typically powered by fossil fuels, such as vehicles and space and water heating. Opening remarks at the workshop highlighted that those new sources of electricity demand may be more flexible than others to the extent that electricity consumption and energy service consumption can be (or in some cases necessarily are) separated in time. Electrifying these end uses is an important part of the energy transition ahead and a larger strategy to decarbonize the economy through reduced fossil fuel use. To the extent that electricity rate design affects incentives to invest in electric vehicles (EVs) and electric heat pumps, these considerations will also play a role in larger questions of rate design to engage flexible demand. Allocation of fixed charges for grid access to customers and end uses could play a role in creating incentives for electrification.

As the opening speaker said, perhaps the question for potential EV owners and for grid operators is, who owns your driveway and is responsible for the operation of the EV charger that resides there? Might subscription services that couple the device with the service be a way of saving consumers from having to actively manage vehicle charging and realize associated cost savings in the presence of time-varying energy rates? The speaker also stressed that distributional impacts on consumers need to be part of the conversation around retail rates. The energy transition that will be needed for decarbonization cannot be completed cost-effectively until the demand side is fully engaged.

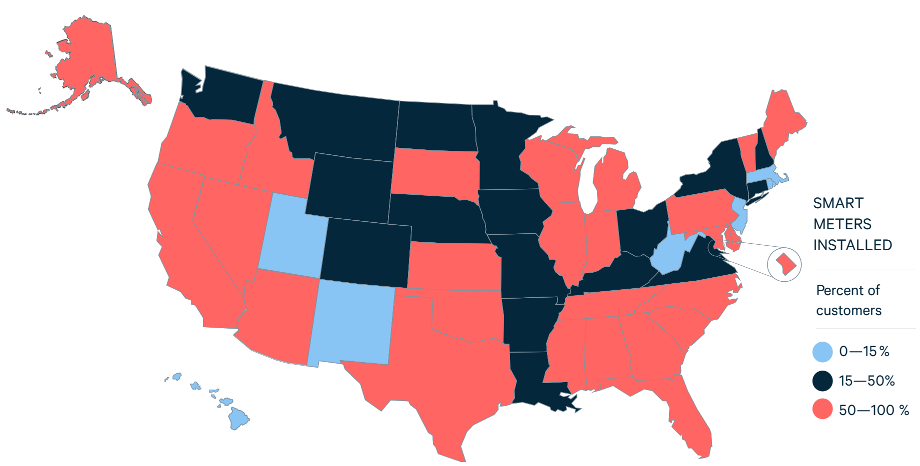
As the workshop began, audience members made note of several points that helped guide the discussion over the course of the afternoon. These included questions about the extent to which customers need to be engaged and attentive to electricity consumption and demand-side programs in order to reshape energy use. Additionally, another participant noted that advances in renewable technologies and distributed generation have muddied the traditional idea of separate demand and supply sides of the electricity market, with “prosumers” that both produce and consume electricity gradually playing a larger role in the future of electricity markets.

2. Identifying Barriers to Using Demand-Side Management to Integrate Renewables

Engaging electricity consumers through demand-side management programs and electricity prices that vary throughout the day to accurately reflect social marginal costs can greatly reduce the cost of renewables integration. To date, multiple barriers have prevented active demand-side management programs and time-varying rates from being implemented. The first workshop panel focused on identifying these barriers and how they can be overcome.

One barrier to widespread implementation of time-varying pricing identified by the panelists is the difference in policy and regulatory frameworks across states. The largest example of this is the difference in the adoption and deployment of smart meters over time by utilities in different states. Smart meters provide the electric utility with the ability to track electricity consumption at a granular timescale throughout the day, rather than the old approach of having a meter reader read a customer's aggregate consumption once per month. Smart meters are a necessary first step, as demand-side management programs and time-varying rates are generally difficult or impossible to implement without the ability of the utility to track household consumption over time. Figure 2 shows substantial heterogeneity in the proportion of electricity customers serviced by smart meters, with at least five states having fewer than 15 percent of homes serviced by smart meters as of the end of 2019. Until all states can get closer to universal smart meter deployment, it will be difficult for demand-side management programs and time-varying rates to become the default electricity pricing approach in the United States.

Figure 2. Percentage of Consumers in Each State Using Smart Meters



Source: Cooper and Shuster (2021).

Inertia in the policymaking and regulatory process was identified as another important barrier to effective implementation of time-varying pricing. In many jurisdictions where time-varying prices have been adopted, the process has taken several years from initial proposal of the rates to actually charging customers time-varying prices. Once such rates have been proposed and implemented, utilities have generally been reticent to change them. Ontario, Canada, provides one such example, as less than 10 percent of customers opt out of a time-varying price for a more traditional regulated rate (Faruqui and Bourbonnais 2020). The most popularly adopted time-varying electricity pricing scheme is the time-of-use (TOU) rate, in which a typical day is split into discrete periods (such as on- and off-peak periods), and a different price is charged for electricity consumed in each period. TOU prices are typically easy to understand and have the benefit of being set in advance, so they are known to customers. However, the panelists generally agreed that TOU rates are not granular enough, nor are the prices often differentiated enough to send the correct price signal to customers to reduce electricity consumption at the times when it most beneficial to the grid. The panelists preferred rates that allow utilities to call special demand events and implement critical-peak prices, or fully dynamic time-varying rates, but these rates are not often observed in practice, and given the existing inertia, it may be difficult to get policymakers to move beyond TOU rates.

