MANAGING THE FUTURE OF THE ELECTRICITY GRID: MODERNIZING RATE DESIGN

Richard L. Revesz and Burcin Unel***

Advancing energy technology, increasing penetration of distributed energy resources, and climate change concerns are forcing a transformation of the electricity grid. And, this transformation is making the economic inefficiency of the current rate designs increasingly apparent. Today's typical rate designs not only fail to provide efficient price signals for electricity consumption, leading to inefficiently high capital expenditures and air pollution, but also fail to incentivize distributed energy resources, such as solar panels and energy storage, in a socially beneficial manner. As a result, reforming rates to accurately reflect the underlying costs, including external costs related to the emissions of greenhouse gases and other pollutants, is becoming an urgent endeavor.

In this Article, we first explain how current electricity rate designs hamper economic efficiency because they break the link between price signals and underlying costs, especially the costs related to environmental externalities. Based on an economic framework, we highlight how better rate designs would improve economic efficiency, provide accurate price signals for distributed energy resources, and advance the seemingly conflicting interests of the relevant stakeholders. We provide a historical context to show that for almost 140 years of electricity rate design discussions, economic efficiency principles have mostly been ignored; yet, problems that stem from inefficient rate designs have continued to be salient. We then argue that the electricity sector is at a critical juncture, and that a shift to a paradigm with a long-term vision that includes better, economically efficient rate designs is necessary if we want to realize the clean energy future that the modern grid promises us.

Table of Contents

---

* Lawrence King Professor of Law and Dean Emeritus, New York University School of Law. The generous financial support of the Filomen D'Agostino and Max E. Greenberg Fund at NYU Law School is grateful acknowledged. Iman Charania, Alan Masinter, and Nina Naghshineh provided excellent research assistance.

** Energy Policy Director, Institute of Policy Integrity, New York University School of Law.

Introduction

The electric grid is rapidly evolving with advancing technology. The advent of small-scale distributed energy resources ("DERs"), such as rooftop solar panels and energy storage, is slowly, but surely, disrupting the traditional model of one-way flow of electricity from centralized large-scale generators to end users.[1] At the same time, new technological devices such as advanced meters, smart thermostats, and smart appliances are giving consumers more control over how and when they use electricity.[2] With more consumers installing these technologies, the electric grid is turning into an interactive platform in which

1. Herman K. Trabish, *How Leading Utilities Are Planning for Distributed Energy Resources*, Util. Dive (Feb. 6, 2018), https://perma.cc/3UB9-7EE9 (showing fast growth of distributed energy resources).

2. *See* Alexander Mey & Sara Hoff, *Nearly Half of All U.S. Electricity Customers Have Smart Meters*, U.S. Energy Info. Admin. (Dec. 6, 2017), https://perma.cc/WKF5-7YXC ("By the end of 2016, U.S. electric utilities had installed about 71 million advanced metering infrastructure (AMI) smart meters, covering 47% of the 150 million electricity customers in the United States."); *see also* Adam Cooper, Inst. for Elec. Innovation, Electric Company Smart Meter Deployments: Foundation for a Smart Grid 1 (2016), https://perma.cc/PV9S-NWNU (projecting that ninety million smart meters will be installed by 2020).

consumers also become providers of services to the grid. And, as many of these technologies can help avoid harmful air pollutants by reducing the need to rely on centralized generation from fossil-fuel-fired power plants, they are becoming a crucial element in the fight against climate change.

While this technological transformation is happening at a fast pace, a matching regulatory transformation has been largely lacking. Most of the discussions in state regulatory proceedings that aim to address the increasing penetration of DERs have narrowly focused on reforming net energy metering, which compensates the owners of certain DERs that can inject electricity into the grid, such as rooftop solar systems, based on the retail rates these consumers pay.[3] Many states have seen intense policy discussions about whether net metering overcompensates or undercompensates DER owners, with some states moving towards more sophisticated designs like "value stacks" to more accurately capture all the value of DERs to the system.[4] Other states are moving towards lower, avoided-cost rates to avoid any potential of overcompensation.[5] Discussions on how to best take advantage of the opportunities that smart meters and appliances bring are taking place in only a few states, and are usually marred by lengthy and unfruitful regulatory proceedings in which the views of utilities, industry groups, and consumer advocates clash.[6]

These discussions, which focus on how to design the right incentives for one specific technology at a time, like rooftop solar systems, miss the mark. As we noted in two previous articles in our "Managing the Future of the Electricity

3. Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering*, 41 Harv. Envtl. L. Rev. 64 (2017) [hereinafter Revesz & Unel, *Distributed Generation and Net Metering*].

4. *See* Madison Condon, Richard Revesz & Burcin Unel, Inst. for Pol'y Integrity, Managing the Future of Energy Storage: Implications for Greenhouse Gas Emissions 14–15 (2018) (describing New York State's "value stack" approach); *see also* N.Y. Pub. Serv. Comm'n, No. 15-E-0751 & 15-E-0082, at 10–13 (Sept. 14, 2017) (order on phase one value of distributed energy resources implementation proposals, cost mitigation issues, and related matters).

5. *See* Coley Girouard, *Top 10 Utility Regulation Trends of 2018—So Far*, Greentech Media (July 27, 2018), https://perma.cc/37B9-GWFN (listing changing rate designs and net metering policies as part of the top ten trends in energy regulation of 2018). *See generally* Enerknol, Net Metering in Retreat as Utilities Seek to Protect Their Interests (2018), https://perma.cc/XZC7-WMDW.

6. *See* Coley Girouard, Opinion, *Rate Design for a DER Future: Designing Rates to Better Integrate and Value Distributed Energy Resources*, Util. Dive (Feb. 12, 2018), https://perma.cc/WNC7-9DQD (discussing state responses to DER and implemented initiatives); Herman K. Trabish, *In 2017, Solar Policy Debates Took the Industry's Future to Higher Ground*, Util. Dive (Feb. 1, 2018), https://perma.cc/8ULL-TF6Y (discussing the conflict between clean energy and utility advocates over solar technology policy); Herman K. Trabish, *Rate Design Roundup: Demand Charges vs. Time-Based Rates*, Util. Dive (June 2, 2016 [hereinafter Trabish, *Rate Design Roundup*]), https://perma.cc/7VWU-HEWQ (listing state reactions to distributed energy resources as of 2016).

Grid" series, the source of many of the inefficiencies in the electric system can be traced backed to inefficiencies in the design of retail electricity rates.[7] The United States has been slow to tackle these rate design problems even though better designs have been used around the world for some time.[8] Recent research shows that only 1.7% of all residential customers face time-variant rate designs.[9] And unless these inefficiencies in rate designs can be addressed, state regulators will fall short of achieving their clean energy transformation goals in an economically efficient manner.[10]

Currently, most U.S. utility customers face a two-part tariff that consists of a fixed charge that does not vary with consumption, and a volumetric charge for each kilowatt-hour ("kWh") a customer uses regardless of when or where within a utility's service territory the electricity is consumed.[11] Regulators determine the structure and the levels of these charges in utility rate cases. While the specific statutory language defining the responsibilities of utility regulators varies from state to state, regulators are generally tasked to set "just and reasonable" rates, reflecting a balance between protecting customers and the need to guarantee financial stability to utilities.[12] Because utilities have a duty to serve all the customers in their jurisdiction, ensuring that utilities can recover all their costs, as long as they were prudently incurred, is understood to be a part of the regulatory compact.[13] As a result, the volumetric charges determined in these proceedings roughly reflect the bundled average cost of generating, transmitting, and distributing electricity to the end users, and include a reasonable rate of return for the utilities.[14] And, these volumetric charges usually do not vary

7. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 101–08; Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Energy Storage and Greenhouse Gas Emissions*, 42 HARV. ENVTL. L. REV. 139, 178–79 (2018) [hereinafter Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*].

8. *See, e.g.*, Geert De Clercq, *Run Your Dishwasher When the Sun Shines: Dynamic Power Pricing Grows*, REUTERS (Aug. 2, 2018), https://perma.cc/DA3W-XSB6 (showing electricity pricing trends in Europe).

9. RYAN HLEDIK, AHMAD FARUQUI & CODY WARNER, THE NATIONAL LANDSCAPE OF RESIDENTIAL TOU RATES 6 (2017).

10. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 101–04; Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*, *supra* note 7, at 179.

11. Brendan Baatz, *Why Rate Design Matters for Energy Efficiency*, AM. COUNCIL FOR AN ENERGY-EFFICIENT ECON. (Mar. 22, 2017), https://perma.cc/9W73-VMNB (explaining the basic two-part rate structure).

12. *See* FRED BOSSELMAN ET AL., ENERGY, ECONOMICS, AND THE ENVIRONMENT 563–608 (3d ed. 2010) (explaining the basic utility regulation); Herman K. Trabish, *As the Power Sector Transforms, Can Utilities and Customers Find Common Ground on Ratemaking?*, UTIL. DIVE (July 2, 2018), https://perma.cc/694Y-7TZD (explaining differences between the models states use to balance between utility revenues and customer protective pricing).

13. BOSSELMAN ET AL., *supra* note 12, at 563–608.

14. *Id.* at 59 (explaining that while some of the details of how exactly rates are set vary from state to state depending on whether the state is deregulated, the basic principles remain the same).

with respect to time or location. Instead, they are bundled, flat, and uniform charges.

But even without considering advances in technology, these bundled, flat, uniform charges are far from ideal from an economics perspective. It is well established that economic efficiency requires that prices be equal to social marginal cost—all the costs of producing one more unit, including those that are borne by outsiders to the transaction.[15] Only then can consumers make informed decisions, and their choices can allocate an economy's scarce resources in a manner that would maximize total welfare.[16] But, when prices are below the social marginal cost, consumers will demand too much of a good, and too much of society's resources will be directed to producing that good. The converse is also true. For example, if consumers were made to pay the high cost of generating enough electricity during a hot day in August to meet everybody's demand, they might think twice before setting their thermostats to sixty-eight degrees Fahrenheit, and might instead reduce their electricity use. But, because electricity rates are not based on the social marginal cost, electricity markets suffer from inefficiencies.[17]

At the same time, these rates have been creating inequities. With today's typical rates, customers who use electricity during high-demand "peak" hours pay less than the costs they impose on the system, and customers who use electricity during low-demand "off-peak" hours pay more than the costs they impose to the system, creating cross-subsidies from the off-peak users to the peak users.[18] In addition, customers who have high electricity demand near locations where the distribution system is close to its capacity underpay compared to the costs they impose to the system.[19] Therefore, not only are there cross-subsidies between different types of customers, but there is also an inefficiently high level of peak demand, resulting in an inefficiently high level of capacity that must be paid by all ratepayers. Furthermore, because the external costs of electricity generation from fossil-fuel-fired plants—environmental and public health consequences of air pollution—are not reflected in these prices, the resulting level of pollution is suboptimally high, which disproportionately affects low-income and minority populations.[20] But regulators, instead of reforming

15. *See infra* Part I.

16. Alfred E. Kahn, 1 The Economics of Regulation: Principles and Institutions 66 (1988).

17. *See* Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 71–75, 102–104 (explaining inefficiencies of rate designs); *see also* Severin Borenstein & James Bushnell, *Do Two Electricity Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency* (Energy Inst. at Haas, Working Paper No. 294, 2018), https://perma.cc/539B-QNKN (explaining the deviations of retail rates from social marginal cost).

18. *See* Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 73–74.

19. *Id.* at 73–75.

20. *Cf.* Kahn, *supra* note 16, at 69.

electricity rates to address these efficiency and equity problems, have been turning to other policies such as energy efficiency incentives and clean energy standards, which are not substitutes for desirable electricity rates.[21]

A confluence of factors over recent years make rate design reforms an urgent endeavor. First, an increasing understanding of the serious negative consequences associated with climate change has been forcing stakeholders to focus more on the environmental consequences of electricity generation and consumption. The consequent desire to clean up the electric grid is resulting in aggressive mandates for individual technologies such as off-shore wind, large-scale wind, energy efficiency, or energy storage, without a sufficient consideration of the economic efficiency of these piecewise mandates as a whole. For example, a 100% large-scale renewable energy mandate might not be a cost-effective solution compared to having a portfolio of various large-scale and small-scale renewables, DERs, including both behind-the-meter and in-front-of-the-meter systems, and customers reducing their peak demand as a response to price signals. Therefore, instead of having targets for various technologies that are not determined by social welfare considerations, it would be more efficient to correct the price signals, with an appropriate signal for emissions, so that prices can inform the portfolio of technologies and consumption patterns that would maximize social welfare. Perhaps for this reason, the idea of sending more accurate price signals to retail electricity customers is gaining traction in many jurisdictions.[22]

Second, the advent of DERs has added another dimension of inefficiency that cannot be solved without directly tackling the source of the problem. Because end-users can also inject electricity into the grid now, the retail rates, on which net metering policies rely, now serve as a signal for both consumption and production. As we explained in the first two articles of our "Managing the Future of the Electricity Grid" series, distributed generation and energy storage can provide many different benefits, such as avoiding the need for bulk system generation and capacity, as well as avoiding air pollution. [23] And, the magnitude of these benefits depends on the time and location of electricity production and consumption.[24] Consequently, when DER injections are compensated at flat,

21. Carol Brotman White, *Many States Have Adopted Policies to Encourage Energy Efficiency*, U.S. Energy Info. Admin. (Aug. 3, 2017), https://perma.cc/9MRB-GGUY (explaining that as of 2017, "[t]wenty-nine states, Washington, D.C., and three territories have adopted [a renewable portfolio standard], while eight states and one territory have set renewable energy goals"); *see also State Renewable Portfolio Standards and Goals*, Nat'l Conf. of State Legislatures (Aug. 2, 2018), https://perma.cc/4WXA-KYRV.

22. *See Time-Based Rates Pick Up as Grid Modernization Efforts Rise*, Enerknol Res. (2018), https://perma.cc/8GGR-SRV7 (listing states that are discussing implementing rate design charges).

23. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 78–93; Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*, *supra* note 7, at 147–50.

24. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 84–86.

bundled retail rates, as current net metering practice dictates, they are either under- or over-valued depending on the time and location.[25] Because these inefficiencies of rate design exacerbate the existing problems, lead to cost recovery concerns for utilities, and add a new potential dimension for cross-subsidization concerns, continuing the current methods to set retail electricity prices can no longer be considered "just and reasonable." Therefore, moving forward with a comprehensive retail rate reform is a policy imperative.

In this third Article of our series, we focus on how, to achieve efficient consumption as well as production incentives, price signals should reflect the underlying cost drivers of providing electricity to customers, including externalities related to air pollution, in a time-, location-, and demand-variant basis. We explain in detail how such tariffs would ensure that prices provide economically efficient consumption and production decisions by signaling the true value of electricity to the society and, hence, guide consumption and investment decisions in a manner that is most beneficial to the society. Importantly, because such designs would show the true costs in an unbundled manner, they would provide a technology-neutral framework that would be able to compensate new types of energy resources, even types of new resources that we cannot currently predict, based on their technical capability to provide each of these values, regardless of their type or scale, without the distortions caused by the inconsistencies of the current patchwork of technology-specific policies.

Only a small number of states have been considering reforms of this sort. And, even those states have been moving slowly and undertaking reforms of limited scope. For example, in 2017, the California Public Utilities Commission decided to change the default retail rate design to a time-varying rate to start in 2019,[26] but the new rate design that is being rolled out is a relatively simple design that lacks the sophistication necessary for fully efficient outcomes.[27] New York has also been considering more advanced rate designs, albeit only for DER owners, as part of its Value of Distributed Energy Resources docket that resulted from its Reforming the Energy Vision initiative.[28] But, the rate design reform discussions that started in 2016 are still ongoing. And, these minor reforms have not made much of a dent on the inefficiencies of current rate structures.

25. *Id.* at 103.

26. Pac. Gas & Elec. Co., Pub. Util. Comm'n of State of Cal., No. 15-07-001, at 76 (July 13, 2015), https://perma.cc/S9Y6-4YTC (decision on residential rate reform and transition to time-of-use rates).

27. *See infra* Part III.

28. N.Y. Pub. Serv. Comm'n, No. 14-00581 (May 19, 2016), https://perma.cc/PYX2-GL2M (order adopting a ratemaking and utility revenue model policy framework); *see generally* N.Y. Pub. Serv. Comm'n, No. 17-01277, https://perma.cc/S3UR-GNXX (the value of distributed energy resources working group regarding rate design).

Our Article's first goal is to explain how the current rate designs are hampering economic efficiency as they break the link between price signals and underlying costs, especially the costs related to environmental externalities, and how better rate designs would help reduce these inefficiencies. Drawing from the well-established academic literature on economics and regulation, we outline the properties that an ideal rate design should have. And, based on these principles, we explain how the most commonly used rate designs hinder grid modernization by failing to provide economically efficient price signals to incentivize not only an efficient level of electricity consumption, but also an efficient portfolio of DERs with the right type of DER being deployed at the right location, where it would be most socially beneficial.

Our second goal is to provide a historical account of rate design discussions, showing how rate designs evolved over time. Even though economists have been arguing for better pricing principles for almost 140 years, these principles have mostly been ignored to the detriment of societal welfare.[29]

Our third goal is to overview the current context, summarize the positions of the most influential stakeholders in regulatory proceedings, and evaluate their arguments. We explain how many of these arguments mostly stem from misperceptions that are not supported by economic research, and, how the principles we outlined can help advance seemingly conflicting interests of all stakeholders.

Our final goal is to explain the paradigm shift that is necessary to modernize today's rate designs. We first explain how the basic trade-off that is usually assumed in policymaking—equity versus efficiency—might not exist today given how inefficient today's designs are, and how rate design improvements can help promote these two principles at the same time. Then, we argue that a long-term vision, with a technology neutral framework should guide any reform, instead of today's "one-problem-at-a-time" approach.

This Article is organized as follows. Part I outlines the economic efficiency principles that should guide rate design discussions. Part II provides a brief history of electricity pricing in the United States to highlight that similar discussions have been taking place for more than a century. Part III explains the inefficiencies of rate designs that are most commonly used today and of various proposed reforms; it also shows why reform has become particularly pressing. Part IV describes and criticizes the stated objections that utilities, consumer advocates, and clean energy advocates against economically efficient reforms. Finally, Part V argues that we must move forward with an efficient, technology-neutral framework with a long-term focus.

---

29. *See infra* Part II.

I. Quest for Economic Efficiency

In this Part, we provide a foundational framework for economic efficiency based on insights from the decades-long economic literature on rate design. We review economic efficiency principles, and give a basic overview of the cost structure of electricity provision. Then, we explain what economically efficient price signals would look like given this cost structure.

A. Basic Economic Efficiency Principles

Basic economic theory posits that consumers make decisions in order to maximize their utility.[30] And, utility-maximizing consumers decide how much of a particular good they want to buy by comparing benefits and costs.[31] In simple terms, if the next unit of a good would bring more benefit to the consumer than its cost, then the consumer would buy one more unit of that good. In more economic terms, consumers will keep buying a product as long as the marginal benefit of consumption is greater than the marginal cost of consumption.[32] Only when the marginal benefit is equal to the marginal cost would a consumer's utility be maximized.[33] In most settings, the marginal cost to the consumer is the price of the product. Therefore, how accurately electricity prices reflect the true cost of electricity provision is essential to the efficiency of the eventual allocation of resources.

Like consumers, profit-maximizing firms make production and pricing decisions by comparing benefits and costs.[34] In the simple setting of perfectly competitive markets, the competition in the market leads producers to offer their goods at the lowest possible price they are willing to accept, which is the cost of producing an additional unit of the good.[35] Thus, in perfectly competitive markets, the equilibrium market price would equal the *private* marginal cost of production.[36] And, in this setting, if there are no market failures such as air pollution externalities, firms' marginal cost of production would be the only resource cost to society. In other words, if there are no market failures, firms' private marginal cost would be equal to *social* marginal cost.

That is the core result of basic economic theory: because prices in perfectly competitive markets signal the social marginal cost of production and because consumers would buy a product only if the marginal benefit they get is higher than the price they pay, the market outcomes in perfectly competitive markets

30. *See* Paul Krugman & Robin Wells, Microeconomics 109 (2d ed. 2009).
31. *See id.* at 237.
32. *See id.* at 234–35.
33. *See id.* at 235.
34. *See* Kahn, *supra* note 16, at 67.
35. *See* Krugman & Wells, *supra* note 30, at 335.
36. *See id.* at 349.

are efficient.[37] In other words, perfectly competitive markets maximize social welfare, which is the aggregate welfare of consumers and producers.[38] Because market prices are linked to both the cost and the benefit of that good to society, markets can allocate society's resources efficiently. As Alfred Kahn explains in his classic textbook on regulation, "[t]he central policy prescription of microeconomics is the equation of price and marginal cost."[39] But, consumers will make socially correct decisions only when faced with prices that reflect true economic costs.[40]

Once this crucial link is broken, efficiency will no longer result. Indeed, in electricity markets, this link is likely to be broken due to the market and regulatory structures. Depending on the state, either some or all of electricity services are provided by monopolies that are subject to regulation by state utility commissions. As a result, most retail electricity prices and designs are determined by state utility commissions. And, generally, regulators set a flat volumetric rate that is roughly the average cost of providing electricity throughout the year.[41]

But, if the price of electricity does not accurately reflect the social marginal cost of producing it, users will either over- or under-consume it compared to the socially efficient outcome.[42] For example, because the demand is so high during certain times, such as hot summer afternoons, the marginal cost of electricity production could be multiple times the average cost.[43] And, when electricity users make decisions based on the prices they see—the (low) average cost—while the true resource cost to society is the (high) marginal cost of production, their utility maximization is no longer consistent with social welfare maximization.[44] From a societal perspective, the marginal cost is higher than the marginal benefit, and it is thus socially undesirable for consumers to be using so much electricity during those hot summer afternoons.

---

37. *See* KRUGMAN & WELLS, *supra* note 30, at 106–09; ROBERT S. PINDYCK & DANIEL L. RUBINFELD, MICROECONOMICS 611–13 (7th ed. 2009) (explaining that competitive markets will achieve an efficient allocation of resources).

38. *See* KRUGMAN & WELLS, *supra* note 30, at 109.

39. KAHN, *supra* note 16, at 66.

40. *Id.* ("If consumers are to make the choices that will yield them the greatest possible satisfaction from society's limited aggregate productive capacity, the prices that they pay for the various goods and services available to them must accurately reflect their respective opportunity costs; only then will buyers be judging, in deciding what to buy and what not, whether the satisfaction they get from the purchase of any particular product is worth the sacrifice of other goods and services that its production entails.").

41. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 72.

42. *Id.*

43. *See, e.g.*, Borenstein & Bushnell, *supra* note 17 (showing the differences between marginal costs and average residential prices).

44. KAHN, *supra* note 16, at 66.

In addition, the overuse of electricity due to inaccurate price signals causes other inefficiencies by distorting investment incentives.[45] Because there are higher than efficient levels of demand during those hours, and utilities are required to serve even this inefficiently high demand, they have to invest in levels of capacity for generating, distributing, and transmitting electricity that are higher than socially optimal levels. As a result, electricity consumers end up having to pay for an inefficiently high level of capacity, which then sits idle for most of the year.

Similar distortions exist if the prices consumers face are higher than the marginal cost of production. This situation leads to the under-consumption of the product.[46] For example, during off-peak periods, the marginal cost of electricity production is generally lower than the average price consumers pay. In other words, the marginal benefit of consumption is higher than the marginal cost. Therefore, from a societal perspective, increasing electricity consumption during these periods would increase welfare. Yet, because consumers do not see the (lower) marginal cost as the price signal, and instead base their decisions on the (higher) average cost, their incentives are not aligned with social welfare maximization.

Externalities, such as greenhouse gas emissions, also lead to economic inefficiency when not addressed. Negative externalities are uncompensated costs of market transactions that are borne by third parties.[47] For example, fossil-fuel generators emit greenhouse gases that contribute to climate change, as well as various local pollutants that lead to adverse public health consequences. Therefore, the generation of electricity by fossil-fuel plants causes additional external costs, or externalities, to society. But, because the generators themselves do not directly bear the burden of these external costs, their private marginal cost, and, hence, their decisions, are not affected by externalities. In this situation, the market price still depends only on the generators' private marginal costs, even though the social marginal cost, which includes the damages caused by air pollution, is higher.[48] Once again, the broken link between the price consumers have to pay and the social marginal cost leads to inefficiently high levels of consumption, and, consequently, inefficiently large investment in fossil-fuel plants.[49]

It is important to highlight that the goal of economic efficiency is not necessarily to reduce the total amount of electricity consumed, but rather to ensure that consumers and producers make decisions based on an understanding of the full cost they are imposing on society's resources, including their

45. *Id.*

46. *Id.*

47. KRUGMAN & WELLS, *supra* note 30, at 437.

48. *Id.* at 449.

49. KAHN, *supra* note 16, at 69.

contribution to peak capacity needs and to externalities. It is economically efficient for a consumer who derives a high marginal benefit from electricity to continue purchasing electricity until the marginal benefit and marginal cost are equalized, even though the result is that this consumer ends up purchasing more electricity than others who derive lower marginal benefits.[50] Similarly, if the marginal cost of additional generation is zero (as it could be during parts of the day with a great deal of renewable generation[51]), there is no capacity constraint, and there are no externalities, economic efficiency would be enhanced if users consume as much electricity as they want as long as they get utility from the additional consumption. During those times, trying to artificially reduce consumption, for example, by energy efficiency programs, would be socially inefficient.

Several current energy policy initiatives, such as energy efficiency programs, demand response programs, and clean energy programs, seek to address the misalignment between consumer incentives and welfare maximization. The first two do so, respectively, by providing monetary incentives for consumers to install more energy efficient equipment and to reduce their consumption at certain times. Policies such as clean energy standards make consumers pay more to incentivize non-emitting generation capacity. These programs try to remedy the broken link between the prices consumers face and the underlying costs, and try to re-align consumers' incentives with social welfare maximization. But, while policymakers have been aware of the inefficiencies caused by this broken link, they have not addressed the program head on by changing the rate design to equalize marginal costs and marginal benefits. Because these alternative approaches rely on subsidies and mandates for specific technologies, instead of on direct price signals, they are unlikely to lead to a cost-effective portfolio of different technologies, harming economic efficiency.[52]

B. Economic Efficiency in Rate Design

As discussed above, better pricing would improve economic efficiency.[53] And, better pricing requires understanding the structure of the cost functions, which system elements and variables drive costs, and how much cost they gen-

---

50. James Bushnell, *How Much Electricity Consumption Is Too Little?*, ENERGY INST. AT HAAS: ENERGY INST. BLOG (June 3, 2019), https://perma.cc/94U6-QW5T.

51. *See* BETHANY A. FREW ET AL., NAT'L RENEWABLE ENERGY LAB., REVENUE SUFFICIENCY AND RELIABILITY IN A ZERO MARGINAL COST FUTURE 2 (2016), https://perma.cc/68CZ-XF85 (noting that variable generation, such as wind and solar, has near-zero marginal costs with increasing hours of net-zero price changes as capacity increases).

52. *See* Lawrence H. Goulder & Ian W.H. Parry, *Instrument Choice in Environmental Policy,* 2 REV. ENVTL. ECON. & POL'Y 155–58 (2008) (explaining why subsidies and technology mandates are not cost-effective).

53. William Vickrey, *Responsive Pricing of Public Utility Services*, 2 BELL J. ECON. MGMT. SCI. 337, 346 (1971) ("Responsive pricing would constitute a fairly radical departure from current

erate.[54] In this Section, we overview the basic cost structure of electricity provision to identify these "cost drivers," and discuss what this structure implies for economically efficient price signals.

1. Cost Structure of Providing Electricity

The electric grid has three main interconnected systems that are essential to providing electricity to the end user: generation, transmission, and distribution. First, electricity is generated by a primary energy source such as thermal energy from burning fossil fuels, kinetic energy from wind, or solar radiation.[55] Once electricity is generated, it is transmitted over long distances using high-voltage transmission lines.[56] Finally, electricity is distributed to end customers using low-voltage distribution lines.[57]

There are multiple types of costs associated with each of these steps, as summarized in Table 1. Energy costs vary directly with the amount of electric energy that has to be generated, transmitted, and distributed to meet the consumers' needs. External costs vary directly by the amount of air pollutants emitted during this process. Capacity costs vary based on the amount of capacity each system component has to have to meet consumers' needs, even when the demand is highest, but otherwise do not depend on the amount of electricity used. Customer-related costs depend only on the number of customers served, but not on either the energy use or the need for capacity. Interconnection costs are one-time costs that are incurred to connect a user to the power system.

---

practices in utility pricing, but it promises very substantial improvements in economic efficiency, well worth the considerable effort that will be needed to put it into practice.").

54. *See* Javier Reneses et al., *Electricity Tariffs*, *in* REGULATION OF THE POWER SECTOR 404 (Ignacio J. Pérez-Arriaga ed., 2013).

55. *See* IGNACIO PÉREZ-ARRIAGA & CHRISTOPHER KNITTEL, MASS. INST. OF TECH. ENERGY INST., UTILITY OF THE FUTURE 4–6, 9 (2016).

56. *See* RICHARD SCHMALENSEE & VLADIMIR BULOVIC, MASS. INST. OF TECH. ENERGY INST., THE FUTURE OF SOLAR ENERGY 154 (2015).

57. *Id.*

TABLE 1: COST STRUCTURE OF ELECTRICITY PROVISION

Type of Cost	*Description*	*Unit*	*The Nature of Variation*
Energy	Cost of providing another unit of electricity, including losses and balancing services	$/kWh	Varies temporally and spatially, based on the amount of use
Capacity	Cost of having enough capacity to generate, transmit, and distribute the maximum electricity demand	$/kW	Varies temporally and spatially, based on the amount of maximum demand during each system's peak period
Externality	Cost of damages to third parties that result directly from electricity generation	$/kWh	Varies temporally and spatially, based on the type and intensity of emissions by the marginal generator
Customer-related	Cost of operations and technology that are necessary to serve and bill customers, such as meters, billing systems, and overhead	$/customer	Fixed, given the type and the number of customers
Interconnection	Cost of connecting a customer to the grid	$/customer	One-time cost

Energy costs are the costs associated with providing another unit of electricity—a kWh—to a particular location at a particular time, and they vary with the amount of electricity use.[58] These costs include the costs associated with electricity generation such as fuel costs, as well as costs associated with delivering that electricity such as line losses.[59] In addition, this category also includes costs of various ancillary services needed to ensure the reliability and the stability of the power system, such as voltage and frequency services.[60]

Energy costs vary temporally and spatially due to many factors.[61] First, the marginal cost of generation varies from hour to hour. When more electricity

58. H.S. Houthakker, *Electricity Tariffs in Theory and Practice*, 61 ELECTRICITY J. 1, 2 (1951).
59. *Id.*
60. *See* Eric Hirst & Brendan Kirby, *Costs for Electric-Power Ancillary Services*, 9 ELECTRICITY J. 26 (1996) (explaining costs associated with ancillary services in per-kWh terms).
61. Reneses et al., *supra* note 54, at 405.

needs to be generated, generators that have higher costs, either because they are less efficient or have higher fuel costs, are asked to generate. The marginal cost of generation depends on the marginal cost of the last generator that is necessary to meet the demand—the marginal generator. Therefore, as demand changes throughout the day, the marginal generator changes, and so does the marginal cost. Second, energy losses during transmission and distribution also vary temporally and spatially. Their amount depends on the distance electricity has to travel, so it varies from one location to another.[62] Furthermore, as the load on the grid increases, losses increase quadratically, so energy losses vary by hour depending on the demand on the power system.[63] Finally, an increase in demand may cause congestion in distribution and transmission networks, both of which have limited capacity, increasing the marginal cost of delivering electricity to a particular location.[64]

External costs are costs associated with the damages that directly result from electricity use and generation. The amount of these costs depends on the type of the pollutant emitted. Greenhouse gases are global pollutants that cause climate change, and the marginal damage caused by one additional ton of carbon dioxide is the same regardless of where it is emitted.[65] SO_2, NO_x, and particulate matter are local pollutants that have adverse health consequences.[66] Because the marginal damages of local pollutants depend on how many people are exposed to these pollutants, and on their demographic characteristics, these damages vary based on the location of the emissions. In addition, the type of the generators running, and therefore their emissions, varies by time and location. As a result, external costs of electricity provision vary by time and location.[67]

Capacity costs are the infrastructure costs that depend only on the maximum capacity needed, and do not vary with actual electricity use. [68] The amount of capacity needed for a system is determined by the maximum rate of electricity use, or *demand*, that the system experiences.[69] A user's electricity demand is analogous to the bandwidth of an internet connection. Downloading three movies at the same time would require a higher bandwidth than

62. *Id.*
63. *Id.*
64. *Id.*
65. *See* JEFFREY SHRADER, BURCIN UNEL & AVI ZEVIN, INST. FOR POL'Y INTEGRITY, VALUING POLLUTION REDUCTIONS 24 (2018), https://perma.cc/TE5J-6YUX.
66. *Id.* at 19–20.
67. *See* Kyle Siler-Evans, Inês Lima Azevedo & M. Granger Morgan, *Marginal Emissions Factors for the U.S. Electricity System*, 46 ENVTL. SCI. & TECH. 4742 (2012); Joshua S. Graff Zivin, Matthew J. Kotchen & Eric T. Mansur, *Spatial and Temporal Heterogeneity of Marginal Emissions: Implications for Electric Cars and Other Electricity-Shifting Policies*, 107 J. ECON. BEHAV. & ORG. 248, 249 (2014).
68. *See* Houthakker, *supra* note 58, at 2.
69. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 74.

downloading them one movie at a time, even though the total amount of data downloaded would be the same. Similarly, using all appliances at the same time would require a "higher bandwidth," and hence higher costs, than using one appliance at a time, even though the total electricity use is the same.

While there have been significant advances in energy storage technology, electricity still cannot be stored in significant amounts.[70] Therefore, power systems need to have enough generation, transmission, and distribution capacity built to meet all of the consumer demand at all times. As a consequence, each system is built to meet the maximum demand of its annual peak, even if that capacity sits idle for the rest of the year when the demand is not as high. Thus, the peak demand is the main driver for generation, transmission, and distribution system capacity costs. It is also important to note that the maximum demand of different systems might occur at different times.[71] For example, a region-wide generation system might have a different peak than the local distribution system.[72]

Customer-related costs are costs, such as meters, customer management and billing systems, and overhead costs that depend on the number and type of customers and not on an individual's consumption behavior.[73] Finally, there might also be one-time *interconnection costs* associated with connecting a customer to the grid.[74] These costs depend on the type and the location of the customer, and whether any other equipment is needed.

2. *Efficient Rate Designs*

An economically efficient rate design should align the price signals consumers receive with the underlying costs of generating, transmitting, and distributing electricity, including capacity costs and externalities. As we explained above, only when consumers see price signals that are based on the costs they impose on society by their electricity use and capacity needs, including the externalities, can the system induce efficient electricity consumption, and, as a consequence, efficient investment in both traditional resources and DERs. Thus, the ideal rate design should convey to the consumers information about these different types of costs, such as energy, capacity, and external costs. Further, given that many of these costs vary based on both time and location, the ideal rate design should also allow such granular variation. Given the structure of the costs we described above, a design that would give economically efficient signals should properly account for the relevant cost drivers, temporal and spa-

70. *See* Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*, *supra* note 7, at 145–46.

71. Houthakker, *supra* note 58, at 2.

72. *Id.*

73. *Id.*

74. Reneses et al., *supra* note 54, at 405.

tial variation, and externalities. And, such a design should be forward looking, focusing only on avoidable costs, not costs that have already been expended.

a. Cost Drivers

Based on the cost structure described above, there are two main drivers of costs: electricity use and capacity.[75] How much electricity is used—kWh usage—drives energy and external costs. The peak usage rate—kW demand—drives capacity costs. To properly reflect these cost drivers, charges for energy use and capacity should be separate.[76]

Energy charges should reflect the short-run social marginal cost of electricity generation.[77] These charges should cover all costs, "present or future, and external as well as internal to the company, for which production is at the margin causally responsible."[78] In the electricity context, this goal can be achieved through a "locational marginal price of electric energy at each point of connection and each moment in time, calculated in the basis of the costs of supply and the demand in response to these prices."[79] Locational marginal prices show the marginal cost of providing electricity to a certain location on the transmission network, taking into account the cost of energy, losses, and congestion. Therefore, they are "perfect short-term energy prices."[80] These locational marginal prices are already being calculated by wholesale market operators in most of the country. As a result, even though they do not fully reflect externalities, moving electricity users to a rate design based on these locational marginal prices, would be an easy first step to applying basic economic principles.

Real-time pricing is a design that is intended to align prices consumers see with the underlying marginal cost at a given time and location. In real-time pricing, the prices consumers see change as the wholesale market prices

75. *Id.* at 404.

76. *Id.*

77. KAHN, *supra* note 16, at 75, 71 ("[A]ll the purchasers of any commodity or service should be made to bear such additional costs—only such, but also all such—as are imposed on the economy by the provision of one additional unit."); *see also* Severin Borenstein, *The Economics of Fixed Cost Recovery by Utilities*, 29 ELECTRICITY J. 5, 5 (2016); Vickrey, *supra* note 53, at 338 ("In an ideal world free from budgetary or financial constraints, it is clear that the rate should be equal to the expected [short-run marginal cost.]").

78. KAHN, *supra* note 16, at 75.

79. PÉREZ-ARRIAGA & KNITTEL, *supra* note 55, at 86.

80. *Id.* at 105.

change.[81] The prices are not known in advance, and they can vary over short intervals to reflect the variation in the actual price in the wholesale markets.[82]

There are many studies that show how real-time pricing can improve economic efficiency. One theoretical analysis establishes that the competitive equilibrium in a market without real-time pricing could be quite inefficient. [83] Another, similar analysis reveals that the potential gains from real-time pricing are almost certainly many times greater than the estimated costs of implementing such a program, at least for large customers.[84] And, an empirical analysis of one of the rare real-time pricing programs in the United States also shows that the program increases consumer welfare.[85]

Capacity charges should reflect the additional marginal capacity cost a user imposes on society. These charges should be based on each consumer's peak responsibility based on the share of demand at the time coinciding with the system's peak, the "coincident-peak demand,"[86] and should be calculated by looking at the marginal cost of capacity, and not the average cost.[87] For commodities like electricity that have time-variant demands but are generally non-storable, it is well accepted that peak users should pay "*marginal* operating plus *marginal* capacity costs and off-peak users should pay only marginal operating costs."[88] Kahn further explains this concept as follows:

> The economic principle here is absolutely clear: if the same type of capacity serves all users, capacity costs as such should be levied only on utilization at the peak. Every purchase at that time makes its proportionate contribution in the long-term to the incurrence of those capacity costs and should therefore have that responsibility reflected in its price. No part of those costs as such should be levied on off-peak users.[89]

---

81. *See* AHMAD FARUQUI & LISA WOOD, EDISON ELEC. INST., QUANTIFYING THE BENEFITS OF DYNAMIC PRICING IN THE MASS MARKET 42 (2008) [hereinafter EEI DYNAMIC PRICING], https://perma.cc/5BR4-KED4.
82. AMAN CHITKARA ET AL., ROCKY MOUNTAIN INST., A REVIEW OF ALTERNATIVE RATE DESIGNS 19 (2016), https://perma.cc/E6LU-TX6Y.
83. *See* Severin Borenstein & Stephen Holland, *On the Efficiency of Competitive Electricity Markets with Time-Invariant Retail Prices*, 36 RAND J. ECON. 469 (2005) (discussing problems associated with time-invariant pricing).
84. Severin Borenstein, *The Long-Run Efficiency of Real-Time Electricity Pricing*, 26 ENERGY J. 93, 115 (2005).
85. *See* Hunt Allcott, *Rethinking Real-Time Electricity Pricing*, 33 RES. & ENERGY ECON. 820 (2011).
86. KAHN, *supra* note 16, at 95–96.
87. *Id.* at 96 (criticizing demand charges being implemented based on average costs, and not marginal costs).
88. Paul L. Joskow, *Contributions to the Theory of Marginal Cost Pricing*, 7 BELL J. ECON. 197, 197–206 (1976) (emphasis added); *see also* KAHN, *supra* note 16, at 89.
89. KAHN, *supra* note 16, at 89.

Because capacity needs depend on demand—the maximum rate of use—the term "demand charge" is often used to describe capacity pricing in the retail electricity context. Demand charges are assessed based on a consumer's maximum demand over a certain time period. The length of the time period to measure the maximum demand is determined by the utility and is usually in the range of fifteen minutes to an hour.

Coincident-peak demand charges are assessed based on a consumer's demand at the time of the system peak.[90] For example, if the system peak occurs in the afternoon during a weekday, a coincident-peak demand charge is based on consumers' rate of use at that time. So, if a consumer needs capacity only for basic appliances such as a refrigerator at that time, that consumer is charged based only on that amount of demand even if the consumer's own maximum demand still occurs on Sunday afternoons, when doing laundry and dishes while cooking. As a result, a coincident-peak demand charge reflects the share of the capacity costs of the whole system for which each user is causally responsible.[91] It is worth highlighting that the inclusion of demand charges does not necessarily come at the detriment of more granular energy pricing. A good design will have both real-time pricing for electricity use and coincident-peak demand charges.