On a related note, the idiosyncratic nature of the electricity ratemaking process in general was also mentioned by several panelists as another barrier to implementing the types of time-varying electricity prices that would help integrate renewables into the grid effectively. When designing electricity rates, utility officials are generally charged with balancing multiple goals, none of which are directly concerned with prioritizing time-varying electricity prices or demand charges. These goals include adequate recovery of revenue to cover costs, efficiency concerns, simplicity of the rate structure, and increasingly, concerns about fairness, equity, and affordability of the rate structure for low-income households. For example, time-varying rates can be complex and difficult for the average electricity consumer to understand.

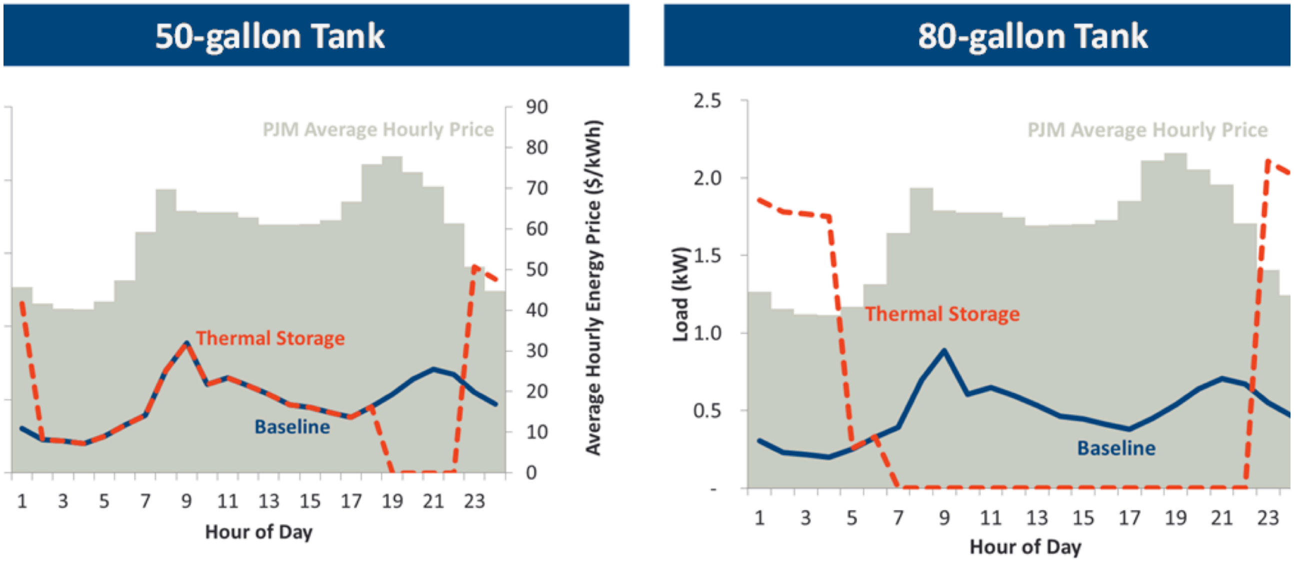
Another common barrier identified was utilities' reticence to adopt rate structures that may introduce a large degree of bill volatility for their residential customers, a particular concern for real-time prices. Especially during peak demand periods, the social marginal cost of the marginal kilowatt-hour (kWh) of electricity consumed is much higher than at other times of the day, and time-varying prices that accurately reflect these social marginal costs may result in much higher electricity prices than residential customers are used to paying (Borenstein and Bushnell 2018). Panelists and audience members stressed the need for more creative types of electricity contracts offered to residential customers that could help reduce the potential for bill volatility, such as hedging instruments. These could come in the form of subscription-style contracts, in which a household contracts for a specific amount of power and then only pays the difference if it goes over its allotted power for the month (and similarly is rebated if it does not use the entire allotment).

One panelist explained that regions with retail competition in electricity supply, such as Texas, offer more flexibility in rate design. In Texas, NRG customers are offered a subscription program in which they get a flat bill that does not vary with kWh use, and this service can be combined with a smart thermostat that the provider can control. Such services need to be priced in a way that accounts for potential adverse selection by high users and for moral hazard of the free marginal kWh resulting in demand increases. Provisions that limit free additional energy consumption up to a point should also be considered. These types of contracts have the potential to provide significant savings to customers who are willing to surrender control of their thermostats within agreed parameters.