Implementing coincident-peak demand charges requires identifying what level of the system will be used to determine the time period for peak coincidence.[92] Utilities in deregulated states might care only about the distribution system peak coincidence, while vertically-integrated utilities might be interested in the whole system peak, including generation and transmission. However, given that the peak period for generation, transmission, and distribution systems might be different,[93] three different capacity charges that depend on a customer's demand coincident with the peak period of each respective system would better link prices with underlying costs. Only if there are avoidable capacity costs that depend solely on a customer's own peak needs, such as a line from the pole to the customer's house, would it be desirable for there to be a *non-coincident* demand charge imposed for a customer's own peak demand.[94]

While only a few studies in the economics literature have analyzed the effects of demand charges, there is a growing understanding of cost saving effects of demand charges.[95] Most of the academic literature on electricity rate

---

90. CHITKARA ET AL., *supra* note 82, at 57.

91. KAHN, *supra* note 16, at 96.

92. CHITKARA ET AL., *supra* note 82, at 58.

93. Houthakker, *supra* note 58, at 2 (explaining generation peak might be different than local or transmission peak).

94. CHITKARA ET AL., *supra* note 82, at 54 (explaining the narrow demand charge that covers only the customer service drop and transformer costs).

95. For example, a recent presentation by Xcel Energy showed that a $9.73/kW demand charge in the summer reduce the peak demand by 7%. Scott Brockett, EUCI 2018 Residential Demand Charges Conference, Update On Public Service Company Residential Demand

design focuses on how to price electricity use, without thinking about how to provide signals for capacity. However, research shows that while real-time pricing for electricity use is likely to increase efficiency, it is not sufficient by itself to provide an efficient capacity signal.[96] Hence, to reduce inefficient capacity investment, there should be an additional capacity price signal.[97] Well-designed coincident-peak demand charges that reflect avoidable capacity costs, therefore, could incentivize consumers to reduce their costly peak demand, as well as incentivizing types of DERs that can help consumers reduce their demand during peak time periods.[98] One study shows that adding capacity costs to real-time pricing during peak hours would significantly improve efficiency.[99] And, there is indeed evidence that demand charges can lead to gains for utilities and for both DER and non-DER customers.[100]

In addition to energy, capacity, and external costs, there are two other cost drivers. Customer-related costs such as billing and operation that depend on the number of customers, but not on a specific customer's behavior, can be recovered by monthly *customer charges*.[101] And, interconnection costs can be recovered by a one-time *interconnection charge*.[102]

b. Temporal and Spatial Variation

As we described above, the marginal cost of electricity generation, transmission, and distribution vary by time and location.[103] As a result, the electricity prices that consumers face should also vary temporally and spatially. Wholesale market operators calculate locational marginal prices in very short time intervals, as little as every five minutes.[104] And, by definition, these prices vary based on location. Therefore, using real-time pricing based on locational marginal

---

Charges 14 (May 2018); s*ee also* SATCHWELL ET AL., LAWRENCE BERKELEY NAT'L LAB., CURRENT DEVELOPMENTS IN RETAIL RATE DESIGN: IMPLICATIONS FOR SOLAR AND OTHER DISTRIBUTED ENERGY RESOURCES, at v (2019), https://perma.cc/X4TJ-9ZEM (explaining an analysis of Arizona Public Service demand charges showing an average of 11% reduction in the billing demand, the measure or the formula a utility uses to calculate a given customer's demand units for bill calculation).

96. Borenstein & Holland, *supra* note 83, at 469.

97. *Id.*

98. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 105.

99. Jacob Mays & Diego Klabjan, *Optimization of Time-Varying Electricity Rates*, 38 ENERGY J. 67, 70 (2017).

100. David P. Brown & David E.M. Sappington, *On the Role of Maximum Demand Charges in the Presence of Distributed Generation Resources*, 69 ENERGY ECON. 237, 237–49 (2018).

101. Reneses et al., *supra* note 54, at 404.

102. *Id.*

103. PÉREZ-ARRIAGA & KNITTEL, *supra* note 55, at 87–89.

104. *Id.* at 88.

prices would significantly improve economic efficiency, aligning prices with the marginal cost of providing electricity at a particular time and location.[105]

Capacity prices need to be differentiated spatially as well. If, for example, distribution lines are congested at one location but not the other, additional demand at the first location would lead to additional costs, while additional demand at the latter location would not. In other words, marginal distribution capacity costs vary within a utility's territory as well as between utilities.[106] A similar reasoning applies to transmission lines as well. As a result, an additional kW demand would lead to different cost implications in different locations within a utility's territory, requiring different price signals.

c. Externalities

The energy charges should also reflect the external costs associated with air pollution resulting from fossil-fuel-fired plants. As we explained above, the outcome cannot be efficient unless the price reflects the social marginal cost of electricity provision, which includes external costs such as the climate change damages from greenhouse gases and the public health consequences of local air pollution caused by a particular act of consumption or production. The economically ideal way of accounting for externalities is an economy-wide emissions tax on polluters that fully internalizes the external damage. In that case, because emitting generators would have to pay the tax, the marginal cost of generation, and, hence, the resulting locational marginal prices, would automatically take into account externalities and lead to efficient price signals for consumption. But, lacking such an emissions tax imposed on generators, these externalities should be reflected in the rate design so that consumers can take them into consideration when making consumption decisions.[107]

To properly account for externalities requires temporal and spatial granularity in rate design for two reasons. First, because the marginal generator changes throughout the day as the demand changes, the emission consequences of additional electricity use or generation changes throughout the day as well.[108] Second, even though the marginal damages from a global pollutant such as

---

105. Note that wholesale market operators calculate locational marginal prices at the transmission level. Ideally, locational marginal prices should be calculated at the distribution level. However, currently there is no utility that calculates distribution locational marginal prices. *See id.*

106. *See* Chi-Keung Woo et al., *Marginal Capacity Costs of Electricity Distribution and Demand for Distributed Generation*, 16 ENERGY J. 111 (1995).

107. There is an extensive economics literature on emissions pricing that shows how the design of the emission price, how these designs distinguish between consumption and production taxes, and how the revenue is collected and distributed affects the economic efficiency of the outcomes. However, such design details of emissions pricing are beyond the scope of this Article. We simply point out that without reflecting these emissions, retail rate designs cannot lead to economic efficiency in the absence of an economy-wide tax.

108. SHRADER, UNEL & ZEVIN, *supra* note 65, at 4–6.

carbon dioxide is the same regardless of where it is emitted, marginal damages from local air pollution vary significantly based on time and location of the emissions.[109] As a result, the ideal economic solution requires a heterogeneous price for local pollutants based on time and location.[110] Therefore, the external cost of electricity consumption should be calculated as granularly as possible.

d. Forward Looking

Both the energy and the capacity charges should be forward looking and reflect only the avoidable costs. As Kahn notes, "[m]arginal costs look to the future, not to the past."[111] This idea is based on a fundamental concept in economics, the "opportunity cost." Because resources are scarce, the true cost of any good to society is the opportunity cost, or what "must be sacrificed in order to produce it."[112] And, consumers would need to understand the true trade-offs of using scarce resources to be able to make rational choices that would lead to the maximum social welfare. Unless future costs can be avoided, additional consumption cannot be causally responsible for any additional costs, and therefore would not have any opportunity cost to society. If unavoidable costs are reflected in the price, then the prices would no longer reflect the opportunity costs, and consumers' decisions would be incorrectly informed, harming economic efficiency.[113]

A corollary of this principle is that a utility might not recover all its costs with a design of the type described above. First, capacity costs, once incurred, become fixed costs that do not vary with electricity use or demand. Because these costs are not avoidable anymore, they would not be included in either the energy prices or the capacity prices. Second, marginal costs might be less than average costs. In this case, the total revenue (the price times the quantity sold) with a price equaling the marginal cost would be less than the total costs (the quantity sold times the average cost). And, third, because of economies of scale or learning by doing, which are arguably prevalent for emerging energy technologies,[114] the amount of costs that could be avoided in the future might be different than the costs that have already been incurred. In any of these situations,

---

109. *Id.* at 19–21.

110. Meredith Fowlie & Nicholas Muller, *Market-Based Emissions Regulation When Damages Vary Across Sources: What Are the Gains from Differentiation?* 2 (Energy Inst. at Haas, Working Paper No. 237, 2013), https://perma.cc/Q53S-ZP9U (explaining the deviations of retail rates from social marginal cost).

111. KAHN, *supra* note 16, at 88.

112. *See id.* at 66.

113. *Id.* (discussing the necessity of pricing accurately reflecting the opportunity costs to guide scarce resources in a way that would maximize total satisfaction).

114. *See* LAZARD, *Lazard's Levelized Cost of Energy Analysis—Version 11.0* (2017), https://perma.cc/9CFF-PEL6 (showing decreasing levelized costs of solar, wind, and energy storage over the years, as well as cost differences between small-scale and large-scale).

the revenues collected by the design described above may not be sufficient to cover all the costs. And, if there are indeed any remaining costs that are not recovered, then the economic efficiency principles we outlined above cannot provide any guidance on who should bear the burden of these residual costs.

Conversely, if marginal costs are higher than average costs, or there are diseconomies of scale, the revenue collected by the rate design above might be higher than the total costs a utility incurs. If there is any such residual revenue, the principles above again would not provide guidance on how it should be distributed to customers.

However, basic economics principles tell us that these remaining costs or revenues should be recovered or redistributed, respectively, in a manner that is least distortionary to the marginal price signals.[115] Distorting marginal price signals would alter consumers' and producers' decisions, and, as a consequence, move society's resource allocation from the economically efficient allocation. For example, recovering the revenue shortfall using fixed charges, or redistributing remaining revenues using fixed rebates, would not distort the marginal prices. And, as a result, as long as any residual costs or revenues are dealt with in a way that does not change the marginal prices signals for energy, capacity, and externalities, efficiency would not be harmed.

II. A Brief History of Electricity Pricing in the United States

In this Part, we provide a brief history of electricity pricing and how rate designs have evolved over time. While a detailed history of electricity pricing and a thorough discussion of every different type of rate design that has ever been tried or implemented is beyond the scope of this Article, it is still useful to go back in time to understand how electricity rates evolved and what factors were most influential in this evolution as we think about how to move forward managing the future of the electricity grid. Then, in Part III, we evaluate this evolution from the perspective of economic efficiency.

A. First Discussions

Thomas Edison opened the United States' first central power plant in New York in September 1882.[116] The initial customers were sold lightbulbs and given free electricity before the first development of working meters in the spring of 1883.[117] The demand at this early time depended on lighting, and

115. Pérez-Arriaga & Knittel, *supra* note 55, at 105.

116. *See* Robert L. Bradley, Edison to Enron: Energy Markets and Political Strategies 42 (2011); Andrew B. Hargadon & Yellowless Douglass, *When Innovations Meet Institutions: Edison and the Design of the Electric Light*, 46 Admin. Sci. Q. 476, 483 (2001); *History of Electricity*, Inst. for Energy Res. https://perma.cc/C9C7-2MQF.

117. Hargadon & Douglass, *supra* note 116, at 483.

utilities either charged a flat rate based on metered use, or a fixed amount per month, based on individual contracts.[118] At the time, lighting was the only source for electricity demand, and, as a consequence, electric light might have been priced to competitively match gas lighting prices rather than the actual cost of generating electricity.[119] By 1890, electricity started to be supplied publicly, and most big towns, and some small towns, were supplying electricity.[120] How to price electricity was discussed intensively during this period.[121]

The context of the rate design discussion at that time was, in many ways, different than today's context: Electricity was not a necessary input for the rest of the economy yet, metering technology was not reliable, and consumers lacked the ability to generate electricity themselves. Air conditioners and electric heaters were far away from becoming household items.

Yet, the core questions ratemakers faced then were the same as the ones that ratemakers face today: The electric system faced sharp peaks, with very little capacity utilization during the rest of the time.[122] Because lighting was the main source of demand, weather patterns, albeit fog rather than heat or cold, and diurnal cycles were the main determinants of peak demand of electricity.[123] And how to classify different categories of costs and fairly charge different customers for those costs were open questions, especially as new technologies and usage patterns emerged.

In 1892, Dr. John Hopkinson, an English electrical engineer, classified the cost of electricity provision into two categories—"standing costs" to reflect the cost of being ready to supply electricity and "running costs" to reflect the cost of actually supplying electricity.[124] The running costs essentially corresponded to the energy costs we described above, and the standing costs corresponded to the capacity costs. Then, in what become to known as the "Hopkinson tariff," he suggested customers should pay for running costs on the basis of their usage, and that they should pay for standing costs on the basis of the peak load they each demanded.[125]

---

118. William J. Hausman & John L. Neufeld, *Time-of-Day Pricing in the U.S. Electric Power Industry at the Turn of the Century*, 15 RAND J. ECON. 116, 117 (1984); Valery Yakubovich et al., *Electric Charges: The Social Construction of Rate Systems*, 34 THEORY & SOC'Y 579, 586–87 (2005).

119. Ahmad Faruqui, THE BRATTLE GRP., The Global Movement Toward Cost-Reflective Tariffs 6 (May 14, 2015), https://perma.cc/AE6W-JZP2.

120. I.C.R. Byatt, *The Genesis of the Present Pricing System in Electricity Supply*, 15 OXFORD ECON. PAPERS 8 (1963).

121. *Id.*

122. *Id.*

123. *Id.* at 9.

124. *Id.* at 9 n.1.

125. *Id.* The paper further defines the two types of costs as follows:

> Standing costs comprised the bulk of total costs; they were the capital costs of the equipment necessary to meet the maximum load on the supply station, the amount

The Hopkinson tariff, with a part for usage and a part for demand, was the first tariff with multiple parts, and the first demand charge, in the history of electricity pricing. Hopkinson's rationale for such design still persists in tariff designs for various other types of utility ratemaking, such as in natural gas.[126] Fundamentally, this tariff was an effort to assign consumers a peak responsibility based on their respective consumption and charge them according to the proportion of fixed capital for which they are responsible.[127]

But, initially, there was no way of measuring a customer's actual maximum demand. So, the Hopkinson tariff in practice was based on different factors, such as the number of lights that the customer had installed, as a measure of the customer's maximum possible demand, which was far from ideal but was forced by technological limitations.[128] Immediately following Hopkinson's article, Arthur Wright, the electrical engineer to Brighton Corporation, developed a new meter that could measure the maximum demand of each customer. As a result, the Wright demand indicator, as it came to be called, was used to charge Hopkinson tariffs.[129]

However, because this meter could only measure the maximum demand and not when it occurred, the *non-coincident peak demand*, and therefore the demand charges were assessed based on consumers' own maximum demand regardless of when the system peak occurred. While Hopkinson initially had the right idea about charging customers based on their peak contribution, the underlying assumption under these initial tariff discussions was a scenario in which all the customers turned on their electric lamps at the same time, such as in the case of a fog setting in. As a result, it did not account for the possibility of "the maximum load occurring at different times var[ying]" across customers and not coinciding with the system's peak.[130] Yet, as we explained above, the capacity costs depend on the system peak demand, and consumers were causally responsible for their own contributions to this system peak demand, regardless of whether demand during the system peak represented their own maximum

> of coal which was used in warming up boilers and keeping up steam in readiness to supply electricity, and the bulk of the wages of the men employed. Running costs were principally the difference between total coal costs and the coal costs included under standing costs.

Id.

126. KAHN, *supra* note 16, at 95. Note that today's tariffs might also have a third part to reflect customer-specific costs such as meter reading and billing.

127. *See id.*

128. *See* Byatt, *supra* note 120, at 10 (discussing tariffs implemented by Liverpool Electric Supply Company).

129. *See id.*

130. *Id.* at 9.

demand.[131] So, even if particular customers were not using any lights during the system peak periods, and hence were not contributing any capacity need, they were still being charged for it. As a result, incorrect assumptions about peak coincidence led to an inefficient outcome.

Debates persisted during this period over to what extent the Hopkinson-style tariff was sufficient to improve the utilization of the existing capacity.[132] At the same time, engineers realized that the cost of supplying electricity varied at different times of the day.[133] But, time-variant tariff proposals were rejected without even being tried.[134] Interestingly, and perhaps more justifiably then, the cost and the technical limitations of metering devices were cited as a main reason for the rejection.[135]

Rapid increases in the uses of electricity, such as tramway electrification "on a fairly large scale" in 1898–1899;[136] driving machineries in factories, which "became important after 1905";[137] "the rapid fall in the price of electrical machinery" after 1905;[138] and the increase in heating and cooking load[139] led to electricity tariffs moving away from "strict adherence" to maximum-demand principles.[140] Driven by customer backlash to the variability in bills when an additional lamp was carelessly left on, by the turn of the century, customers were already being billed based on what were thought as demand determinants, such as the value of their houses, instead of their actual demand.[141] Of course, these methods were not related to costs. Further, because initially heating and cooking did not contribute to peak demand, they were somewhat shortsightedly thought as off-peak loads, and there were special, cheaper, tariffs offered for those uses.[142] As a result, soon after the first electricity tariffs were implemented, they moved away from cost-causation principles.

While at the beginning the discussions were based on proper account of cost drivers, the reality was different by the end of the period. Even though the structure of Hopkinson tariffs with a usage charge and a demand charge was still in use, the prices were based on other determinants, such as the value of houses or the number of bulbs, and not costs. The linking of prices with under-

131. *See* KAHN, *supra* note 16, at 95–96; *see also* W. Arthur Lewis, *The Two-Part Tariff*, 8 ECONOMICA 249, 252 (1941).

132. *See* Byatt, *supra* note 120, at 11–12.

133. *See id.* at 9.

134. *Id.* at 13; Faruqui, *supra* note 119, at 6.

135. *See* Byatt, *supra* note 120, at 13–14.

136. *Id.* at 14–15.

137. *Id.* at 15.

138. *Id.* at 16.

139. *Id.* at 16–18 (using "domestic" to refer to residential (e.g., for lighting, heating, cooking) and commercial customers (e.g., shopkeepers)).

140. *Id.* at 16.

141. *Id.* at 16–17.

142. *Id.*

lying costs ended up being only a short-lived idea during this period. By 1910, the industry was facing regulation, the focus of which was to determine the total return of utilities and to secure enough revenue for their investors.[143] As a result, the economic efficiency of rate designs was not a top concern.[144]

B. Mid-20th Century

During the 1940s and 1950s, there was another burst in discussion about electricity tariffs and how to align prices with costs. During this time, there was more discussion on the time-varying nature of electricity costs, and whether there was a need for time-varying rates.[145] And this time there was an actual, real-life implementation of such a design. Even though almost all the U.S. utilities were still on some variation of the Hopkinson tariff, French industrial and wholesale customers, were put on the "Tarif Vert" or "Green Tariff" starting in late 1956.[146]

This tariff divided the energy charges into two seasons and multiple time periods.[147] Winter season had peak hour periods of 7:00 to 9:00 A.M. and 5:00 to 7:00 P.M., periods of lowest use between 10:00 P.M. and 6:00 A.M. and all day Sunday, and all the remaining hours. In the summer, there were only two periods, the hours of lowest use, from 10:00 P.M. to 6:00 A.M., and Sundays; and the remaining hours.[148] There was also a demand charge based on the type of use.[149] This structure was a better approximation of the cost structure of electricity provision than the Hopkinson tariff, or any other pricing structure used in the United States.[150] It took cost drivers into account, and energy charges reflected the temporal variation in marginal costs.

During this period, the United Kingdom was also behind France in being guided by marginal cost pricing concepts from 1945 to 1970.[151] These differences may have been due to more established professional networks between

143. *See* John Neufeld, *Competitive Rates—A Break from the Past?*, *in* PRICING IN COMPETITIVE ELECTRICITY MARKETS 65, 76–77 (Ahmad Faruqui & Kelly Eakin eds., 2000).

144. *See* Hausman & Neufeld, *supra* note 118, at 123.

145. *See* Houthakker, *supra* note 58, at 12, 13; Lewis, *supra* note 131, at 255 (explaining how it was not feasible to have prices that were indexed to consumption due to metering costs); *see also* Nancy Ruggles, Recent Developments in the Theory of Marginal Cost Pricing, 17 REV. ECON. STUD. 107 (1949).

146. Eli W. Clemens, *Marginal Cost Pricing: A Comparison of French and American Industrial Power Rates*, 40 LAND ECON. 389, 391 (1964).

147. *Id.*

148. Martin Chick, *Le Tarif Vert Retrouvé: The Marginal Cost Concept and the Pricing of Electricity in Britain and France, 1945–1970*, 23 ENERGY J. 97, 98–99 (2002).