Finally, panelists noted that some existing demand response programs operated by the utilities and the regional transmission organizations may be paradoxically hindering the renewables integration transition through the perverse incentives created by payments under these existing programs. Many existing demand response programs offer big incentive payments to heavy electricity users in the industrial and commercial sectors for being available to curtail their electricity use if called to do so; these can be thought of as business attraction rates for the utilities. Some companies build their entire business models around these demand response programs and, as a result, lobby to keep them in place, thereby preventing further experimentation with dynamic pricing and other forms of consumer engagement. Paying for demand response introduces a moral hazard problem in that the electricity system operators cannot directly base financial rewards on customer effort to reduce demand. Reductions are not observable, only levels, so there is no way to tell whether customers are making an effort to reduce demand. Indeed, sometimes programs create incentives to increase demand during peak hours on noncritical peak days in order to increase the baseline against which payments for demand response are assessed. An adverse selection problem also arises in that these demand response programs are often opt-in by nature. This means that the type of firms that opt in to the programs may be those that already have relatively low electricity use during system peak periods, so the consumption levels they exhibit when called do not necessarily reflect true “additional” reductions in energy use necessary to reduce peak load.

The panel did note opportunities moving forward in this space. One prominent solution discussed was energy storage technologies. While technologies like batteries have largely been too expensive to scale, advances in household devices such as electric vehicle charging technology and smart water heaters are changing the game and allowing for energy storage in ways that have not been possible before. For example, water heaters can store thermal energy and keep water hot for many hours after the initial electricity use for heating. In essence, this allows the water heater to act as a battery, shifting electricity consumption away from peak hours by heating water overnight and during other low-cost periods of the day. Figure 3 illustrates how this load shifting works. As more households install electric water heaters and drive electric cars, it will be crucial to exploit the energy storage opportunities that these technologies offer.

Figure 3. Using Water Heaters as Energy Storage to Shift Load



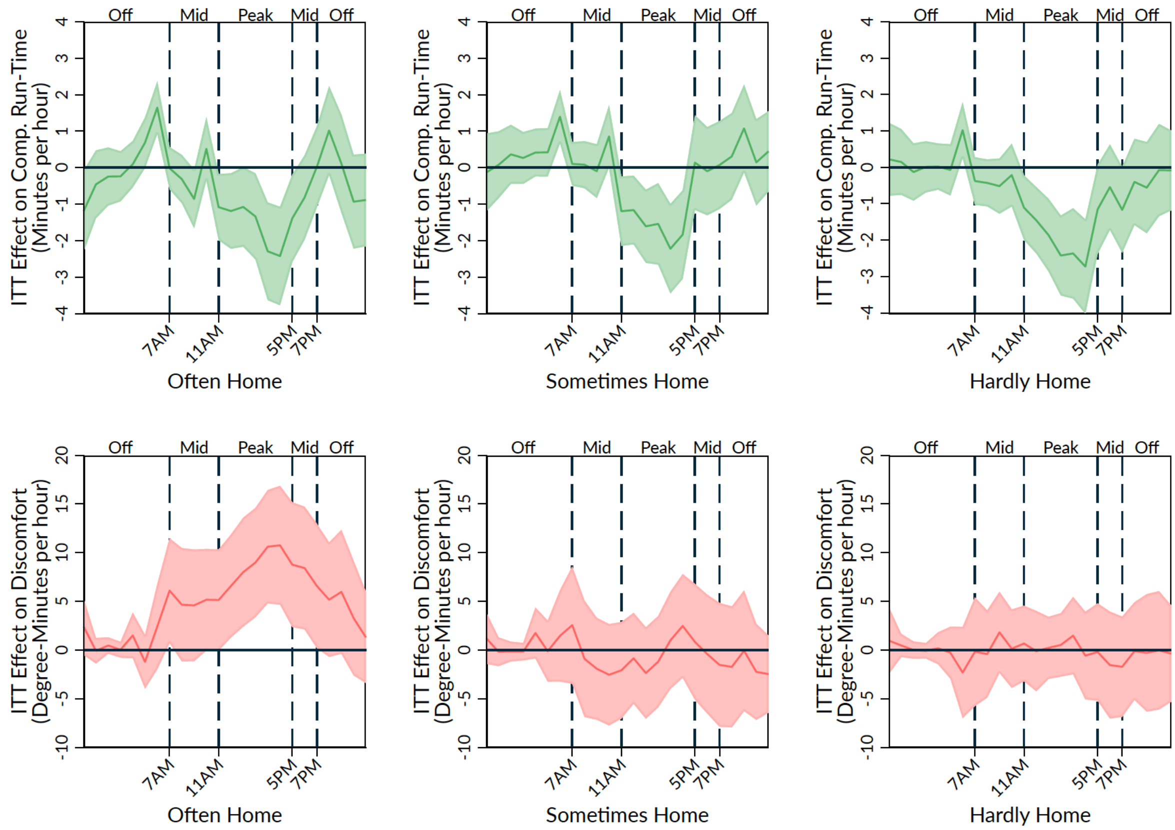
Source: Hledik et al. (2016).

3. Lessons from Academic Research

After considering the barriers to using demand-side management, workshop participants moved into a discussion of recent research on electricity pricing, economic incentives, and smart technologies. Presentations focused on the role that such smart technologies can play in shaping demand and helping overcome the barriers discussed in the previous panel. Panelists largely agreed that informed electricity consumers do respond to prices. However, they also agreed that nonprice factors, such as inattention and complex rate structures, play a critical role in potentially limiting the effectiveness of prices in shaping demand. Our understanding of how these factors affect demand and how they can be addressed is incomplete, and good research designs informed by institutional knowledge are important to improving that understanding.

If addressing customer inattention is likely an important factor in shaping demand, what is the proper role for automation? Will customers cede control of the thermostat and allow for automatic heating and cooling adjustments within the home? One study addressed this question through the use of a randomized experiment in which existing smart thermostat customers were encouraged to activate a feature that partially automated customer cooling patterns in response to time-varying prices. Customers who were only sometimes or rarely at home saw reductions in central air conditioner run times without correspondingly large increases in household discomfort, as measured by deviations in realized indoor temperature from desired temperature, indicating that households in the experiment were willing to trade small monetary energy savings for small increases in discomfort. These trends are illustrated in Figure 4. Further experimentation with automation programs such as these paired with time-varying rates could prove promising in shifting electricity demand in time and further aiding renewables integration efforts.

Figure 4. Changes in AC Compressor Run Time and Household Discomfort



Source: Blonz et al. (2021).

Other research presented in the session yielded promising results for the future of automation and time-varying prices in shaping electricity demand. Evidence from simulation-based modeling shows that TOU pricing for both energy and demand charges for commercial load can lead to large operating cost savings for electric bus fleets by providing incentives to shift times at which they charge away from peak periods. Another study focuses on new methods for evaluating the effect of peak pricing policies on electricity consumption. While randomized controlled trials are often held up as the gold standard in the evaluation of public programs, they can be difficult and costly for utilities to conduct. The presented research demonstrates that machine learning techniques can accurately predict counterfactual electricity consumption (i.e., what consumption would have been if a policy had not been introduced) and thus can replicate experimental findings on how pricing and other policies affect consumption. Machine learning techniques paired with high-frequency consumption data from smart meters will enable utilities and others with access to meter data to evaluate new pricing mechanisms and other policies more easily, and without the time and monetary costs of running a full randomized evaluation.

Broader discussion among the panelists and attendees focused on several areas where additional research could be particularly valuable. These include commercial and industrial buildings, which have been generally understudied by economists. The heavy-duty trucking industry is another fruitful area for research. Contrary to popular perception, most heavy-duty trucks are privately owned by smaller owner-operators and not by large corporations, and thus getting the owners to both electrify their vehicles and employ smart charging will take significant effort. Research about distributional impacts of rate designs is also lacking, due in part to limited information about household socioeconomic characteristics in metered data. Having access to this information could enable a better understanding of heterogenous impacts of various pricing approaches and other measures to shape electricity demand. Lastly, the next frontier for research in this space could be to study energy demand management by a utility or other intermediary that is not the customer. Would customers be open to a program that sets a monthly service price and, with their permission, allows an intermediary to manage air conditioner operation in the home (or other end uses) to take advantage of energy price fluctuations? Or would customers opt out of such a service?

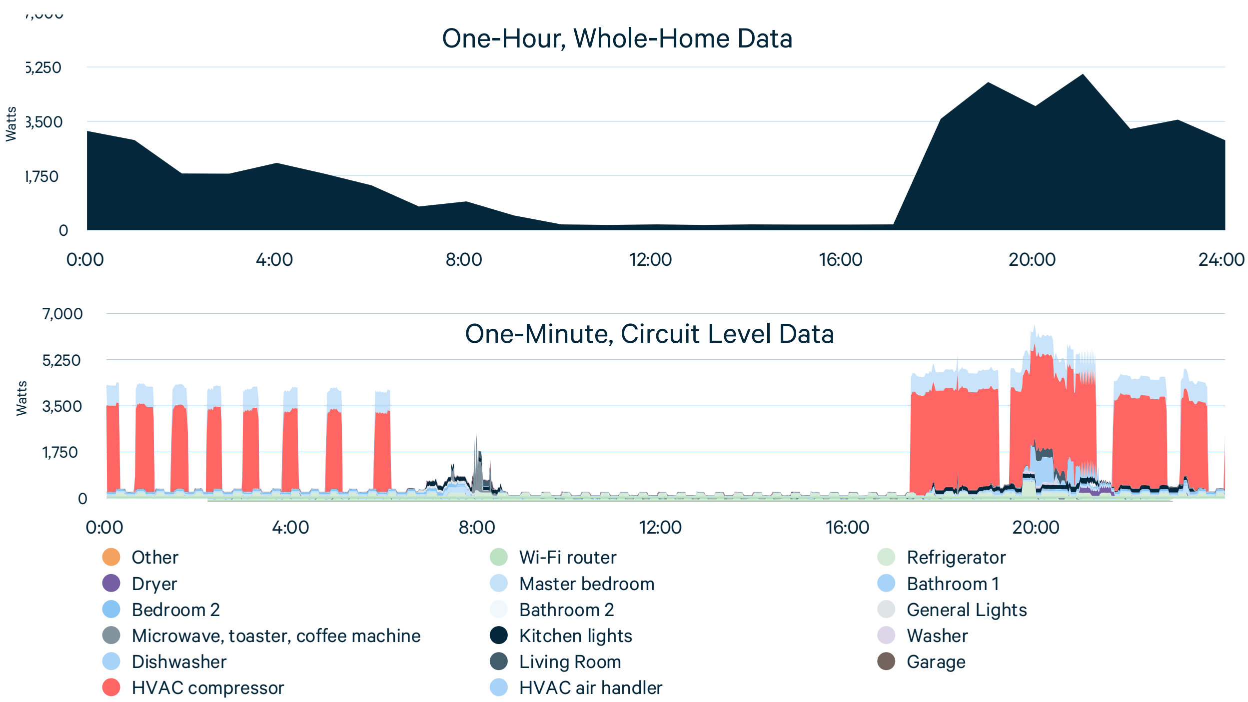
4. Perspectives from Device, Software, and Data Providers