149. Clemens, *supra* note 146, at 391.

150. *Id.* at 396.

151. *See* Chick, *supra* note 148, at 98–99.

industry and university economists,[152] greater postwar appeal of "national unity and economic modernization,"[153] a higher proportionate importance of domestic rather than industrial customers in Britain,[154] or a more centralized organizational structure in the French electricity industry.[155]

However, in the 1960s, the United Kingdom made some strides in aligning tariffs with underlying costs when it restructured the bulk supply of electricity.[156] The British Central Electricity Generating Board introduced coincident-peak demand charges to correspond with the demand of the respective Area Boards—the entities responsible for the distribution of electricity—at the time of "national simultaneous maximum demand."[157] Further, in 1967–1968, recognizing that the energy charges were based upon "average (day and night) instead of marginal operating costs, it introduced differential time-of-day, -week, and -year energy charges reflecting the increasing [short-run marginal cost] function."[158] These tariffs were intended to reflect marginal costs, both in the calculation of energy charges and in the demand charges.[159] It does not appear, however, that the Area Boards passed on demand charges to non-bulk (e.g., residential or commercial) customers in a similar manner.[160] Thus, while the concept of economically efficient pricing matured both in theory and in practice in wholesale sales, this transformation did not reach residential customers.

One of the most significant developments in utility ratemaking during this period was the publication in 1961 of James Bonbright's "Principles of Public Utility Rates."[161] In this seminal book, he discussed different, and sometimes conflicting, goals of utility ratemaking and laid out principles that since then are known as "Bonbright Principles."[162]

---

152. *Id.* at 99–101.
153. *Id.* at 101.
154. *Id.* at 103–04.
155. *Id.* at 104–08.
156. The structure of the British electric sectors at the time was such that Central Electricity Generating Board charged bulk supply rates to twelve Area Electricity Boards, which then distributed the electricity to final customers. Ronald L. Meek, *The New Bulk Supply Tariff for Electricity*, 78 ECON. J. 43, 43 (1968).
157. *Id.* at 45.
158. KAHN, *supra* note 16, at 97 (citing a contemporaneous article from *The Economist*).
159. Meek, *supra* note 156, at 43, 48–51 (going into the details of how the new demand charges were calculated).
160. *Id.*
161. JAMES BONBRIGHT, PRINCIPLES OF PUBLIC UTILITY RATES (1961), https://perma.cc/Q5TV-K6U3.
162. *Id.* at 291. The eight principles of rate design are "practical" attributes of simplicity, understandability, public acceptability, and feasibility of application; freedom from controversies as to proper interpretation; effectiveness in yielding total revenue requirements under the fair-return standard; revenue stability from year to year; stability of the rates themselves, with a minimum of unexpected changes seriously adverse to existing customers; fairness of the specific rates in the apportionment of total costs of service among the different consumers;

Bonbright summarized his ratemaking principles as seeking to achieve three primary objectives: revenue requirement, fair apportionment, and optimum-use.[163] The revenue requirement objective leads to total cost recovery and revenue stability for the utilities.[164] This principle is meant to ensure a standard of fair return for the utility. The fair apportionment objective translates into a standard of fair division of production costs among consumers.[165] This principle is meant to guarantee that the burden of collecting enough revenue to meet a utility's revenue requirement is shared fairly among its beneficiaries. Finally, the optimum-use objective, is essentially an efficiency goal.[166] It aims to "discourage the wasteful use of public utility services while promoting all use that is economically justified," both in terms of the total services supplied by the utility and in terms of the relative uses of alternative types of services provided by the utility.[167]

Bonbright also observed that electricity rate designs in the United States at the time were "far from ideal" and that policymakers would be better off considering the "infirmities" identified by the "academic economists."[168] In particular, he identified demand charges that were not coinciding with the peak of the system as a whole as one such infirmity, with discounts that are not defensible on the cost-of-service principles as another.[169] His criticisms of not using demand charges for residential customers and his suggestions for coincident peak demand charges have been largely ignored in practice for the past sixty years. Yet, Bonbright's book remains a commonly cited authority on principles of rate design even today.[170]

During this period from the 1950s through the early 1970s, economically efficient pricing was mostly thought of as an academic exercise in the United States.[171] The focus of ratemaking at the time was overall adequacy or sufficiency of utility compensation rather than marginal-cost pricing.[172] Rates were set at the same level for broad classes of customers, were fixed across time to

---

avoidance of "undue discrimination" in rate relationships; and efficiency of rate classes and rate blocks in discouraging wasteful use of service while promoting all justified types of use.

163. *Id.* at 292.

164. *Id.*

165. *Id.*

166. *Id.*

167. *Id.* at 292.

168. *Id.* at 315–16.

169. *Id.*

170. *See, e.g.*, Ahmad Faruqui, *Rate Design 3.0*, 156 PUB. UTIL. FORT. 34, 35 (2018) (quoting Bonbright's support for a three-part rate, presaging the modern movement toward such rates); JIM LAZAR, ELECTRICITY REGULATION IN THE US 1 (2016) (referring to Bonbright as a seminal work).

171. STEVEN BRAITHWAIT ET AL., EDISON ELEC. INST., RETAIL ELECTRICITY PRICING AND RATE DESIGN IN EVOLVING MARKETS 43 (2006), https://perma.cc/F4R8-SDPJ.

172. *Id.*

reflect the overall average of the hourly costs, and were meant to recover utilities' incurred costs.[173] Even with the rapid growth of electricity usage, rate design reform was not a policy priority, partly because electricity costs were declining.[174] As a result, rate designs remained disconnected from the efficiency principles outlined in Part I.

C. Late 20th Century

Driven partially by the energy crisis, and partially by the increases in marginal costs, a new wave of rate design discussions got underway in the United States in the 1970s.[175] A combination of factors including high inflation, rising fossil fuel prices, and the end of economies of scale in power plant construction led marginal costs of electricity provision to exceed average costs.[176] This upward pressure on prices led to a new interest on marginal cost pricing as a way to encourage more efficient use of energy.[177]

This interest not only renewed academic interest on electricity marginal costs, but also led significant industry associations, including the National Association of Regulatory Utility Commissioners, the Edison Electric Institute, and the Electric Power Research Institute, to collaborate on a comprehensive rate design study. The goal of this study was to determine the appropriate methods for estimating marginal costs and "to assess the feasibility and cost of shifting various types of usage from peak to off-peak periods."[178]

In addition to the joint study done by these associations, the federal government also conducted experiments with different rate designs. During the 1970s, the Federal Energy Administration, the predecessor to the U.S. Department of Energy, administered multiple experiments.[179] The results were promising, with peak energy consumption reductions of more than 30% in three of the experiments.[180] These projects, however, had "a considerable range of sophistication in their design, number of customers covered, and quality of analy-

173. *Id.* at 2.
174. *Id.* at 43.
175. *Id.*
176. BRAITHWAIT ET AL., *supra* note 171.
177. *Id.*
178. *Id.*
179. Ahmad Faruqui, Sanem Sergici & Cody Warner, *Arcturus 2.0: A Meta-Analysis of Time-Varying Rates for Electricity*, 30 ELECTRICITY J. 64, 64 (2017).
180. Ahmad Faruqui & J. Robert Malko, *The Residential Demand for Electricity by Time-of-Use*, 8 ENERGY 781, 786 (1983) (summarizing statistically significant findings of peak load reduction in Arkansas (42%), Connecticut (31%), Ohio (38%), Wisconsin (26%), Arizona (16%), and Puerto Rico (14%), but not in North Carolina, Oklahoma, or Rhode Island).

sis,"[181] and, researchers struggled to take away generalizable findings from the projects to eventually advise policy makers.[182]

Still, states may have been encouraged by results from these pilots. By 1977, "state rate proceedings in California, Michigan, New York and Wisconsin led to the first use of time-of-use pricing for very large customers."[183] *Time-of-use pricing*, like the Green Tariff,[184] differentiates prices by time of day.[185] Most time-of-use rates have two (peak, off-peak) or three (peak, shoulder, off-peak) periods.[186] In addition, there can be seasonal variation as well.[187] In California, large commercial and industrial customers have been on mandatory time-of-use pricings since the late 1970s or early 1980s, depending on the size of the customer.[188]

Another significant driver of innovation in rate design during the late 20th century was the passage of the Public Utilities Regulatory Policy Act of 1978 ("PURPA").[189] PURPA required state public utility commissions and nonregulated electric utilities to "consider and determine" whether six ratemaking standards should be adopted:

> (1) cost of service rates "to the maximum extent practicable"; (2) declining block rates only where cost justified; (3) time-of-day rates based on cost of service unless not cost-justified; (4) seasonal rates reflecting season cost variations; (5) interruptible rates; and (6) practicable, cost-effective and reliable load management techniques.[190]

These new standards provided new momentum for rate design discussions, but many commissions still did not welcome the idea of marginal cost pricing. They were not only troubled by the difficulty of figuring out marginal costs and

---

181. Jan Paul Acton, *An Evaluation of Economists' Influence on Electric Utility Rate Reforms*, 72 AM. ECON. REV. 114, 114 (1982); *see also id.* at 115 (describing various experimental design issues and practical reasons for such deficiencies).

182. *See* Douglas W. Caves, Laurits R. Christensen & Joseph Herriges, *Consistency of Customer Response in Time-of-Use Experiments*, 26 J. ECONOMETRICS 179, 180 (1984) (describing papers in 1980 and 1981).

183. BRAITHWAIT ET AL., *supra* note 171, at 43 (citing B.M. MITCHELL ET AL., PEAK-LOAD PRICING, EUROPEAN LESSONS FOR U.S. ENERGY POLICY (1978)).

184. *See supra* text accompanying notes 145–49.

185. CHITKARA ET AL., *supra* note 82, at 19.

186. *Id.* at 23; *see also* Reneses et al., *supra* note 54, at 408.

187. CHITKARA ET AL., *supra* note 82, at 26.

188. Pac. Gas & Elec. Co., Cal. Pub. Util. Comm'n, No. 08-07-045, at 10 (July 31, 2008), https://perma.cc/X3PA-L3WJ (decision adopting dynamic pricing timetable and rate design guidance).

189. Pub. L. No. 95-617, 92 Stat. 3117 (1987) (codified as amended in scattered sections of titles 15, 16, 42, and 43 U.S.C.).

190. John T. Miller, Jr., *Conscripting State Regulatory Authorities in A Federal Electric Rate Regulatory Scheme: A Goal of PURPA Partially Realized*, 4 ENERGY L.J. 77, 77 (1983) (citing PURPA § 111(d), 16 U.S.C. § 2621(d)).

translating them into rates, but also not convinced by the underlying economic theory or the assumption that economic efficiency is "the sole goal of the regulator's office."[191]

Despite this hesitation, many innovative pilots took place soon after the passage of PURPA. Notably, in the early 1980s, "TransText" pilots took place with participation from Southern Bell, Southern Company, and the Massachusetts Institute of Technology.[192] The pilots included a four-interval time-of-use price structure, a dispatchable thermostat that could be programmed with conventional set points as well as customer price-activated load management options, a gateway that could read the revenue meter, and power line control devices the customer could use to control loads in response to energy company price signals.[193] Customers in the pilot programmed their thermostats and loads to respond to a three-part time-of-use pricing themselves.[194] TransText, the "two-way communication and control technology," enabled the utilities to charge a fourth, higher price for a small number of hours during the year that were not announced in advance.[195] These pilots continued through the 1990s, with "convincingly positive energy and customer results" with bill reductions of over 10% and an average load reduction of 41% during critical periods.[196]

Additionally, the first real-time pricing programs were instituted during this period. Pacific Gas & Electric is generally credited with starting such a program for industrial and commercial customers in 1985.[197] However, the prices in that program far exceeded marginal costs because of that program's one-part design: all revenue requirements were recovered solely through the real-time pricing energy charge. To get efficient energy prices, Niagara Mohawk instituted a novel time-variant design under which customers were charged a flat fee based on their historical usage, but were assessed additional charges or received credits according to the real-time price to the extent their

---

191. *Id.* at 82–83 (citations omitted).

192. *See* Lawrence Berkeley Nat'l Lab., Smart Grid Technical Advisory Project, An Introduction—Smart Grid 101, ch. 5 at 14 (2011); Severin Borenstein, Michael Jaske & Arthur Rosenfeld, *Dynamic Pricing, Advanced Metering, and Demand Response in Electricity Markets* at B-1 (Ctr. for the Study of Energy Mkts., Working Paper No. 105, 2002), https://perma.cc/KU37-GFED.

193. Borenstein, Jaske & Rosenfeld, *supra* note 192, at B-1 to B-2.

194. *Id.* at B-2.

195. Ahmad Faruqui & Stephen S. George, *The Value of Dynamic Pricing in Mass Markets*, 15 Electricity J. 45, 49 (2002). The pilots took place in General Public Utilities (now known as FirstEnergy), American Electric Power, and Georgia Power. *Id.*; *see also* Lawrence Berkeley Nat'l Lab., *supra* note 192, at 14.

196. Borenstein, Jaske & Rosenfeld, *supra* note 192, at B-2, B-8.

197. Galen Barbose, Charles Goldman & Bernie Neenan, Lawrence Berkeley Nat'l Lab., A Survey of Utility Experience with Real-Time Pricing 94 (2004), https://perma.cc/S3XM-375J; Braithwait et al., *supra* note 171, at 43.

consumption differed from that historical baseline.[198] This innovative design became the standard time-variant tariff design in the early and mid-1990s.[199] For example, Georgia Power's program, adopted during this time, has since grown into the largest real-time pricing program in the United States.[200]

One group of researchers (funded by the Electric Power Research Institute) later performed a "careful investigation of sample procedures, data quality, and data availability" and re-analyzed five of the experiments that were sufficiently similar in design and had sufficiently high-quality data.[201] The results of this reanalysis, published in 1984, found that the level of customer response to the tariffs was similar across the groups across these five rate pilots, even though two of the experiments were in California, one in Connecticut, one in North Carolina, and one in Wisconsin.[202] Later, summarizing this research, one author believed that it revealed a "model of customer behavior . . . that could be applied successfully across the country."[203]

Yet, there was still no widespread adoption of efficient rate designs for residential customers during this period. While many large commercial and industrial customers moved to designs that better reflect the cost drivers and the granular variation in costs, residential designs remained the same.

D. Early 21st Century

At the turn of the century, some significant events for the electricity sector brought new attention to more dynamic and cost-reflective rate design. The restructuring of electricity markets as a result of FERC Orders 888, 889, and 2000, which encouraged competition in wholesale market operations to promote economic efficiency, and the subsequent rise of more established wholesale energy markets led to five-minute locational marginal prices becoming a

---

198. Barbose et al., *supra* note 197, at ES-3; Bruce Chapman & Tom Tramutola, *Real-Time Pricing: DSM at Its Best?*, 3 Electricity J. 40, 42 (1990); Joseph A. Herriges, *The Response of Industrial Customers to Electric Rates Based Upon Dynamic Marginal Costs*, 75 Rev. Econ. & Stat. 446, 447–48 (1993).

199. Barbose et al., *supra* note 197, at ES-3.

200. *Id.* at 54 n.49 (explaining that Georgia Power's program had the same baseline-plus-adjustment design); Braithwait et al., *supra* note 171, at 44; *see also* Lawrence Berkeley Nat'l Lab., *supra* note 192, at 11 (noting that two-part real-time pricing rates were developed in the late 1980's to address under-collection of the utility revenue requirement under a marginal-cost-only real-time pricing rate).

201. Caves et al., *supra* note 182, at 180–81.

202. *See id.* at 180, 192, 198 (explaining that more precisely, the researchers could not reject hypotheses that the elasticities of substitution between electricity and other goods or that rate structure effect parameters in their model were equal across all designs).

203. Ahmad Faruqui, Ryan Hledik & Sanem Sergici, *Rethinking Prices: The Changing Architecture of Demand Response in America*, 148 Pub. Util. Fort. 30, 37 (2010); *see also* Faruqui, Sergici & Warner, *supra* note 179, at 64 (characterizing this study as finding "consistent evidence of demand response across the five studies").

part of the standard wholesale market design.[204] These prices, as we explained in Part I, reflect the marginal cost of providing electricity to a particular location given the transmission constraints. Therefore, the discrepancy between the retail prices end users faced and the actual marginal costs, and hence the potential for dynamic rate designs to increase economic efficiency, became more apparent.

At the same time, significant electricity shortages and blackouts in California caused by market manipulation and electricity price regulations,[205] as well price spikes in the Midwest and on the East Coast,[206] created another reason to figure out how to link retail and wholesale markets to prevent a recurrence of such a crisis.[207] Policymakers recognized that "organized wholesale energy markets . . . need some degree of responsive demand to operate efficiently."[208] And, research showed that had California been using time-variant pricing during the crisis, power sellers would not have had the same incentives to withhold power, trying to manipulate and drive up prices.[209] As a result, time-variant pricing was seen as a way of enabling customer response to reduce usage during peak periods, averting the need for regulatory intervention.[210]

Different types of time-variant pricing pilot programs became increasingly prevalent during the early 2000s. Between 2003 and 2007, utilities across the country ran several significant time-variant pricing pilots including the California Statewide Pricing Pilot, the California Automated Demand Response System Pilot, the Anaheim, California Peak Time Rebate Experiment, and

204. Order No. 888, 75 FERC ¶ 61,080 (Apr. 24, 1996) (promoting wholesale competition through open access nondiscriminatory transmission services by public utilities); Order No. 889, 75 FERC ¶ 61,078 (Apr. 24, 1996) (open access same-time information system and standards of conduct); Order No. 2000, 89 FERC ¶ 61,285 (Dec. 20, 1999) (Regional Transmission Organizations).

205. *See* Faruqui, Sergici & Warner, *supra* note 179, at 64; John Kwoka & Vladlena Sabodash, *Price Spikes in Energy Markets: "Business by Usual Methods" or Strategic Withholding?*, 38 REV. INDUS. ORG. 285, 287–88 (2011); *see also* BRAITHWAIT ET AL., *supra* note 171, at 43.

206. *See* FERC OFFICE OF THE CHIEF ACCOUNTANT ET AL., STAFF REPORT TO THE FEDERAL ENERGY REGULATORY COMMISSION ON THE CAUSES OF WHOLESALE ELECTRIC PRICING ABNORMALITIES IN THE MIDWEST DURING JUNE 1998, at v to vi (1998); Kwoka & Sabodash, *supra* note 205, at 287–88; Diana L. Moss, *Electricity and Market Power: Current Issues for Restructuring Markets (A Survey)*, 1 ENVTL. & ENERGY L. & POL'Y J. 11, 31 (2006).

207. *See* FERC OFFICE OF THE CHIEF ACCOUNTANT ET AL., *supra* note 206, at ix; Moss, *supra* note 206, at 34–35.

208. BRAITHWAIT ET AL., *supra* note 171, at 44.

209. Severin Borenstein, *Effective and Equitable Adoption of Opt-In Residential Dynamic Electricity Pricing*, 42 REV. INDUS. ORG. 127, 130 (2013).

210. Faruqui, Sergici & Warner, *supra* note 179, at 64.

Chicago's Community Energy Cooperative's Energy-Smart Pricing Plan.[211] But, still, none immediately led to a significant redesign of residential electricity rates. Residential customers were still largely on two-part tariffs with flat volumetric charges.

E. The Present and the Reforms in Progress

In recent years, there has been much more experimentation with and adoption of more sophisticated rate designs. Today's rates take on many different forms and are implemented with various success rates across the country. There have been at least 337 treatments in sixty-three pilots of electricity pricing globally, starting in the late 1990s, with a large increase in such pilots from 2005 to 2014.[212] While some of these pilots were for both energy and capacity charges, the majority were focused on reforming the energy charges. And currently around 8.5 million customers face some form of time-variant energy rates.[213]

Maryland has the highest adoption of time-variant rates amongst the states, with over 75% of residential customers on such rates. This success is largely the result of Baltimore Gas & Electric's peak-time rebate program.[214] Under the program, the utility notifies enrolled customers of Energy Savings Days (i.e., days when demand is expected to be close to the peak, or the peak) the evening before they occur, usually a handful of times each summer. If customers in the program consume less electricity during the peak hours on those days, compared to their baseline usage, they receive a refund on their bills for the difference.[215] However, from an economic efficiency perspective, these rebate programs are less desirable than charging peak prices, because rebates create a perverse incentive for customers to manipulate their "baseline" usage to qualify for a bigger rebate.

California has also been experimenting with various time-variant energy rates for residential customers in the past decade.[216] For example, it has used

211. Ahmad Faruqui, Ryan Hledik & Sanem Sergici, *Piloting the Smart Grid*, 22 ELECTRICITY J. 55, 60 (2009); *see also Time-of-Use Peak-Sensitive Rates*, 1 L. INDEP. POWER § 5:19.30 (2019) (summarizing the California statewide pricing pilot).