With the rise of the prosumer and the ever-increasing complexity of the grid, effective renewables integration will require buy-in from more agents than just the utility and the customer. Increasingly, smart device companies, nonprofits, and data aggregators have a role to play in helping shape electricity demand. Such companies also include nontraditional market participants that directly trade in wholesale energy markets by reducing demand rather than producing newly contracted power. These types of companies often have access to high-frequency electricity consumption data or generate their own. The final panel of the workshop sought to identify fruitful areas for potential collaboration between these companies and researchers to help identify the most effective tools for policymakers to encourage demand flexibility moving forward.

While smart meters deliver high-frequency data on overall consumption, more detailed instrumentation, as done by Pecan Street for selected homes in Austin, Texas, and a growing number of locations, enables collection of more disaggregated data revealing how load varies at more frequent intervals and how much different types of devices contribute to load at different times of the day. Figure 5 provides an example of how total household load varies across the hours of the day for a single home in Austin. Additionally, the data can identify the contribution of various devices or collections of devices to total load at different points in time within each hour. The figure reveals the unsurprising role of air conditioners in both total electricity use and variation in electricity use, especially when the home is occupied. These types of data can be used to target interventions to shape demand and to envision how demand engagement and direct load control could play a role in supplying other types of grid services.

Panelists identified several insights from the data and evaluations that these companies have run. They largely agreed that the data show that the economics matter for households in the context of demand-side management. Households do not join these programs, which include active demand reduction in response to price or to emissions intensity signals or surrendering control of devices to third parties, simply for the "green glow" of creating environmental benefits—they do so because it makes financial sense. Households also appear to value various types of financial incentives differently. Successful demand response relies on making rewards salient and apparent, and one demand aggregator on the panel found that customers respond more strongly to a gift card sent to them than they do to a bill credit that they might not even notice. Panelists also focused on the large negative effects of transaction costs, such as requiring customers to enter an account number to which they may not have easy access, in limiting sign-ups for demand response programs. Additionally, panelists discussed the importance of further penetration of smart devices like thermostats and water heaters. Future demand response programs can be integrated with these devices directly to allow for automation and remove transaction costs for inattentive consumers.

Figure 5. Disaggregated Data on Residential Electricity Use by Different Components



Source: Russo (2021).

5. Conclusions

Several key insights ultimately emerged over the course of the workshop. While customers, particularly well-informed ones, do respond to prices, inattention and inconvenience can limit responses to frequent price changes, and smart devices and automation may potentially play a large role in enabling price responsiveness and shifting consumer demand to help integrate renewables into the grid. The workshop highlighted research suggesting that automated responses to price can save customers money in ways that do not diminish their experiences of energy service provision, such as comfort provided by HVAC systems. Abundant data from devices and smart meters enable the use of new machine learning methods to study the effectiveness of pricing and other approaches in shaping demand. Existing opportunities for load aggregators to profit from shaping electricity demand tend to focus on competing in traditional supply-side markets and displacing the need for generation during peak hours. These programs may not incentivize sufficient demand flexibility for renewables integration and may also be a barrier to further adoption of more granular time-varying prices going to consumers or new types of demand aggregators that manage electricity use on behalf of customers.

Workshop participants also identified several areas where additional research would be valuable. Understudied aspects of the problem include distributional concerns and the characterization of different groups of customers to identify where opportunities for demand flexibility may be greatest. Much high-value research remains to be done on how best to influence and shape demand in the commercial and industrial sectors as well. While monthly subscription offerings coupled with provider control of smart home devices are starting to appear in some places, more formal research on consumer acceptance of such models and their costs and performance could help identify potential opportunities in this space. As the penetration of smart meters and smart devices in homes and businesses across the United States is only expected to rise in the coming years, opportunities to implement new types of dynamic pricing and demand-side management programs will grow as well. Research can help identify which combinations of prices, policies, and new service offerings will most be most effective in shaping demand on the grid of the future.

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7. Appendix A: Online Workshop Agenda

Using Prices, Automation, and Data to Shape Electricity Demand and Integrate Renewables into the Grid: An Online Research and Policy Workshop

Wednesday, December 15, 2021
1:00–5:00 p.m. EST

Realizing the ambitious clean electricity goals of many states, the Biden administration and many utilities will require finding ways to integrate variable renewables into the grid to support system reliability. One way to do that is to shift electricity demand toward low-cost hours when renewable energy is abundant by using dynamic prices or other more direct means. Historically, regulator and public resistance to time-varying pricing has been strong. However, the situation is starting to change—some regions have already implemented time-varying prices for residential customers. Smart devices and automation could enable price responsiveness and lower costs to consumers if they are willing to surrender control of certain devices.

In this half-day virtual workshop funded by the Alfred P. Sloan Foundation, we will bring together economic researchers, regulators, utility representatives, smart device companies, demand aggregators and policy experts to discuss the barriers to and opportunities for pricing, automation, and data, as well as new statistical methods to advance the role of electricity demand management in the grid.

Agenda

1:00-1:05 **Welcome and Overview of Workshop**

- **Karen Palmer**, Resources for the Future

1:05-1:20 **Opening Remarks: Renewables Integration Challenges and Demand Management Opportunities**

- **Dallas Burtraw**, Resources for the Future

1:20-2:20 **Session 1: Policy and Measurement Barriers to Using Demand-Side Strategies to Integrate Renewables**

Pricing structures, data access rules, measurement challenges, and issues of regulatory jurisdiction all affect the potential for demand management through pricing or other means to facilitate renewable integration. This panel will address these barriers.

- **Severin Borenstein**, UC Berkeley
- **Keith Dennis**, Beneficial Electrification League
- **Travis Kavulla**, NRG
- **Peter Cappers**, Lawrence Berkeley National Labs
- **Sanya Carley**, Indiana University (Moderator)

2:20-3:35 **Session 2: Findings and Lessons for Policy from Recent and Ongoing Research on Shaping Electricity Demand**

This panel consists of four short presentations from researchers working on pricing and demand. Presenters will focus on cutting-edge research by themselves and others on the role of economic incentives, smart technologies, and data analytics in helping shape electricity demand and facilitate integration of renewable energy into the grid.

- **Katrina Jessoe**, University of California, Davis
- **Beia Spiller**, EDF
- **Casey Wichman**, Georgia Tech and Resources for the Future
- **Brian Prest**, Resources for the Future
- **Matt Harding**, University of California, Irvine (Moderator)

3:34-3:45 **Break**

3:50-4:50 **Session 3: Engaging Smart Device Companies, Energy Data Companies and New Energy Service Providers in Policy Relevant Research**

The focus of this panel will be on identifying the role of various organizations represented on the panel in the use of demand management to help decarbonize the grid, ways to address policy barriers to greater use of device-related demand management services, and how economic research, including partnerships between organizations such as those represented by today's panelists and researchers, can enable those activities.

- **Tamara Xzubay**, ecobee
- **Suzzanne Russo**, Pecan Street
- **Cisco Devries**, OhmConnect
- **Keven Brough**, Google
- **Karen Palmer**, Resources for the Future (Moderator)

4:50-5:00 **Review of Insights from the Day and Wrap-Up**

- **Susan Tierney**, Analysis Group and Resources for the Future

8. Appendix B: Panelist Information

Karen Palmer

Karen Palmer is a senior fellow at Resources for the Future and an expert on the economics of environmental, climate, and public utility regulation of the electric power sector. Her work seeks to improve the design of environmental and technology regulations in the sector and the development of new institutions to help guide the ongoing transition of the electricity sector. To these ends, she explores climate policy design, analyzes efficient ways to promote use of renewable and other clean sources of electricity, and investigates new market designs, new approaches to electricity pricing and regulatory reforms to pave the way for long-term decarbonization of electricity supply and electrification of the energy economy.

Dallas Burtraw

Dallas Burtraw has worked to promote efficient control of air pollution and written extensively on electricity industry regulation and environmental outcomes. Burtraw's current research includes analysis of the distributional and regional consequences of climate policy, the evolution of electricity markets including renewable integration, and the interaction of climate policy with electricity markets. He has provided technical support in the design of carbon dioxide emissions trading programs in the Northeast states, California, and the European Union. He also has studied regulation of nitrogen oxides and sulfur dioxide under the Clean Air Act and conducted integrated assessment of costs, and modeled health and ecosystem effects and valuation, including ecosystem improvement in the Adirondack Park and the southern Appalachian region. Burtraw currently serves as Chair of California's Independent Emissions Market Advisory Committee. Burtraw holds a PhD in economics and a master's degree in public policy from the University of Michigan and a bachelor's degree from the University of California, Davis.