212. Faruqui, Sergici & Warner, *supra* note 179, at 65 Fig. 3 (showing the number of experimental pricing treatments rising from about twenty-five to over 300 from 2005 to 2014).

213. *Annual Electric Power Industry Report Form EIA-861 Detailed Data Files*, U.S. ENERGY INFO. ADMIN. (2019) [hereinafter "EIA DATA"], https://perma.cc/Z9SB-AJJT (providing 2017 data on dynamic pricing, summing total reported number of customers enrolled in any time-variant pricing scheme).

214. *See* Ahmad Faruqui et al., *Smart by Default*, 152 PUB. UTIL. FORT. 24, 25–26 (Aug. 2014) (describing one of the first residential default pricing deployments beginning in Maryland for Baltimore Gas & Electric).

215. *See Energy Savings Days*, BALT. GAS & ELEC., https://perma.cc/96UD-3CMC.

216. *See* Pac. Gas & Elec. Co., *supra* note 188, at 90–93.

critical-peak pricing, which charges customers high prices during certain "critical event" days when the system costs are especially high.[217] However, the number of these critical events was limited and they had to be "called" in advance by the utility to allow customers the chance to change their consumption.[218] As a result, the design was not flexible. And, the success in correctly predicting the actual peaks was low.[219]

In 2018, California began rolling out system-wide *default* time-of-use rates.[220] Consumers are presented with these rates as a default to promote wide-scale adoption but can choose to opt out of them.[221] California understands the particular designs might need to change depending on the resource mix.[222] While California still has relatively low levels of solar penetration and the peak period still occurs when solar panels are still producing,[223] some utilities have already been modifying their tariff designs to accommodate the significant amounts of solar resources.[224]

Illinois is perhaps most advanced in terms of the sophistication of the tariffs offered. In 2006, the Illinois General Assembly required Commonwealth Edison ("ComEd") and Ameren, the two large investor-owned utilities in Illinois, to offer real-time pricing to customers as an optional service.[225] The legislation put a third-party program implementer in charge, and also mandated that the costs of the program, including a meter that could track hourly usage,

217. Chitkara et al., *supra* note 82, at 19.

218. *Id.* at 19.

219. *Id.* at 33 (showing that 42% of the peak event days Pacific Gas & Electric called between 2009 and 2011 did not align with the actual peak days during that time).

220. *Utilities Planning to Move Californians to Time-of-Use Pricing Need Solutions for Low-Income Customers*, Envtl. Def. Fund: Energy Exch. (Jan. 30, 2018), https://perma.cc/DD4U-LUPS (describing current plans to enroll customers from San Diego Gas & Electric in 2019, Pacific Gas & Electric plans to begin in 2020, and Southern California Edison in 2021).

221. Peter Cappers et al., Lawrence Berkeley Nat'l Lab., Time-of-Use as a Default Rate for Residential Customers: Issues and Insights 3 (2016), https://perma.cc/ZL3C-BVA7.

222. *See, e.g.*, Herman K. Trabish, *One Small Step for Hawaii Solar, One Leap Toward 100% Renewables*, Util. Dive (Nov. 9, 2017), https://perma.cc/JYH4-4HMJ (describing new solar tariffs in Hawaii that do not compensate solar-generating customers during peak hours); Ryan Hledik, Ahmad Faruqui & Cody Warner, The National Landscape of Residential TOU Rates 14 (2017), https://perma.cc/QQ2K-7HEM (describing how increasing solar adoption in California and other western states has changed the design of San Diego Gas & Electric's TOU design to shift to later in the afternoon).

223. *See* Hledik, Faruqui & Warner, *supra* note 222, at 14.

224. *See id.*

225. Anthony Star et al., Making Waves in the Heartland: How Illinois' Experience with Residential Real-Time Pricing Can Be a National Model 2-281 (2008) [hereinafter Star, Illinois' Experience] https://perma.cc/UE4C-QS8M.

be both partially paid by the participants and also socialized across all residential ratepayers.[226]

ComEd had already piloted its residential real-time pricing design in 2003 prior to this legislation. And, the success of the pilot was a motivator and justification for the Illinois General Assembly's decision to authorize residential real-time rates.[227] ComEd was "very much motivated by an interest in load management and peak demand reduction," and it was "interested in continuing the program if the pilot results [were] encouraging."[228] ComEd currently offers its customers hourly, real-time pricing.[229] To reduce uncertainty for customers, ComEd ensures "[d]ay ahead prices are available each evening to serve as advisory prices for the next day."[230] In addition to this hourly energy charge, these customers are responsible for a fixed charge, a per-kilowatt charge for coincident peak generation capacity, and a flat kilowatt-hour price for transmission and distribution.[231] Thus, ComEd's design comes close to meeting the principles we laid out in Part I. But it still falls short of fully internalizing externalities.

Hawaii introduced time-of-use rates that look quite different from most others. Because Hawaii has a very high penetration of solar resources, with a significant number of rooftop solar customers, there is abundant electricity during the day. But as soon as the sun goes down, so does the generation from all the solar panels. As a result, when the Hawaii Public Utilities Commission began piloting time-of-use pricing in 2016, the lowest rates for the islands of Maui and Hawaii occurred during the day, in contrast to the typical pattern with high day time prices and low overnight prices.[232] And, there were large price differentials between the daytime and evening periods.[233] This rate design

226. *Id.* at 2-284–85.

227. ANTHONY STAR ET AL., THE DYNAMIC PRICING MOUSETRAP: WHY ISN'T THE WORLD BEATING DOWN OUR DOOR? 2-257 (2010) [hereinafter STAR, DYNAMIC PRICING], https://perma.cc/P6WW-NUVR.

228. BARBOSE, *supra* note 197, at 81.

229. *Program Overview*, COMMONWEALTH EDISON, https://perma.cc/AQ93-DD43.

230. STAR, ILLINOIS' EXPERIENCE, *supra* note 225, at 2-287.

231. *See* Faruqui, Hledik & Sergici, *supra* note 203, at 39.

232. Seth Mullendore, *Time-of-Use Means It's Time for Storage*, CLEAN ENERGY GRP. (Jan. 20, 2017), https://perma.cc/KYE8-YGPW; *see* Peter Maloney, *Hawaiian Regulators Approve Time-of-Use Rate Pilot to Aid Solar Integration*, UTIL. DIVE (Sept. 22, 2016), https://perma.cc/5G84-FC22.

233. *See* MAKENA COFFMAN ET AL., UNIV. OF HAW. ECON. RES. ORG., ESTIMATING THE OPPORTUNITY FOR LOAD-SHIFTING IN HAWAII: AN ANALYSIS OF PROPOSED RESIDENTIAL TIME-OF-USE RATES 4 (2016), https://perma.cc/MUQ2-8BS9 (describing a proposed rate structure with daytime rates of about ten cents per kWh and evening rates of nearly sixty cents per kWh); *see also* Hawaii Electricity Light Co., Haw. Pub. Util. Comm'n., No. 2014-1092 (Oct. 9, 2018), https://perma.cc/T7UE-3CT9 (showing the interim TOU residential rate with daytime charge of 0.86 cents per kWh and peak rates of nearly 28 cents per kWh).

is mandatory for customers who own solar panels and want to export their excess electricity to the grid.[234]

Internationally, more granular rates have been adopted in several foreign jurisdictions, including in Ontario, Canada, where utilities have had time-of-use rates as the default option since 2012.[235] In Spain, in 2014 regulators adopted a voluntary real-time price tariff for small consumers, primarily consisting of a grid access charge and a charge reflecting the hourly cost of energy.[236] By the end of 2018, 100% of consumers in Spain were expected to have smart meters installed, but even those without a meter can be charged under the tariff by means of a consumption profile.[237] In Italy, mandatory residential time-of-use rates have also been in place since 2012.[238] In Ireland, time-of-use charges will be required by 2020.[239] These countries and others continue to experiment with other dynamic rate designs.[240] However, European efforts have historically focused on smart grid deployment rather than time-variant pricing, potentially because Europe is thought to have less to gain from peak demand reduction as the peaks in Europe are less severe due to lower prevalence of air conditioners compared to the United States.[241]

Reforming the flat volumetric charges to better reflect the temporal variation in energy costs have been driving most of these reforms. But there has not been a similar impetus to reform capacity charges. Demand charges have typi-

---

234. Haw. Pub. Util. Comm'n, No. 33258, No. 2014-1092 (Oct. 12, 2015), https://perma.cc/MTE7-VMXQ (documenting the structure of the new mandatory program on distributed energy resource policies).

235. Niel Lessem et al., *Time-of-Use Rates in Ontario*, 155 PUB. UTIL. FORT. 56, 57 (2017).

236. Juan Manuel Roldán Fernández et al., *The Voluntary Price for the Small Consumer: Real-Time Pricing in Spain*, 102 ENERGY POL'Y 41, 41 (2017); *see also Voluntary Price for the Small Consumer,* RED ELÉCTRICA DE ESPAÑA (Oct. 1, 2019), https://perma.cc/435R-S2CV (explaining the tariff).

237. Roldán Fernández et al., *supra* note 236, at 42.

238. Walter Graterri & Simone Maggiore, Impact of a Mandatory Time-of-Use Tariff on the Residential Customers in Italy, Ricerca Sisterna Energetico (Nov. 14, 2012), https://perma.cc/Z57D-WVPP.

239. Faruqui, Sergici & Warner, *supra* note 179, at 69.

240. *Id.* at 68–69 (listing pilot programs in Australia, Canada, Japan, Ireland, Italy, and the United Kingdom); *see also* Ahmad Faruqui, THE BRATTLE GRP., Rate Design 3.0 and The Efficient Pricing Frontier 13 (May 15, 2018), https://perma.cc/PM4F-UD6H (noting a rollout of a peak-time-rebate program to 27,000 customers in Hong Kong).

241. *See* Zheng Hu et al., *Review of Dynamic Pricing Programs in the U.S. and Europe*, 42 RENEWABLE & SUSTAINABLE ENERGY REV. 743, 747 (2015) (attributing the difference in part to a lower peak-to-average ratio in Europe, and a higher prevalence of air conditioning in the U.S. that could respond to higher prices during summer peak demand); *see also* Ahmad Faruqui et al., *Unlocking the €53 Billion Savings from Smart Meters in the EU,* 38 ENERGY POL'Y 6222, 6222 (2010) (describing the significant European investment in smart meters and advocating for increased adoption of dynamic pricing to take advantage of this investment).

cally been applied only to larger commercial and industrial customers in recent history.[242] The prevailing view is that, because larger customers are more sophisticated about their energy consumption and "have far greater peak usage" they are more able to take advantage of the cost savings from reducing their consumption during their peak demand time compared to smaller, residential customers.[243] Residential customers have had the option to opt in to demand charges but have not been mandatorily subject to them.[244] As of 2018, about thirty utilities across fifteen states were offering residential demand charges.[245]

Recently, however, utilities have become interested in residential demand charges as a result of increased DER penetration. Because utilities see demand charges as a way to create revenue stability that can help compensate for any cost recovery concerns caused by DERs, the latest pilots started including residential demand charges as well.[246] And some utilities, such as Arizona Public Service, which has about 10% of its residential customers on a demand charge, have already proposed deploying demand charges on a default basis for its residential customers.[247] And other utilities around the country have also begun to push for demand charges with varying designs.[248] Nonetheless, residential demand charges remain contested today.[249]

As this brief review of 140 years of electricity pricing history shows, linking underlying costs with prices has been a mainstay of the pricing debates. But,

---

242. Trabish, *Rate Design Roundup*, *supra* note 6 (stating that demand charges "have typically been restricted to C&I customers").

243. James Tong & Jon Wellinghoff, *The Flaws in the Utilities' Push for Residential Demand Charges*, UTIL. DIVE (Oct. 3, 2016), https://perma.cc/7H4Y-2CUR.

244. Kari Lyderson, *Move Over Fixed Fees—Utilities See Demand Charges as Revenue Cure*, ENERGY NEWS NETWORK (Dec. 2, 2015), https://perma.cc/QR9G-933H.

245. Faruqui, Sergici & Warner, *supra* note 179, at 64 (noting over thirty utilities have demand charges); CHITKARA ET AL., *supra* note 82, at 49 (noting fifteen states have utilities with demand charges).

246. CHITKARA ET AL., *supra* note 82, at 49.

247. *Id.*

248. *See* ENERKNOL, UTILITIES SEEK DEMAND CHARGES AS STATES TUSSLE WITH NET METERING POLICIES (2018) (for a list of states that are discussing implementing demand charges) (on file with the authors); *see also* SATCHWELL ET AL., *supra* note 95, at 19–22 (discussing demand charges imposed by different utilities).

249. *See, e.g.*, JANINE MIGDEN-OSTRANDER, REG. ASSISTANCE PROJECT, RECOMMENDATIONS FOR OHIO'S POWER FORWARD INQUIRY 49–51 (Sept. 12, 2017) (advising the Ohio Public Utilities Commission regarding drawbacks to demand charges, including the problems regarding coincidence with the system peak, consumer confusion, and resulting unfairness). *But see* Ahmad Faruqui, Residential Demand Charges: An Overview 10–13 (Mar. 15, 2016), https://perma.cc/KV2U-2BNW (arguing that small customers' bills will not automatically increase, and that customers should be able to understand charges based on maximum wattage).

now, the technological limitations that hindered progress no longer exist.[250] Advanced metering infrastructure that would allow two-way communication between the customers and the utility in real-time had already been installed in about seventy-nine million customers by the end of 2017, covering more than half of the 150 million electricity customers in the United States.[251] And, such infrastructure is projected to cover a significant majority of the customers by 2020.[252] Yet, despite the pilot programs with more sophisticated rate designs that began in the 1980s,[253] only about 8.5 million industrial, commercial, and residential customers are enrolled in any form of time-variant pricing.[254] And, perhaps even more surprisingly, there is still no rate design in practice that satisfies the basic principles we laid out in Part I.

III. Shortcomings of Current Designs and Proposed Reforms

As we summarized in Part II, rate designs have not followed the economic principles on efficient pricing. In this Part, we review the rate designs commonly used in the United States, explain their inefficiencies, and discuss why even the reforms that are in progress today are too narrow to achieve economic efficiency. Finally, we explain why better price signals are especially important today, when policymakers need to rapidly move forward concurrently with both grid modernization and climate change policies.

A. Inefficiencies of Current Rate Designs

Current residential electricity rates typically have two parts: a fixed charge and a volumetric charge. A few utilities use designs with an additional part, a demand charge. Below, we discuss the inefficiencies associated with each of these designs.

1. Two-Part Tariffs

A typical two-part tariff has a fixed customer charge and a volumetric usage charge. A *fixed customer charge* is a base dollar amount that consumers have to pay regardless of their behavior.[255] Consumers cannot avoid these charges

250. Paul L. Joskow & Catherine D. Wolfram, *Dynamic Pricing of Electricity*, 102 Am. Econ. Rev. 381, 382 (2012).

251. *How Many Smart Meters Are Installed in the United States, and Who Has Them?*, U.S. Energy Info. Admin. (Oct. 26, 2018), https://perma.cc/B5FB-TMGM.

252. Cooper, *supra* note 2.

253. Lawrence Berkeley Nat'l Lab., *supra* note 192, at 14.

254. EIA Data, *supra* note 213 (summing, in linked excel sheets by year, total reported number of customers enrolled in any time-variant pricing scheme).

255. Samantha Williams, *Is There a "War of Attrition" on Electricity Fixed Charges?*, Nat. Res. Def. Council (Feb. 13, 2018), https://perma.cc/G3R3-DGHR (explaining fixed charges).

even if they reduce their consumption significantly. A *volumetric charge* is a charge that consumers pay for each kWh of electricity they use. The structure and levels of both of these charges are determined in regulatory ratemaking cases, usually as settlements among stakeholders. This type of design does not have explicit capacity prices. Capacity costs are instead usually embedded in the calculations of the volumetric charge.

Flat rates, which do not vary by time or location, are the most commonly used type of volumetric charges for electricity use.[256] They are roughly the average cost of generating, transmitting, and distributing electricity to end users, all bundled in one rate.[257] In states with deregulated electricity markets, there are usually two separate volumetric charges; one for electricity supply to recover the costs of generation and transmission, and one for delivery to recover the cost of distribution, but each charge still reflects the average cost of the respective elements.[258] So, these charges are tied to the total costs of providing electricity to end users as a whole and are not reflective of marginal cost of providing electricity to an individual end user at a particular time and location. While a design with a flat rate is unarguably simple, it violates all the economic efficiency principles we listed above.

First, because the volumetric charge in this design represents a bundled rate, it cannot account for cost drivers properly. This type of rate structure, by design, does not allow for properly unbundled price signals for energy and capacity. As a result, even in deregulated states, where distribution and supply charges are separated for consumers to see, consumers do not receive signals about the true cost they impose on society when they contribute to the peak demand, or when they use electricity at times when the marginal cost is high.

Second, this design is neither temporally nor spatially granular. The bundled, flat rate roughly represents the average cost of electricity provision over a certain period of time, and across the utility service area. Therefore, it does not capture the hourly variations in the marginal cost of producing electricity, or the locational variations in congestion of the distribution and transmission networks. As a result, it cannot communicate prices that reflect the actual societal value of energy at a particular time and location, falling short of providing efficient price signals. Lack of such variation has led to inefficiently high electricity system costs in the United States.[259] Further, because everybody pays the same price, regardless of when and where they use electricity, this design creates cross-subsidies among different types of consumers. For example, a consumer

256. Chitkara et al., *supra* note 82, at 5, 19.

257. *See* Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 72.

258. *See*, *e.g.*, *Schedule of Electricity Service*, ConEdison, https://perma.cc/635Z-7Z6G (showing rates and tariffs for separate delivery and supply charges).

259. *See* Borenstein & Holland, *supra* note 83, at 486 ("[P]utting just a third of customers on RTP would cut the number of peakers by about 44% and the total installed capacity by more than 10%.").

who uses electricity when the marginal cost is low but pays the average cost subsidizes a consumer who uses electricity when the marginal cost is high but also pays the average cost.

Third, this design cannot fully reflect the external cost of electricity provision. Even in states that directly price greenhouse gas emissions by cap-and-trade programs, these externalities are not fully internalized currently. Both California's cap-and-trade system and the Regional Greenhouse Gas Initiative have permit prices that are significantly lower than the external damages caused by carbon dioxide.[260] Therefore, even though the generators have to pay some additional amount to buy permits, and hence the marginal cost of generation rises by that additional amount, energy prices still do not fully reflect the full cost of damages caused by air pollution.

But, even if there were a sufficiently high emissions price that would internalize the externality, it would still not be possible for consumers to fully understand the external costs they are imposing on society because a flat rate still breaks the link between the time- and location-variant social marginal cost and the price that consumer sees. As a result, consumers base their decisions on an inaccurate price that does not show the true social marginal cost, leading to too much pollution from the electricity sector.

And, finally, the levels of these charges are usually determined in a backwards-looking manner, and are meant to recover costs already incurred by utilities. As we mentioned in Section I.B, recovery of residual, non-avoidable costs should be done in the least distortionary manner. Basing marginal price signals on these costs that are unavoidable regardless of what the consumer does, would be economically inefficient. Marginal price signals should be designed based on forward-looking avoidable capacity and energy costs. And, modifications to these prices should be considered only if the revenues based on these forward-looking prices are not sufficient to meet a utility's revenue requirement.

2. *Demand Charges*

Even though the two-part tariff is the most commonly used rate design, there are also utilities that charge a three-part tariff for residential customers, with a demand charge for capacity in addition to the typical two-part tariff described above.[261] However, there is no uniformity on either the kind of capacity costs these demand charges try to recover, or the design.[262] Depending on the jurisdiction, demand charges may be intended to recover capacity costs for generation, transmission, and distribution altogether, or just to distribution ca-

260. Shrader, Unel & Zevin, *supra* note 65, at 26.

261. Chitkara et al., *supra* note 82, at 49.

262. *Id.* at 54.

pacity costs, or just customer-related capacity costs.[263] And they can be based on ex ante or ex post peak demands, or connected demands.[264]

Including a demand charges does not automatically improve economic efficiency. As we explained in Section I.B, coincident-peak demand charges based on avoidable marginal capacity costs would provide efficient signals. But, most of the demand charges that are in use today fail to do so.

First, most of the existing residential demand charges in the United States are non-coincident peak demand charges.[265] Among different types of demand charges, this type is probably the most intuitive to consumers. But, this type of demand charge does not reflect cost causation, except for when applied to capacity costs that are specific to that consumer.[266] As we explained above, it is the system's total peak, not any individuals' peak, that drives the need for investment. Hence, non-coincident peak demand charges fall short of aligning price signals with the underlying cost drivers.