Severin Borenstein

Severin Borenstein is E.T. Grether Professor of Business Administration and Public Policy at the Haas School of Business and faculty director of the Energy Institute at Haas. His research focuses on business competition, strategy, and regulation. He has published extensively on the airline industry, the oil and gasoline industries, and electricity markets. His current research projects include the economics of renewable energy, economic policies for reducing greenhouse gases, and alternative models of retail electricity pricing. Borenstein is also a research associate of the National Bureau of Economic Research in Cambridge, Massachusetts. Since 2015, he has served on the Advisory Council of the Bay Area Air Quality Management District. In 2019, he was appointed to the Governing Board of the California Independent System Operator.

Keith Dennis

Keith Dennis is President of the Beneficial Electrification League, a 501c3 nonprofit organization whose mission is to increase understanding of the benefits of electrification by promoting the market acceptance of beneficial electrification. He is also the CEO of Electrification Strategies LLC. Dennis has an interdisciplinary background in engineering, business, and law. He worked for nearly a decade at NRECA, where he was Vice President of consumer member engagement. Prior to joining NRECA, Dennis worked at the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), where he led a Policy and Guidance Team for a $3.2-billion energy efficiency and conservation grant program. He also served at The White House Council on Environmental Quality, where he supported several large energy efficiency and renewable energy programs. He has also held numerous positions in the private sector.

Travis Kavulla

Travis Kavulla is Vice President of Regulatory Affairs at NRG Energy, where he works to ensure that energy markets continue to deliver value for electricity consumers. Kavulla joined NRG after a decade of work as a government regulator and energy policy expert. Before joining NRG, Kavulla held a position at R Street Institute, where he led the think tank's energy and environmental policy program. Prior to that, Kavulla served eight years as a utility commissioner at the Montana Public Service Commission, during which time he served as the President of the National Association of Regulatory Utility Commissioners (NARUC) and as a member of the Electric Power Research Institute advisory council. He also had the opportunity to serve on the governing body of the Western Energy Imbalance Market, one of North America's largest electricity markets.

Peter Cappers

Peter Cappers, a research scientist and strategic advisor to the Electricity Markets and Policy Department at the Lawrence Berkeley National Laboratory, has conducted research for the past 18 years into demand response and electric utility regulatory and business models issues. At present, he leads the Demand Response & Smart Grid subteam comprised of four other gifted and talented researchers. With them, he has been able to perform a tremendous amount of research over the past five years on residential customer acceptance and response to time-based rates, by leveraging data collected through rigorous utility pricing experiments he managed on behalf of DOE under its Smart Grid Investment Grant. Cappers is also currently performing quantitative analysis of regulated electric utility business models and the impacts of distributed energy resources on utility shareholders and ratepayers. Prior to joining LBNL, he worked for Neenan Associates, where he helped to develop and implement techniques for quantifying customer price response to both dynamic retail rates and wholesale demand response programs, and their subsequent impact on wholesale market prices, price volatility, and service reliability.

Sanya Carley

Professor Sanya Carley's research focuses on energy justice, as well as on policies aimed at advancing the innovation of low-carbon and efficient energy technologies in both the electricity and transportation sectors. In her most recent projects, she and collaborators study the incidence of energy insecurity among US households and the equity and justice dimensions of the US energy transition. A member of Indiana University faculty since 2010, Carley teaches courses on energy economics, markets, and policy, research design, and project-based capstones.

Katrina Jessoe

Katrina Jessoe is an associate professor in the Department of Agricultural and Resource Economics at UC Davis, where she specializes in environmental and energy economics. Much of her research centers on the design and evaluation of pricing and conservation polices in the water and electricity sectors. In her research, she often collaborates with electric and water utilities, as well as state agencies. Some recent and ongoing projects include a framed field experiment to understand the water and energy impacts of water conservation instruments, the estimation of the price elasticity of demand for agricultural groundwater and land use, rate design and regulation in urban water utilities, and a RCT to understand the effects of default options in commercial energy efficiency. She received a BA from Princeton University in 2002 and a PhD in Environmental and Resource Economics from Yale University in 2009.

Beia Spiller

Beia Spiller is a lead senior economist in the Office of the Chief Economist of the Environmental Defense Fund. She has expertise in domestic climate and energy policies, with a main focus on electricity pricing and regulation. Her work includes research on economic impacts of shale gas, public and private transportation issues, gasoline taxes, electricity pricing, energy policies, emissions modeling, distributed energy resources, ex-post policy analysis, and health impacts of air pollution.