Second, the commonly used demand charges bundle all capacity costs into one charge. But, as we mentioned above, peaks of different systems, and therefore the time periods for peak coincidence, might be different. A single demand charge would fail to provide efficient signals, unless generation, transmission, and distribution peaks all coincide.

Third, to reduce uncertainty to customers, some utilities set demand charges ex ante based on anticipated peak periods. Some demand charges are based on "contracted" or "connected" demand, after which the customer's connection is interrupted, similar to internet subscriptions with different bandwidths. But, determining periods ex ante may miss the correct time of the actual system peak. And, limiting customers' use when the contract limit is reached might prevent some beneficial transactions from happening.

Overall, both the two-part tariffs with fixed and volumetric charges, and the three-part tariffs with fixed, volumetric, and demand charges that are in use today fail to satisfy the efficiency principles we outlined in Section I.B.

B. Insufficiencies of Proposed Reforms

As indicated in Section II.E, regulators and stakeholders in many states recognize the inefficiencies of current designs, and are currently considering or implementing rate design reforms. However, aside from a few exceptions, these reforms fall short of satisfying the principles outlined above. Some of these proposed reforms even undermine efficiency principles. And, while some of

---

263. *Id.*

264. *Id.* at 58.

265. *Id.* at 57.

266. *Id.*; *see also* Tong & Wellinghoff, *supra* note 243 ("[T]he only things that utilities size according to demand from individual residential customers are the final line transformers and connecting secondary lines.").

these reforms do provide improvements compared to status quo, those improvements are limited. Below, we discuss two common types of proposed reforms: time-of-use rates and demand charges.

1. *Time-of-Use Rates*

Some states are trying to improve the link between the prices and the cost drivers by increasing the temporal granularity of the rate designs. California's new default time-of-use pricing for residential customers is an example of this kind of reform.[267] Designs that are being implemented by the utilities have either two or three time periods. In addition, prices vary by seasons, as well. For example, Pacific Gas & Electric, one of California's largest utilities, has a time-of-use design with three time periods in the summer and two in the winter.[268]

But time-of-use structures typically reflect the historical variation in system costs.[269] And there is a significant mismatch between the prices consumers see and the locational marginal prices.[270] While time-of-use pricing could improve the economic efficiency of energy price signals compared to flat rates, assuming peak periods are chosen to correspond well with the periods when the marginal costs are high, this mechanism leaves significant efficiency gains on the table.[271] In fact, a recent empirical study shows that using simple peak and off-peak prices does not improve economic efficiency much.[272] The same study also shows that even though more flexible designs increase efficiency gains, even the most sophisticated time-of-use design could fail to capture half of the efficiency improvement that real-time pricing could achieve.[273]

Furthermore, a time-of-use rate with only volumetric charges for electricity use cannot properly account for all cost drivers, even though it is time-variant. In theory, having time-of-use pricing could reduce the peak demand by charging a high price during that period, and, thus, could help avoid an inefficiently high level of capacity. But such a rate would not necessarily align prices with capacity costs. As we explained above,[274] the amounts of generation, transmission, and distribution capacity costs are driven by the amount of capacity needed to meet the peak demand of each respective system. Therefore, the effectiveness of a time-of-use rate with only volumetric charges to provide eco-

---

267. Pac. Gas & Elec. Co., *supra* note 26.

268. *Residential TOU Rates*, PAC. GAS & ELEC., https://perma.cc/VU67-DVLF (presenting a downloadable spreadsheet of current TOU rates).

269. CHITKARA ET AL., *supra* note 82, at 19.

270. PÉREZ-ARRIAGA & KNITTEL, *supra* note 55, at 88.

271. *Id.*

272. Mark R. Jacobsen et al., *The Use of Regression Statistics to Analyze Imperfect Pricing Policies*, J. POL. ECON. (forthcoming) (manuscript at 28–30).

273. *Id.*

274. *See supra* text accompanying notes 68–72.

nomically efficient signals for capacity installation would depend on whether the peaks for generation, transmission, and distribution systems occur in the same time period.

If the peak demand for the distribution network occurs at a different time period than either the generation or transmission systems' peaks, as is usually the case,[275] then a bundled time-of-use rate would fall short of providing economically efficient incentives. Some regulators might opt for longer time periods when designing the time-of-use rates to make sure that the duration of the most expensive period of design covers all the peaks to avoid this potential problem. But having longer time periods limits consumers' ability to shift their demand away from the peak period, hindering the effectiveness of the design. Finally, these designs lack the flexibility of real-time pricing to quickly respond to changing peak periods with changing resource mix and consumption patterns.

2. Demand Charges

Other states are trying to improve the link between the prices and the cost drivers by introducing demand charges to price capacity, especially for the owners of DERs.[276] With flat rates, utilities recovered their capacity costs through predictable revenues from volumetric charges, but advances in the energy sector like energy efficiency and DERs are leading to fewer kWhs sold by utilities, creating revenue instability. As a result, these demand charges are driven mostly by utility concerns about revenue sufficiency and stability, rather than concerns about providing economically efficient price signals for capacity. Consequently, many of these charges implemented in recent reforms are based on an individual's own maximum demand to provide a consistent revenue stream for the utilities.[277]

However, as we explained above, a consumer is causally responsible based on the consumer's maximum demand that is *coincident* with the system peak.[278] A demand charge based on an individual's own maximum demand, a non-coincident peak demand charge, is "illogical." In addition, because the peaks for generation, transmission, and distribution systems might be different, a single, generic demand charge is not a sufficient price signal. In other words, these proposed reforms are not sufficient to provide socially efficient signals.

---

275. *See* CHITKARA ET AL., *supra* note 82, at 59 (showing an example of a typical load graph with different peaks).

276. *See* ENERKNOL, *supra* note 248 (providing a list of states that are discussing implementing demand charges).

277. Tong & Wellinghoff, *supra* note 243 ("The [demand charges] being proposed for residential customers typically involve monthly fees based on one's highest average usage (measured in kilowatt or kW) over a certain time interval (e.g., 15 minutes) in a given billing period.").

278. KAHN, *supra* note 16, at 95–96.

Another limitation with the current reforms is that they sometimes impose charges of this sort only on DER owners. But, there is no logical reason to single them out in this way. While the actual price levels for each component would be different for DER owners than for other consumers because the levels of costs they impose or avoid would be different, having different rate structures for DER and non-DER customers would distort the marginal incentives, potentially harming economic efficiency.

Even though the reforms are generally trying to improve the alignment between the prices and the cost drivers, not one of them considers externalities explicitly; they do so only to the extent that compliance costs with state environmental programs are included in the marginal cost of electricity generation. But, given that no state or regional carbon pricing program comes close to pricing emissions at the level of the actual damages, the resulting marginal costs are still lower than the social marginal cost. Thus, without an explicit consideration of externalities, rate designs will fail to induce economically efficient outcomes.

Finally, despite all the talk about grid modernization and "the utility of the future," almost all the reforms suggested are focused on short-term goals. Some designs are based on the potential for short-run bill savings,[279] and not long-term avoided societal cost savings, even though the main benefit of more efficient pricing would indeed be the longer-term cost savings associated with avoided capacity investments. Furthermore, designs are decided based on past patterns and costs and are not flexible, even though the actual peaks change from year to year based on technological advances and resource mix changes. But, utilities still have difficulty accurately predicting the actual peak days.[280] And, without a flexible, forward-looking, technology-neutral framework for structuring rates, it is not possible to realize the promises of the "utility of the future."[281]

C. The Modern Grid and the Increasing Need for Advanced Rate Design

As shown in Part II, the same core questions of how to price electricity and the tension between academic prescriptions and policymaker priorities existed since the time when Thomas Edison opened the first power plant. The passage of time has not led to much progress. And today, once again, the elec-

279. N.Y. State Dep't of Pub. Serv., No. 16-M-0430, 10 (2018), https://perma.cc/5G6E-ZRWV (staff guiding instructions to utilities and stakeholders on the approach and implementation of mass market rate reform and bill impact analysis).

280. Chitkara et al., *supra* note 82, at 33 (showing that only 42% of the peak days Pacific Gas & Electric predicted for critical-peak pricing, in which customers are charged high prices during certain "critical event" days when the system costs are especially high, between 2009 and 2011 aligned with the actual peak days during that time).

281. Pérez-Arriaga & Knittel, *supra* note 55.

tric industry is debating rate design reforms. But the industry now is perhaps riper than ever to move forward with these reforms due to a confluence of factors.

First, new technology such as DERs, smart meters, and smart appliances created an unstoppable momentum for grid transformation. Not only do today's electric consumers have an unprecedented control over their electricity use as a result of smart appliances, they can also simultaneously be consumers and producers of electricity because of DERs. And, because the commonly used policies for new technologies, such as net metering, rely on retail rates in many jurisdictions to compensate consumers for their grid injections, retail rates have a significant effect on users' installment and operation decisions.[282] Similarly, the deployment and the use of electric vehicles, which can provide multiple services to the grid in addition to their transport functionality, depend heavily on rate design.[283] Rates that lack the structure needed to granularly reflect the true value of electricity provision at a particular time and location, including its capacity and externality value, are likely to distort signals for investment, and as a result, fall short of resulting in DER investment that would create the highest net benefits to society overall. For example, net metering with flat volumetric rates, which reflect average costs, might over-incentivize DERs at certain location, while under-incentivizing in others. Thus, the consequences of inefficient retail rates for advancing new technologies is becoming more apparent. Many regulators and industry stakeholders now see rate design, however contested it might be, as an important tool for integrating DERs and transitioning to a smarter grid.[284]

Second, as the nation started to see the direct and costly consequences of climate change with the more frequent occurrence of crippling hurricanes, floods, and wildfires, the environmental consequences of electricity generation

---

282. *See* Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 103 (explaining that such designs would incentivize the solar panel installations to face the direction that would maximize generation when electricity is most beneficial to the grid); *see also* RICHARD BOAMPONG & DAVID P. BROWN, ON THE BENEFITS OF BEHIND-THE-METER ROOFTOP SOLAR AND ENERGY STORAGE: THE IMPORTANCE OF RETAIL RATE DESIGN (2018), https://perma.cc/G7DS-A7MB (explaining how rate design affects investment and operation decisions, as well as system benefits, of rooftop solar and energy systems); Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*, *supra* note 7, at 178–79 (explaining how improving rate design would also increase incentives for energy storage).

283. *See* S. Küfeoğlu et al., *Understanding Tariff Designs and Consumer Behavior to Employ Electric Vehicles for Secondary Purposes in the United Kingdom*, 32 ELECTRICITY J. 6, 1 (2019); *see also* SATCHWELL ET AL., *supra* note 95, at vi (discussing the variation in rate designs for electric vehicles).

284. *See* Herman K. Trabish, *Beyond TOU: Is More Dynamic Pricing the Future of Rate Design?*, UTIL. DIVE (July 17, 2017) [hereinafter Trabish, *Beyond TOU*], https://perma.cc/XAP2-SBP4; Herman K. Trabish, *True Value: To Get to Tomorrow's Grid, DER Grid Services Must Be Compensated Right Today*, UTIL. DIVE (Oct. 1, 2018), https://perma.cc/74QC-WZ2F.

and consumption, and how to mitigate them, became an even more important policy question. Given the lack of sustained federal action on climate change, many states started taking action with ambitious targets and mandates on clean electricity, various renewable resources, DERs, as well as energy efficiency and demand response programs. But not much consideration has been given to whether these piecemeal policies are cost-effective when analyzed as an overall portfolio, or whether they are truly addressing the structural inefficiencies embedded in the grid. As a result, many stakeholders, both at the state and federal level, are urging a technology-neutral way of providing price signals to address externalities caused by air pollution as part of energy policies. And rate design reforms provide such a technology-neutral solution to these challenges.

Finally, as our discussion in Part II shows, almost 140 years of history suggest that the same debates are bound to be repeated, over and over again, unless we fundamentally change the rate design paradigm. Perhaps because of the unforeseen new uses for electricity or the rapid advances in technology, the electric industry has evolved and transformed itself at a speed that regulators cannot keep up with. And, at each juncture, the sector grappled with similar discussions about why rate designs of that day were inefficient and harmful to progress, and why there was a need for better, more cost-reflective, and more efficient designs. Given that there is no end in sight to the progress in energy technologies and that even academic engineers are still debating the future architecture of the grid, it is even more difficult today to correctly forecast how the grid will look in the future and design technology-specific policies that will work well in that future. We do not know when the peak period is going to be in the next decade to be able to set a time-of-use rate, or what technology will dominate to set a technology-specific target. Thus, a technology-neutral framework that can provide economically efficient consumption and production signals by showing the true value of electricity to the society in a time-, location-, and demand-variant basis, regardless of the mix of realized technologies, seems like the only rational way forward at this crucial juncture.

IV. Stakeholder Positions on Rate Design

The economic guidance on rate design has always been clear: efficiency is closely tied to marginal cost. However, despite the clarity of the economic guidance on this starting point for policy debates on rate design, even at this juncture, policymakers have been hesitant to thoroughly consider better rate designs, mostly due to various arguments that have been brought up in the debates by different stakeholders: utilities, consumer advocates, and clean energy advocates. The arguments of these stakeholders carry significant weight in regulatory proceedings. But many of these arguments are misperceptions and are not supported by economic research.

One common argument that is often brought up by various stakeholders is that electricity customers do not respond to more dynamic designs.[285] However, there has been ample evidence in the economics literature over the years that show that customers do indeed respond to the prices.[286] One review of past studies shows that customers really respond to peak price signals, with a reduction in peak demand in the range between 13% and 20%.[287] Other studies show that if there is accompanying technology, the customer response is even higher.[288] And, as customers learn how to better manage their load, they benefit more.[289]

One of the sources of this misperception might be that the demand for electricity is inelastic.[290] Inelasticity means that a 1% increase in price leads to less than a 1% decrease in consumer demand.[291] Using the economics nomenclature, electricity consumers are considered to not be very responsive to price changes. However, the fact that electricity is price inelastic does not mean the response to price changes is zero; it just means that the response is low. But a low consumer response could still lead to economically significant changes. Be-

285. Ahmad Faruqi & Jenny Palmer, *Dynamic Pricing and Its Discontents*, 34 REG., Fall 2011, at 16, 18.

286. *See, e.g.*, Allcott, *supra* note 85, at 823 (2011) (showing that consumers responded to a move to real-time pricing by conserving energy during peak times, without increasing consumption during off-peak times); Ahmad Faruqui & Stephen George, *Quantifying Customer Response to Dynamic Pricing*, 18 ELECTRICITY J. 53, 62 (2005) (showing that residential, commercial, and industrial customers conclusively reduced peak period electricity use in response to time varying pricing in California); Ahmad Faruqui & J. Robert Malko, *The Residential Demand for Electricity by Time-of-Use*, 8 ENERGY 781 (1983) (explaining that even back in 1983 when there was not sufficient technology to easily respond, residential customers responded to prices in twelve different experiments, with an estimated short-run price elasticities in the range of zero to _.045); Faruqui et al., *supra* note 175, at 64–72 (noting that time-of-use rates lower customer's usage in peak periods, leading to lower average wholesale prices); Frank A. Wolak, *Do Residential Customers Respond to Hourly Prices? Evidence from a Dynamic Pricing Experiment*, 101 AM. ECON. REV. 83, 87 (2011) (showing that it is not costly for customers to take action to reduce their consumption).

287. Ahmad Faruqui & Sanem Sergici, *Household Response to Dynamic Pricing of Electricity*, 38 J. REG. ECON. 193, 221 (2010).

288. *Id.*; *see also* Steven Braithwait, *Residential TOU Price Response in the Presence of Interactive Communication Equipment*, *in* PRICING IN COMPETITIVE ELECTRICITY MARKETS 359 (Ahmad Faruqui & Kelly Eakin eds., 2000); Ahmad Faruqui et al., *The Power of Dynamic Pricing*, 22 ELECTRICITY J. 42, 56 (2009); Ahmad Faruqui & Sanem Sergici, Arcturus*: International Evidence on Dynamic Pricing*, 26 ELECTRICITY J. 55, 56 (2013); Ahmad Faruqui & Sanem Sergici, *Dynamic Pricing of Electricity in the Mid-Atlantic Region: Econometric Results from the Baltimore Gas and Electric Company Experiment*, 40 J. REG. ECON. 82, 104 (2011).

289. Thomas N. Taylor et al., *24/7 Hourly Response to Electricity Real-Time Pricing with up to Eight Summers of Experience*, 27 J. REG. ECON. 235, 257 (2005).

290. Mark G. Lijesen, *The Real-Time Price Elasticity of Electricity*, 29 ENERGY ECON. 249, 251 (2007) (showing all but one recent estimates of price elasticities less than one).

291. KRUGMAN & WELLS, *supra* note 30, at 149.

cause a large portion of the cost of providing electricity comes from capacity costs, even a minimal reduction in peak demand could lead to high efficiency gains for society. For example, according to one study, even a reduction of 5% of peak demand would lead to $3 billion savings in one year, and $35 billion over two decades.[292] Furthermore, as climate change increases the frequency and the intensity of extreme weather events, both the average and the peak electricity demand are estimated to increase significantly. The additional costs are estimated to be up to $180 billion a year.[293] Therefore, even the inelasticity of electricity demand is a misleading argument for the resistance to move forward with rate design reforms.

In addition to this common argument, each stakeholder makes different arguments in the debate. It is, of course, expected that stakeholders in regulatory proceedings advance arguments that further their own, private interests. And, it can be difficult for regulators to take a step back from these arguments to figure out which arguments are valid and would lead to socially beneficial solutions, especially when the proceedings are contested. Therefore, using an economic foundation is helpful to identify the arguments that are most beneficial to society as whole, and therefore that should be adopted by the regulators.

A. Utilities

Utilities, in general, have been open to several variants of more time-variant volumetric charges including time-of-use pricing, critical-peak pricing, and real-time pricing. They have also been increasingly advocating for demand charges either as a complement or as a substitute for these volumetric rates.

As we summarized in Part II, utilities have especially been spurred to research dynamic pricing starting with PURPA,[294] which required them to consider new types of rates, including dynamic rates, but left the adoption to the utilities' discretion.[295] And, more recently, the federal government has supported and provided monetary backing for utility trials to integrate smart meters into tests of real time pricing structures.[296] As a result, many utilities across

292. Ahmad Faruqui et al., *The Power of 5 Percent*, 20 ELECTRICITY J. 68 (2007).

293. *See, e.g.*, Maximilian Auffhammer et al., *Climate Change Is Projected to Have Severe Impacts on the Frequency and Intensity of Peak Electricity Demand Across the United States*, 114 PROC. NAT'L ACAD. SCI. 1886 (2017).

294. *See* Public Utility Regulatory Policies Act of 1978 (PURPA), Pub. L. No. 95-617, 92 Stat. 3117 (codified as amended in scattered sections of titles 15, 16, 42, and 43 U.S.C.).

295. *See* 16 U.S.C. § 2622(b) (2018) (showing PURPA mandated that "each State regulatory authority . . . and each nonregulated electric utility shall commence the consideration" of cost of service, declining block rates, time-of-day rates, seasonal rates, interruptible rates, and load management techniques, among other standards, but did not require that these bodies adopt anything they considered).

296. *See* Joskow & Wolfram, *supra* note 250, at 382–84 ("The federal government has provided significant incentives for utilities to adopt 'smart grid' policies, including smart meters and variations on real-time pricing.").

the country have been experimenting with various types of rates. As of 2017, utilities in all fifty states and Washington D.C. offered some form of time-variant rate, with Montana being the only state without a residential time-variant rate.[297]

A white paper about time-varying rates from Edison Electric Institute, an association of U.S. shareholder-owned electric companies, determined that time-varying rates have benefits for both utilities and customers, but that the extent of that benefit varied depending on which time-varying rate was implemented.[298] The white paper concluded that time-varying rates provided many benefits such as reductions to a customer's bill and "avoided capacity costs, avoided energy costs, avoided [transmission and distribution] costs, and reduced wholesale market prices" for the utilities.[299] It also showed that simple time-of-use rates were less efficient and provided fewer benefits than the more granular real-time pricing, because time-of-use rates do not reflect the actual price of energy like real-time pricing does, and therefore, they give less accurate price signals to customers, leading to inefficiency.

Despite this finding, however, many utilities are still resistant to real-time pricing,[300] perhaps because they think that real-time pricing may be too complicated for customers to respond to or understand without advanced technology,[301] or because they are worried that "real-time pricing will be implemented in a way that leaves them with a revenue shortfall."[302] Since ComEd and Ameren developed real-time pricing rates for residential use, no other utilities in Illinois have adopted this rate design, preferring to use other forms of time-variant pricing models instead.[303]

Utilities might also be concerned about the low adoption rates. Customer participation in ComEd and Ameren's programs in Illinois is low.[304] One possible explanation is that the Illinois programs are opt-in.[305] But, despite low rates

297. EIA DATA, *supra* note 213 (showing time-varying rates include time-of-use, real-time, variable peak, critical peak, and critical peak rebate pricing).

298. EEI DYNAMIC PRICING, *supra* note 81, at 42.

299. *Id.* at xi.

300. STAR, DYNAMIC PRICING, *supra* note 227, at 2-257 (stating that the United States has very few real-time pricing programs); *see also* EEI DYNAMIC PRICING, *supra* note 81, at 42 (discussing that time-of-use rates have been widely deployed in the United States for thirty years).

301. MARY KLOS, WHY REAL-TIME PRICING IS BETTER THAN OTHER DYNAMIC PRICING RATES (2013), https://perma.cc/4FMV-H2GV (explaining that real-time pricing is considered risky and too complicated to understand for residential customers).

302. Borenstein, Jaske & Rosenfeld, *supra* note 192.

303. CHITKARA ET AL., *supra* note 82, at 18.

304. STAR, DYNAMIC PRICING, *supra* note 227, at 2-257 ("As of early 2010, the program sizes . . . approached 1% of households for PSP, and 0.25% of households for ComEd [residential real-time pricing] (participants numbering 9,133 and 9,040, respectively).").

305. *Id.* at 2-258–60.

of adoption, real-time pricing also has low attrition rates, signaling that customers who do have these rates are satisfied with them.[306]

Utilities, especially in deregulated states, tend to advocate for inclusion of a demand charge in their rate designs.[307] They find demand charges appealing "because they see [them] as providing a more certain way to cover flat or declining revenues."[308] The leading consultants for the utilities on the topic generally favor a three-part rate for utilities that has a fixed customer charge, a per-kW demand charge, and a per-kWh energy charge. As Ahmad Faruqui explains, "[d]ynamic pricing or another form of time-varying rate would be used for energy costs. Fixed and demand charges would address capacity costs."[309]

Utilities now see these demand charges as a means to ensure that they can recover the costs they have incurred. They argue that they "better reflect . . . a customer's actual use of the grid and contribution to system costs," and that these charges will make rate design more efficient while giving utilities more stable revenues.[310] As a result, despite not using demand charges for residential customers in recent history, utilities are now in favor of residential demand charges. They believe that moving away from a rate design that depends on usage to recover the costs of peak capacity to a demand charge can help alleviate cost recovery concerns.[311]

---

306. *Id.* at 2-262 (Ameren's PSP had a lower than 1% voluntary attrition rate after the mandatory 12-month period; ComEd's real-time pricing percent attrition is not given).

307. *See, e.g.*, Minn. Xcel, No. E002/M-17-775, Redline at Attachment F p. 5 (Nov. 1, 2017) (petition on northern states power company for approval of a time of use rate design pilot program); Distributed Energy Res. Working Grp. Regarding Rate Design, N.Y. Dep't Pub. Serv., No. 17-01277 (2018) (explaining the New York's join utilities' rate design would not be a pure time-of-use plan but rather would include "a fixed customer charge, and non-coincident peak (NCP) and coincident peak (CP) demand charges"); Pac. Gas & Electric Co., Pub. Util. Commission of State of Cal. (2018), https://perma.cc/B8YR-TWT9 (explaining that the utilities' time of use proposal has been accepted, but that there is pending discussion and protests over the fixed rate and monthly minimum aspects of their rate design); Press Release, Colo. Dep't of Reg. Agencies, PUC Approves Settlement Resolving Three Major Xcel Energy Cases (Nov. 9, 2016), https://perma.cc/SMG3-S2Z7 (detailing the settlement agreement that eliminates Xcel's fixed monthly grid charge and develops a pilot program for residential time-of-use rates ahead of a statewide rollout).

308. Trabish, *Rate Design Roundup*, *supra* note 6.

309. Trabish, *Beyond TOU*, *supra* note 284.

310. Jeff St. John, *What's the Role for Demand Charges in Modern Rate Design?*, GREENTECH MEDIA (Feb. 8, 2018), https://perma.cc/HVL7-QFN6 (explaining that utilities were very enthusiastic about demand charges despite other groups hesitance or disapproval of these charges).

311. Herman K. Trabish, *Is a Residential Three-Part Rate the Way to a Modern Grid or Bad News for Utility Customers?*, UTIL. DIVE (Mar. 13, 2018), https://perma.cc/E2E5-HNNQ (explaining that utilities are looking for rate design tools that will help them recover revenues without needing to sell more kWh, while also incentivizing customers to move their load off system peak, so that utilities will not have to build more infrastructure to accommodate an increased peak).

In theory, these arguments for demand charges align with the principles we outlined in Part I. However, in practice, not all demand charges are beneficial. Most demand charges that are in place today are non-coincident peak demand charges. Under these schemes, what a customer has to pay depends on the customer's own maximum rate of use, regardless of when that may be. But, as we explained above, demand during times that do not coincide with system peaks do not contribute to capacity costs, except for the last part of the distribution network that is dedicated to the individual customer. Doing laundry, washing dishes, and cooking all at the same time on a Sunday afternoon in winter would not contribute to additional capacity needs, while doing the same in the afternoon on the hottest day of the year would. So, if utilities' goals are really to "better reflect contribution to grid costs," non-coincident peak demand charges are not warranted to cover anything beyond the avoidable, customer-specific, capacity costs.

B. Clean Energy Advocates

The current position of clean energy advocates is a balancing act. On the one hand, they favor time-variant pricing because of its potential to increase the demand for the use of cheaper electricity from renewable energy resources.[312] On the other hand, depending on how it is implemented, time-variant pricing can potentially have a negative effect on the deployment of some of the DERs that rely on net metering policies, such as solar panels.[313] As a result, clean energy advocates generally exercise caution with respect to more advanced rate designs.

Clean energy advocates, of course, prefer rates that give consumers price signals that encourage energy use during times of high renewable production.[314] For example, if low-price periods correspond to when clean energy resources is on the margin and high prices correspond to when fossil-fuel generation is on the margin, time-variant pricing can incentivize consumers to move their use away from fossil fuels to cleaner energy, and reduce emissions as a result. But, in the opposite scenario, time-variant prices would shift the demand to time periods with fossil fuel generators on the margin and lead to higher emissions. Therefore, clean energy advocates might not prefer dynamic rates, especially if externalities are not fully reflected in the rate design.

Also, depending on how time-variant rates affect DER compensation, they could discourage consumers from investing in DERs that rely on net me-

312. John T. Colgan et al., Guidance For Utilities Commissions On Time Of Use Rates 4, 21 (2017).

313. *Id.* at 15.

314. *Id.* at 21 (explaining that, from an emissions perspective, it might be wiser to encourage load shifting to times where there are high levels of renewable energy available as opposed to times when the system is at its lowest load).

tering. The fact that many states still rely on net metering as a way to compensate DERs' injections is one of the main reasons clean energy advocates are in favor of keeping flat rates in place. Because the level of compensation in net metering depends on the underlying rate design, time-variant pricing may result in reduced compensation for energy sent back to the electricity grid at certain times.[315] If low-price periods correspond with times when consumers are sending their excess generation to the grid, DER compensation will be lower, and that might reduce the incentives for solar panels. As a result, rate design heavily affects how attractive DER is as an investment, and, hence, its deployment.[316]

To allay this concern, clean energy advocates try to protect the status quo for solar panel owners. For example, they favor grandfathering existing customers in net metering, while moving the rest of the electricity customers and new adopters of DERs to time-of-use rates.[317] Such a balanced position allows them to still advocate for advanced rate designs, while not harming the stability of existing DER markets.

While worrying about investment signals for DERs is important for economic efficiency, and this worry in fact is one of the reasons that we have been arguing for better policies in our "Managing the Future of the Electricity Grid" series, it is important to distinguish between just increasing the level of DER investment and increasing the level of socially efficient DER investment. Arguing for the status quo of two-part tariffs with flat volumetric rates, or with minor modifications such as volumetric time-of-use rates with peak periods to correspond to the peak solar generation, just to protect the investment incentives for any DERs such as solar panels, energy efficiency, and energy storage, regardless of the underlying benefits, might indeed be harmful to economic efficiency and to the future of the grid.

For example, increased solar penetration might impose other costs to increase the flexibility of the system to respond to changing solar generation, especially when the sun is setting.[318] California's experience indeed confirms the need for flexibility to compensate for the rapidly decreasing solar generation as the sun sets.[319] Furthermore, research shows that there is significant locational variation in the benefits of solar panels, including the externalities from air pollution, supporting regulatory initiatives that try to match compensation to the

---

315. Letter from S. Envtl. Law Ctr. to Comm'r Travis Kavulla, President, Nat'l Ass'n of Regulatory Util. Comm'rs (Sept. 2, 2016), https://perma.cc/7H6J-THBR.

316. *See* COLGAN ET AL., *supra* note 312, at 15.

317. *See* Letter from S. Envtl. Law Ctr., *supra* note 315.

318. *See* Richard Schmalensee, *The Future of Solar Energy: A Personal Assessment*, 52 ENERGY ECON. S142, S145 (2015).

319. *See* CAL. ENERGY COMM'N, TRACKING PROGRESS, RESOURCE FLEXIBILITY 1–2 (2019), https://perma.cc/VTU6-KKQZ (explaining the need for flexibility due to the shape of the net load curve).

underlying value.[320] Research also shows that untargeted energy efficiency can indeed be economically inefficient because it misaligns incentives,[321] and that targeted energy efficiency based on the time-varying value is more helpful.[322]

In addition, just trying to increase the level of DERs without considering the effects of increased penetration as a whole might indeed lead to outcomes that are contrary to the goals of clean energy advocates. For example, research shows that energy storage, which is usually believed to be helping reduce greenhouse gas emissions, could increase emissions because of the incentives created by retail rate design.[323] Indeed, energy storage increased emissions in California in both 2016 and 2017.[324] And, as a result, the California Public Utility Commission had to establish a "Greenhouse Gas Signal Working Group" to try to figure out how to provide correct incentives to energy storage to reduce emissions, instead of increasing them.[325]

But, as we outlined in Part I, the goal of economic efficiency is not to reduce total consumption at any cost, or to induce investment of any one technology that is thought to be beneficial at any cost. Rather, it is to reduce consumption only if the marginal benefit is actually less than the social marginal cost, and to induce investment if the marginal benefit is actually higher than the social marginal cost. Arguing for an increase in energy efficiency mandates or arguing for increased deployment of DERs without considering the underlying costs and benefits, as most clean energy advocates do, might lead to outcomes that are contrary to their goals and that harm economic efficiency. In contrast, the principles we outlined in Part I would indeed help transition to clean energy economy by providing the right price signals for efficient deployment of clean energy resources, as well as DERs, where they can be most beneficial and in a manner that would reduce emissions.

---

320. Parth Vaishnav et al., *Was It Worthwhile? Where Have the Benefits of Rooftop Solar Photovoltaic Generation Exceeded the Cost?*, 12 ENVTL. RES. LETTERS, no. 094015, 2017, at 11 ("Our analysis lends support to regulatory initiatives that more closely match the value of electricity at a particular time and place to the compensation offered distributed generators, while also expanding access across socioeconomic strata (e.g. by supporting community solar).").

321. *See* Meredith Fowlie et al., *Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program*, 133 Q.J. ECON. 1597 (2018).

322. NATALIE MIMS ET AL., LAWRENCE BERKELEY NAT'L LAB., TIME-VARYING VALUE OF ELECTRIC ENERGY EFFICIENCY, at vii (2017), https://perma.cc/6Q4B-L6G4; *see also* Andrew Campbell, *Redirecting Energy Efficiency Policies for the Climate*, ENERGY INST. AT HAAS: ENERGY INST. BLOG (Aug. 5, 2019), https://perma.cc/72TA-UYEU.

323. Megan Geuss, *Under Current Policies, Residential Batteries Increase Emissions in Most Cases*, ARS TECHNICA (Dec. 28, 2018), https://perma.cc/5EQL-SQR2 (explaining how energy storage can increase emissions because of rate design).

324. ITRON, 2016 SGIP ADVANCED ENERGY STORAGE IMPACT EVALUATION (2017), https://perma.cc/NA3J-GW8Y; ALT. ENERGY SYS. CONSULTING, SGIP GHG SIGNAL WORKING GROUP FINAL REPORT (2018), https://perma.cc/2KQL-NMU5.

325. Peter Maloney, *California's BTM Energy Storage Moves Forward, But Is it Good for the Climate?*, UTIL. DIVE (Sept. 4, 2018), https://perma.cc/Z72N-JXPS.

C. Consumer Advocates

Consumer advocates tentatively favor improving rate designs, but they generally worry that low-income consumers will be negatively affected. Equity and distribution concerns lie at the heart of their position. They argue that low-income consumers generally lack the ability to respond to more sophisticated designs, and therefore, that they are likely to be harmed by such designs. One main concern is that such consumers tend to use comparatively little electricity, and therefore may have "less discretionary load to shift than higher income customers," and because they are already only using electricity when necessary, they may not have the ability to move the hours of their usage.

The Utility Reform Network, a non-profit consumer advocacy organization has voiced a concern in California "that dynamic pricing inflicts harm on low-income consumers, seniors and people with disabilities who stay at home a lot, people with medical conditions that require special electrical equipment, people with young children, and small businesses" and that "these consumers are unable to curtail peak period usage, in part because they have very little load to begin with."[326] Because these consumers do not use much electricity, they are unlikely to be able to cut their usage or move usage to off-peak hours without giving up necessities. Instead, in California, the organization advocates for tiered rates.[327]

Under *tiered rates* (also called *increasing-block rates*), the price increases with tier of usage.[328] Customers who use little electricity pay the lowest volumetric rates, and this volumetric charge increases if customers use more electricity.[329] The belief underlying this support is that it benefits low income users.[330] But, this design does not have any relation to underlying costs.[331]

Furthermore, the support for this type of rate design rests on two assumptions: that low-income customers are also low energy users, and that low-users of electricity do not impose high costs on the society.[332] But, neither of those assumptions is always correct. First, there is no conclusive evidence that low-income customers are also low energy users. Indeed, based on rounds of testimony and analysis, the California Public Utilities Commission "decline[d] to conclude that rate design proposals that impact low-usage customers necessarily impact low-income and moderate-income ratepayers on a class-wide basis,"

326. Ahmad Faruqui, *The Ethics of Dynamic Pricing*, 23 ELECTRICITY J. 13, 17 (2010).

327. Herman K. Trabish, *An Emerging Push for Time-of-Use Rates Sparks New Debates About Customer and Grid Impacts*, UTIL. DIVE (Jan. 28, 2019), https://perma.cc/JHM7-Y3RS.

328. *Id.*

329. *Id.*

330. Severin Borenstein, *Effective and Equitable Adoption of Opt-In Residential Dynamic Electricity Pricing*, 42 REV. INDUS. ORG. 127, 137 (2012).

331. *Id.*

332. Trabish, *supra* note 327.

even if there might be a general positive correlation between income and usage.[333] Second, as the principles in Part I indicate, usage patterns significantly affect cost consequences. Even a low-energy user can impose significant costs to the society if that use is all concentrated in the system peak period. This use might especially be consequential for society if that period is also the most emission-intensive. Therefore, distorting the price signals for social principles might indeed lead to the perverse result of increasing the costs for everyone, including low-income customers.

General concerns about the effects of more sophisticated designs on low-income customers were echoed by a group of consumer and clean energy advocates from the U.S. Public Interest Research Groups ("PIRG"), which proposed dynamic rates that would still provide price signals for customers to lower usage while not penalizing those who are unable to.[334] PIRG argued that time-of-use rates with long daytime, on-peak hours "are burdensome to stay-at-home seniors, and others who have high and somewhat inflexible daytime usage."[335] It maintained that when an on-peak time is too long, customers may stop responding to it as an incentive to shift load because it would not make a difference if they used electricity as usual or waited a few hours. In either event, the customers would still be charged the peak-time rate.[336]

Instead, PIRG suggested avoiding a design where all daytime hours are on-peak, with fewer time periods where the rates change, and pricing differences that are high enough to shift demand but that are not extreme.[337] In this proposal, the choice of when to have the on-peak periods, and the price differential, would depend on grid conditions. According to PIRG, designing rates in this way would serve the dual purpose of preventing high bills for customers who are unable to shift their daytime usage by limiting the number of daytime hours at peak pricing while also more accurately aligning time-of-use rates to system costs. And, the shorter peak period would give customers an opportunity to respond without fatiguing them from a long on-peak time. PIRG also argued that the limited number of time periods makes this rate design easier to understand as well.[338]

Concerns over the effect of more dynamic rate designs on those who do not have the ability to change their consumption easily or budget for unex-

333. Pac. Gas & Elec. Co., *supra* note 26.

334. *See* COLGAN ET AL., *supra* note 312, at 10.

335. *Id.*

336. Trabish, *Rate Design Roundup*, *supra* note 6.

337. *See* COLGAN ET AL., *supra* note 312, at 33–34 (PIRG's suggestion for utilities is to keep time-of-use "rate design to a relatively few time periods (e.g. 2–3) that are well-synced with underlying system costs; ensur[ing] the pricing differences are appropriate; and consider[ing] closely the length of the on peak price period to facilitate customer adoption and load response").

338. *Id.*

pected bills have frequently led to a schism between consumer and clean energy advocates. This schism is frequently highlighted by utilities or libertarian groups, which "rais[es] questions about the[] underlying motivations" of groups advancing such arguments.[339]

As a result, consumer groups and clean energy advocates have become concerned about how their arguments are presented. For example, New York's consumer advocates jointly filed with environmental groups to avoid having third parties control the narrative.[340] They wanted to ensure that environmental progress would not be seen as coming at the expense of low-income consumers, and that the interests of low-income consumers would not be assumed to be in conflict with the positions of environmentalists during New York's Reforming the Energy Vision ("REV") proceedings.[341]

One of the main points of consumer groups was for the "Commission to give considerably more thought to how to integrate low-income affordability and the broader goals of the REV proceeding, by providing more funding for low-income efficiency programs."[342] The consumer advocates wanted to give low-income consumers the same choices about their electricity consumption that higher-income consumers with larger discretionary spending have. While acknowledging that dynamic energy pricing could negatively affect consumers who already contribute a significant portions of their income to electricity, consumer advocates still want to discuss and find ways for time-variant pricing to benefit all consumers. For example, in New York, customer advocates recommended that the state look at creative solutions that will give "low-income people a choice in where their electricity comes from [while] reducing their utility costs."[343]

A corollary to the argument that low-income consumers lack the ability to respond to price changes is that if such consumers cannot shift their consumption to respond to higher price signals, they might end up with large monthly variations in their bills. And, because low-income households might not have the budgetary flexibility to accommodate an unexpected expenditure, they might not be able to pay their bills. Therefore, these households may not "necessarily [be] benefited if the *average* annual electricity bill is lower" if some months are higher than average and are just balanced by lower than average

339. Shelley Welton, *Clean Electrification*, 88 U. Colo. L. Rev. 571, 575 (2017).

340. Shelley Welton, *Grid Modernization and Energy Poverty*, 18 N.C. J.L. & Tech. 565, 571–72 (2017) ("There is a significant risk that the challenges of grid modernization may splinter groups working on causes frequently cast together . . . those struggling for a cleaner environment, and those struggling against persistent and deepening inequality . . . [but in New York] environmentalists and social justice organizers have staunchly stood together, insisting in joint filings that their causes not be . . . pitted against one another.").

341. *Id.* at 572.

342. *Id.* at 599.

343. *Id.* at 599–600.

months.[344] So, advocates argue that low-income consumers might be harmed by dynamic designs if the monthly swings in bills are high enough. In fact, these concerns have led to cancellation of a time-of-use pilot in one state, before data on the effect of these rates could even be collected.[345]

As a result, the move towards real-time pricing has been hindered by the concern that it gives rise to too much risk, without corresponding benefits.[346] However, research shows that a simple hedging strategy that allows customers to purchase some electricity earlier at pre-determined prices to avoid volatile spot prices can eliminate more than 80% of the bill volatility that would otherwise occur for large customers.[347] And, a similar hedging plan could help residential customers as well.[348]

One final worry of consumer advocates is that the technology that makes time-variant pricing easier to take advantage of is expensive and low-income customers cannot afford such technology.[349] Consequently, advocates worry that the economic benefits of such designs will be realized only by customers who have the means to invest in necessary technology, monitor energy prices, and shift their load to times with lower prices while leaving customers who are unable to shift their load with higher and more volatile energy bills than before.[350] And, that result would be inequitable.