Casey Wichman

Dr. Casey Wichman is an applied microeconomist working on issues at the intersection of environmental and public economics. His research focuses on how people interact with the natural and built environment, and what that behavior reveals about the value of environmental amenities. His research spans water and energy demand, valuation of environmental resources and infrastructure, urban transportation, public goods provision, demand for outdoor recreation, and climate change. Methodologically, he relies on the application of program evaluation techniques, often using large micro-data sets, to estimate causal effects of environmental policies on economic behavior.

Brian Prest

Brian Prest is an economist and fellow at Resources for the Future specializing in climate change, oil and gas, and energy economics. Prest uses economic theory and econometric models to improve energy and environmental policies by assessing their impacts on markets and pollution outcomes. His recent work includes economic modeling of federal oil and gas leasing policies, including implementing carbon pricing into federal oil and gas royalties. He is also working to improve the scientific basis of the social cost of carbon by establishing an empirical basis for determining discount rates and developing probabilistic Bayesian projections of country-level energy intensity. He also uses machine learning techniques to improve understanding of household electricity demand and time-varying pricing. His past work includes econometric modeling of the US oil and gas industry, evaluating the effects of coal subsidies on emissions, understanding the economic effects of rising temperatures, modeling the market dynamics of climate change policy under policy uncertainty. His work has appeared in peer-reviewed journals including the Journal of the Association of Environmental and Resource Economists, Journal of Environmental Economics and Management, Energy Economics, and The Energy Journal.

Matt Harding

Matthew Harding is an econometrician and data scientist who develops techniques at the intersection of machine learning and econometrics to answer "big data" questions related to individual consumption and investment decisions in areas such as health, energy, and consumer finance. He often focuses on the analysis of "deep data," large and information-rich data sets derived from many seemingly unrelated sources but linked across individuals to provide novel behavioral insights. He is particularly interested in the role of technology and automation to induce behavior change and help individuals live happier and more sustainable lives. At the same time, his research emphasizes solutions for achieving triple-win strategies. These are solutions that not only benefit individual consumers, but are profitable for firms, and have a large positive impact on society at large.

Tamara Dzubay

Tamara Dzubay is senior manager of regulatory affairs & emerging markets at ecobee, where she is responsible for engaging with regulatory authorities and identifying emerging opportunities in the energy landscape. Tamara has participated in various energy efficiency, demand response, and grid modernization stakeholder advisory groups and submitted testimony and comments to state agencies and regulatory authorities in the United States. Prior to joining ecobee, she worked in financial roles in the nonprofit and private sectors. This work included creating energy pricing and financial models to evaluate the effects of different rate structures on proposed clean energy solutions. Dzubay holds a Master of Business Administration degree from Northwestern University's Kellogg School of Management and a Bachelor of Business Administration degree from the University of Michigan's Ross School of Business.

Suzzanne Russo

Suzanne Russo is chief executive officer for Pecan Street. Prior to joining the organization in 2010, she was director of sustainability initiatives for New York City's Department of Housing Preservation and Development, where she led the development of green building and sustainable retrofit standards for municipally funded affordable housing. Over the past seven years, Russo served as chief of staff and then chief operating officer for Pecan Street, during which time Forbes named her one of five women "Using Technology to Blow Up Social Change." An urban planner with a master's degree in community and regional planning from the University of Texas at Austin, Russo has worked in Africa, China, India, and the United States on community-based sustainable development.

Cisco Devries

As CEO, Cisco DeVries guides OhmConnect's strategy, execution, and culture. He joined in 2019 after more than two decades helping lead the transition to clean energy in private companies and public service. DeVries's passion lies in solving big problems. He led policy changes that enabled infill housing, created a financial product that is helping democratize access to clean energy, put $2 billion of private capital to work on energy efficiency and rooftop solar, and now is leading the charge to create a dynamic electric grid that supports 100 percent clean energy. Prior to OhmConnect, he cofounded and led Renew Financial, served as chief of staff to the Mayor of Berkeley and was appointed by President Bill Clinton to serve in the US Departments of Transportation and Energy.

Keven Brough

Keven Brough is a leader in the product planning and strategy team at Google Nest. He has extensive experience in both the public and private sectors providing strategic guidance to clients on new market strategies and partnerships, particularly in the sustainability, smart city, climate change, and green growth spaces. He was a Chief Operating Officer at the Climate Policy Initiative and a program officer at Climate Works and has spent time as a legislative staff person for the US House of Representatives. Brough has a JD from Harvard Law School and a BA from Haverford College.

Susan Tierney

Dr. Susan Tierney is a Senior Advisor at Analysis Group and chair of the Board of Directors at Resources for the Future. She is an expert on energy economics, regulation, and policy, particularly in the electric and natural gas industries. She has consulted to businesses, federal and state governments, tribes, environmental groups, foundations, and other organizations on energy markets, economic and environmental regulation and strategy, and energy projects. She has served as an analyst of and an expert witness on a variety of issues, including: industry structure, regulation, and markets; resource planning and procurements; siting of electric and gas infrastructure projects; electric system reliability; ratemaking for electric and gas utilities; clean energy-resource, climate-change and carbon-emission-reduction policies; and other environmental policy and regulation.