However, this view of inequity is an incomplete view. The perception that real-time pricing would be "unfair" rests on the idea that prices at certain times will be high, and that will lead to inequitable outcomes for customers who consume more during those hours. But, this argument about the unfairness of dynamic prices rests on the assumption that current prices are fair.[351] And, today's flat rates already embed many cross-subsidies. For example, consumers

---

344. BARBARA ALEXANDER, SMART METERS, REAL TIME PRICING, AND DEMAND RESPONSE PROGRAMS: IMPLICATIONS FOR LOW INCOME ELECTRIC CUSTOMERS 15 (2007), https://perma.cc/E494-BD4E.

345. Iulia Gheorghiu, *Colorado Regulators Cancel Black Hills Energy TOU Pilot Amid Concerns for Low-Income Customers*, UTIL. DIVE (July 17, 2019), https://perma.cc/XVP4-XJDK.

346. Ahmad Faruqui & Melanie Mauldin, *The Barriers to Real-Time Pricing: Separating Fact from Fiction*, 140 PUB. UTIL. FORT. 3, 3 (2002).

347. Severin Borenstein, *Customer Risk from Real-Time Retail Electricity Pricing*, 28 ENERGY J. 111, 111 (2007).

348. Borenstein, Jaske & Rosenfeld, *supra* note 192, at 136.

349. *See* ALEXANDER, *supra* note 344, at 15.

350. *See* COLGAN ET AL., *supra* note 312, at 10 ("[Time-of-use] rates can have adverse impacts on consumers, especially on those who may have less ability to shift their usage to capture the benefits of time-of-use pricing, and on those who have trouble budgeting for bills that exhibit greater monthly volatility."); Robert Walton, *TOU Rates Could Spur Energy and Bill Savings, But Customer Advocates Urge Caution,* UTIL. DIVE (Aug. 16, 2017), https://perma.cc/L5TC-Z9XM (explaining that not all customers have access to the technology to control their energy usage easily, and that time and "wherewithal to look at and be aware of [] expensive periods" are not "equally-distributed" resources).

351. Faruqui, *supra* note 326, at 13.

who use electricity during low marginal cost hours subsidize consumers who use electricity during high marginal cost hours.[352] Adopting real-time electricity pricing removes such existing cross-subsidies.[353] As a result, real-time pricing might, contrary to the common perception, move us to a more equitable solution by eliminating existing cross-subsidies and reduce total bills for all customer groups. Therefore, a proper equity argument would require a cumulative analysis of multiple sources of inequity, instead of focusing on one narrow dimension such as access to technology.

In fact, because these distributional concerns are such an important part of the debate, scholars have also attempted to quantify the possible redistributive risk of time-variant pricing to low-income consumers, and have found that such consumers would not systemically be hurt by a variable rate and that the majority would end up saving money.[354] Research shows that, while the magnitude of the responses might differ by income group,[355] there is evidence that even low-income customers respond to prices.[356] Low-income consumers tend to have flatter load profiles, meaning that they use a fairly constant amount of energy through the day.[357] Because they will be purchasing relatively less electricity at peak time, as compared to the rest of the consumers as a whole, they will end up having a lower average price per kWh compared to customers who have "peakier" demand therefore will buy more electricity at the higher, peak time prices.[358] Furthermore, recent analysis shows that when demand elasticity is taken into account, all socioeconomic groups benefit on average from more so-

352. KAHN, *supra* note 16, at 101–02 (explaining the inefficiencies and cross-subsidization inherent in charging peak and off-peak users the same price).

353. Severin Borenstein, *Wealth Transfers Among Large Customers from Implementing Real-Time Retail Electricity Pricing*, 28 ENERGY J. 131, 131 (2007).

354. AHMAD FARUQUI, SANEM SERGICI & JENNIFER PALMER, THE IMPACT OF DYNAMIC PRICING ON LOW INCOME CUSTOMERS 9, 26 (2010), https://perma.cc/ZGZ7-UGR4 ("Furthermore, even without responding to dynamic rates, a large percentage of low income customers will be immediate beneficiaries of dynamic rates due to their flatter than average load profiles."); Joskow & Wolfram, *supra* note 250, at 384 ("Borenstein (2011) shows that most customers would benefit from critical peak pricing, and low-income households would not be systematically hurt by it.").

355. *See* Mattias Vesterberg, *The Hourly Income Elasticity of Electricity*, 59 ENERGY ECON. 188, 188 (2016) (showing hourly income elasticity is highest in peak hour, with significant elasticities for kitchen appliances and lighting but not for residential heating).

356. Ahmad Faruqui et al., *Dynamic Pricing of Electricity for Residential Customers: The Evidence from Michigan*, 6 ENERGY EFFICIENCY 571, 571 (2012).

357. *See* AHMAD FARUQUI ET AL., *supra* note 354 ("Furthermore, even without responding to dynamic rates, a large percentage of low income customers will be immediate beneficiaries of dynamic rates due to their flatter than average load profiles."); Jeff Zethmayr & Ramandeep Singh Makhija, *Six Unique Load Shapes: A Segmentation Analysis of Illinois Residential Electricity Consumers*, CITIZENS UTIL. BD. (June 5, 2019), https://perma.cc/3696-3TSU (showing that low-income customers are more likely to have flatter load profiles).

358. Borenstein, Jaske & Rosenfeld, *supra* note 192, at 26.

phisticated designs. In particular, real-time pricing and coincident-peak demand charges lead to very high gains in consumer surplus.[359]

A 2016 article also found that "[r]ecent pilot programs have shown that a large majority of low-income consumers benefit immediately from the implementation of peak pricing because they use less peak power than higher income households and are responsive to increases in electricity prices during peak periods and will reduce consumption."[360] But, consumer advocates tend to be skeptical about these studies because they are frequently based on the performance of customers in pilots that are over a short time period. In addition, there is "evidence that opt-in customers perform better than the average customer," so the results are no guarantee that other customers will be able to realize the same benefits from these rates.[361]

An Illinois consumer advocate group, the Citizens Utility Board, and the Environmental Defense Fund also recently did a study of Commonwealth Edison in Illinois' consumer data, and found that its Hourly Pricing program would have saved 97% of its consumers money without any change in their energy consumption patterns.[362] They found that the median bill impact for those who would lose money was about $6.23, and that there were not significant differences between how real-time pricing affected the bills of those with low incomes and other customers.[363] These results, although based on a cursory study that does not address whether the resulting revenue with new prices were enough to recover utility costs, do signal that time-variant pricing may not be bad for low or fixed income consumers, and may actually benefit them under some circumstances, even when they do not have access to technology that can help them change their behavior more easily.

In turn, consumer advocates are generally not in favor of demand charges because they see them as essentially another type of a fixed charge that customers cannot avoid.[364] Further, they argue that demand charges are difficult to understand, and therefore difficult to respond to. And, they worry that low-income customers will be disproportionately affected by the introduction of such demand charges given that these customers have less discretionary load. While these arguments have some merit in practice because of the design of

359. Scott P. Burger et al., *The Efficiency and Distributional Effects of Alternative Residential Electricity Rate Designs* 23 (Nat'l Bureau of Econ. Res., Working Paper No. 25570, 2019), https://perma.cc/G59T-KQKN.

360. William Boyd & Ann E. Carlson, *Accidents of Federalism: Ratemaking and Policy Innovation in Public Utility Law*, 63 UCLA L. REV. 810, 874 (2016).

361. COLGAN ET AL., *supra* note 312, at 20.

362. Dick Munson, *Data Reveals Real-Time Electricity Pricing Would Help Nearly All ComEd Customers Save Money*, ENVTL. DEF. FUND (Nov. 14, 2017), https://perma.cc/VL9J-6HBC.

363. *Id.*

364. PAUL CHERNICK ET AL., CHARGE WITHOUT A CAUSE? ASSESSING ELECTRIC UTILITY DEMAND CHARGES ON SMALL CONSUMERS 1 (2016), https://perma.cc/K9R3-VAGV.

demand charges that utilities want to impose,[365] as we explained in Part I, well-designed demand charges would reduce the need for costly capacity investments in the future, reducing costs for all ratepayers.

V. Road Forward

We have shown that principles of economic efficiency have not been followed throughout the history of electricity ratemaking. And it is clear that ignoring these principles has led to significant costs to society, including inefficiently low capacity utilization and inefficiently high air pollution emissions from energy generation. Furthermore, ignoring them has also led to inequitable outcomes such as cross-subsidies among different types of customer groups, and a disproportionate environmental and public health burden on low-income and minority groups, with even more dire consequences of climate change on these communities yet to come.

But the power sector today is at a critical point. Advanced technologies such as smart meters, smart appliances, and smart phone apps provide consumers with unprecedented control over their consumption patterns, giving us the freedom to think about more sophisticated rate designs. And DERs such as solar panels and energy storage allow consumers to become producers themselves, requiring us to rethink the future architecture of the grid. Moreover, climate change forces us to take immediate action to try to reduce emissions from the power system as a whole.

So, at this critical point, how can we move forward with modernizing rate design? In this Part we discuss how the current ratemaking paradigm needs to be changed. We first overview today's basic ratemaking principles and discuss the trade-offs implied by these principles. We argue that what stakeholders and regulators think of as the biggest trade-off, the equity-efficiency trade-off, is also a misperception given today's rate designs. Next, we lay out a long-term vision that should guide rate design reforms. Finally, we discuss complementary policies that are needed to make this vision a success from both an efficiency and an equity perspective.

A. Moving Beyond Perceived Trade-offs in Today's Ratemaking Principles

As we explained in Part IV, stakeholder positions in regulatory proceedings are quite influential in rate cases. Stakeholders participate in rate cases with their own priorities and own experts, arguing for their own interests. And, public utility commissions, guided by the record presented to them and by several established principles, make trade-offs as they try to meet their statutory obligations.

365. *See supra* text accompanying notes 86–102.

Below, we briefly overview some of these common principles that commissioners rely on to make such trade-offs. We then argue that, because of the current inadequacies of rate designs, it is likely that improving rate designs will lead to improving both efficiency and equity, contrary to the commonly cited efficiency-equity trade-off. Indeed, rate design reforms satisfying the principles we outline in Part I can improve both efficiency and equity at the same time.

1. Secondary Role of Economic Efficiency

In the United States, retail electricity rates are governed by state laws.[366] Most state legislatures historically have required retail electricity rates to be "just and reasonable" and nondiscriminatory or to be set under a similar general standard, in order to strike the appropriate balance between ratepayers and investors, leaving most details of ratemaking to public utility commissions.[367] These state ratemaking standards remain common today,[368] and generally mirror the standard the Federal Power Act sets for wholesale rates:

> All rates and charges made, demanded, or received by any public utility for or in connection with the transmission or sale of electric energy . . . and all rules and regulations affecting or pertaining to such rates or charges shall be just and reasonable.[369]

---

366. Boyd & Carson, *supra* note 360, at 823–27 (explaining the regulatory role of public utility commissions).

367. *See* Inara Scott, *Teaching an Old Dog New Tricks: Adapting Public Utility Commissions to Meet Twenty-First Century Climate Challenges*, 38 HARV. ENVTL. L. REV. 371, 378–79 (2014) (tracing development of state public utility commissions' regulation of electricity rates in the early part of the twentieth century).

368. *See, e.g.*, ALA. CODE § 37-1-80 (2019) ("The rates and charges for the services rendered and required shall be reasonable and just to both the utility and the public."); ALASKA STAT. § 42.05.381 (2019) ("All rates demanded or received by a public utility . . . shall be just and reasonable."); ARIZ. REV. STAT. ANN. § 40-203 (2019) (granting authority to correct rates that are "unjust, discriminatory or preferential, illegal or insufficient"); HAW. REV. STAT. § 269-16 (2019) ("All rates, fares, charges, classifications, schedules, rules, and practices made, charged, or observed by any public utility or by two or more public utilities jointly shall be just and reasonable . . . ."); N.H. REV. STAT. ANN. § 374:2 (2019) ("All charges made or demanded by any public utility for any service rendered by it or to be rendered in connection therewith, shall be just and reasonable . . . ."); N.C. GEN. STAT. § 62-130 (2019) ("The Commission shall make, fix, establish or allow just and reasonable rates for all public utilities subject to its jurisdiction.").

369. 16 U.S.C. § 824d (2018). For example, New York provides that "[a]ll charges made or demanded by any [utility] shall be just and reasonable" and that "[e]very unjust or unreasonable charge made or demanded for gas, electricity or any such service, or in connection therewith . . . is prohibited." N.Y. PUB. SERV. LAW § 65 (McKinney 2019). Similarly, Wyoming provides that "if . . . any rate shall be found by the commission to be inadequate or unremunerative, or to be unjust, or unreasonable, or unjustly discriminatory, or unduly preferential or otherwise in any respect in violation of any provision of this act, the commission

What "just and reasonable" means as a rate-setting standard, and how to meet this standard, are, of course, questions that every regulator has to grapple with. However, the Bonbright principles, which date back to 1961, have been influential in guiding utility ratemaking.[370] Three of these principles have been particularly salient: revenue sufficiency, fairness, and efficiency.[371]

The ***revenue sufficiency principle*** seeks to ensure the financial stability of a regulated utility: the amount of revenue collected must be sufficient to cover the utilities' incurred costs and future investments, including a fair rate of return.[372] This principle is at the core of the regulatory compact between the regulated firm and the regulator.[373] As long as the costs are prudently incurred, or "used and useful," utilities expect to recover their costs by collecting enough revenue from their customers.[374] And, perhaps for this reason, this principle is usually accepted as "the point of departure" for rate design.[375]

The ***fairness principle*** aims to equitably distribute the burden of meeting the revenue requirement among the beneficiaries of the service.[376] Fairness does not necessarily mean that everybody should be charged the same price regardless of what costs they are causally responsible for, but rather refers to the idea of nondiscrimination for similar customers.[377] Customers that are in the same "rate classes," for example, all commercial or all residential customers, respectively, should be charged similarly. Some jurisdictions implement a "social equity" version of fairness, and charge certain groups of customers such as low-income customers differently, even if they impose similar costs on the system.[378] However, that version of fairness is often secondary to the dominant nondiscrimination approach.[379]

The ***efficiency principle*** refers to resource allocation decisions.[380] It seeks to ensure that electricity is consumed by whomever benefits the most from it.

. . . may fix and order substituted therefor a rate as it shall determine to be just and reasonable." WYO. STAT. ANN. § 37-2-121 (2019).

370. *See supra* Section II.B.

371. Note that Bonbright uses the terms "revenue requirement," "fair apportionment," and "optimum use" to refer to these concepts. BONBRIGHT, *supra* note 161.

372. BONBRIGHT, *supra* note 161, at 291; Reneses et al., *supra* note 54, at 401.

373. BOSSELMAN ET AL., *supra* note 12, at 563–608.

374. *Id.*; *see also* Boyd & Carson, *supra* note 360, at 827.

375. BONBRIGHT, *supra* note 161, at 293 (explaining an assumption of "imput[ing] an unqualified priority" to the fair-return standard, and that rates as a whole must be designed to costs as a whole, including a fair return on capital investment); *see also* Reneses et al., *supra* note 54, at 401.

376. *See* BONBRIGHT, *supra* note 161, at 291–92.

377. Reneses et al., *supra* note 54, at 402.

378. BONBRIGHT, *supra* note 161, at 294; Reneses et al., *supra* note 54, at 402.

379. BONBRIGHT, *supra* note 161, at 294 (ruling out all social principles of ratemaking before discussing rate structures).

380. Reneses et al., *supra* note 54, at 401.

Prices should therefore be as close to the marginal cost of providing service as possible to transmit to consumers the causal consequences on the power system of their decisions.[381] As Bonbright explains, rates should "discourag[e] wasteful use of service while promoting all justified types and amounts of use."[382]

Satisfying these three principles at the same time is no easy task.[383] Utility regulators, therefore, might have to deal with trade-offs to balance the interest of different parties and arrive at "just and reasonable" rates at the end of lengthy, contested rate cases. Utility rate cases often end up in settlements, where the rate structures and components are negotiated among different stakeholders. And, given the strong influence of utilities, which value revenue sufficiency more than other principles, and consumer and clean energy advocates, which value equity principles more, efficiency principles are usually an afterthought. As a result, current rate designs are far from desirable from the perspective of economic efficiency.

The economic efficiency principle can potentially create trade-offs between both revenue sufficiency and fairness principles. Whether there is trade-off between efficiency and revenue sufficiency, or how much, depends on multiple factors including the exact type of revenue regulation a utility is subject to and its cost structures. For example, in states with revenue decoupling mechanisms, once utilities' investments and regulated rate-of-returns are approved by commissioners, utilities' revenue requirement—the amount of revenue that they must collect from the customers to pay their costs and earn a reasonable return—is set, and whatever rate design is chosen, the resulting revenue must meet that amount.[384] In other words, the potential trade-off between efficiency and revenue sufficiency would be lower. And, in states with limited, partial, or no decoupling, the dynamics would be different.[385] That detailed analysis, however, is beyond the scope of this Article. Instead, we will focus on the other potential trade-off: efficiency versus equity.

2. *Aligning Equity and Efficiency in Ratemaking*

Equity versus efficiency is perhaps the quintessential trade-off in policymaking. For example, in the ratemaking context, trying to keep average prices low for everyone to protect low-income customers is usually thought of as a compromise of efficiency in the name of equity. Indeed, as we explained in Part IV, one of the reasons consumer advocates oppose time-variant rates is because

381. *Id.*

382. BONBRIGHT, *supra* note 161, at 291.

383. *See id.* (describing other principles).

384. THE REG. ASSISTANCE PROJECT, REVENUE REGULATION AND DECOUPLING: A GUIDE TO THEORY AND APPLICATION 2–3 (2011), https://perma.cc/HU6U-LP9W.

385. *See generally id.* (explaining different types of revenue decoupling and how they might affect utility incentives).

they think the outcome will be inequitable for certain groups of customers. But, invoking the equity versus efficiency trade-off in rate design debates today to keep the status quo is misplaced.

First, when there are externalities that are not being taken into account in the rate scheme, incorporating those externalities into rate design might increase both efficiency and equity. For example, when an oil-fired power plant generates electricity in New York City during peak demand hours in the summer, the resulting air pollution causes external damages of roughly $0.54 per kWh.[386] In contrast, the average retail electricity price, which includes all private costs, taxes, surcharges, and credits, was around $0.18 per kWh in the summer of 2016 in New York.[387] This average price takes into account some minimal externality value based on Regional Greenhouse Gas Initiative ("RGGI") allowance prices that generators have to pay for carbon-dioxide externality, but RGGI prices are only a small fraction of even just the damages caused by carbon dioxide, let alone other air pollution, and, therefore, that minimal externality value is not enough to fully internalize the damages caused by air pollution. The average retail electricity price of $0.18 is roughly the sum of the average energy, capacity, and customer costs, which are the private costs of energy production. Thus, a kWh of electricity generated by these plants at peak hours during the summer of 2016 in New York City was imposing $0.54 of external damages to society in addition to the fuel costs, but consumers were paying almost nothing for this damage. It is obvious that this state of affairs is not efficient.

But it is also not equitable. Indeed, the burden of such external damages is not distributed equitably. Damages related to local air pollution are primarily caused by premature mortality, and adverse health consequences of SO_2, NO_x, and particulate matter emissions are disproportionately borne by low-income and minority populations,[388] because they tend to live closer to fossil-fuel generators and thereby are exposed to more pollution. In addition, because health status and other social factors affect the health impact of local pollution on the exposed population, already vulnerable low-income and low-health groups bear an even larger burden.[389] Similarly, climate change is currently disproportion-

386. *See* Shrader, Unel & Zevin, *supra* note 65, at 30–31 (demonstrating example calculation, multiplying average emissions rate in table 4 with average damages per unit for summer season in a high population area in table 5, where the value produced is an average, and the range of the damages varies depending on the day and the exact location of emissions).

387. *Monthly Average Retail Price of Electricity—Residential*, N.Y. State Energy Res. & Dev. Auth., https://perma.cc/3GZ4-X5YC (showing average monthly electricity rates in New York).

388. Shrader, Unel & Zevin, *supra* note 65, at 21.

389. *Id.*

ately harming low-income and minority populations, and will continue to do so in the future.[390]

Second, when utilities have high capacity costs that would have to be recovered in full from ratepayers once incurred, incorporating proper peak capacity price signals might also increase both efficiency and equity. As we explained above, capacity investment in generation, transmission, and distribution systems are made to meet the peak demand. And, reducing that peak demand can bring large savings, reducing the energy burden on everyone, including low-income communities.

And third, because most DERs such as solar panels are compensated by net metering and net metering relies on the underlying rate design, if the underlying rate design is inefficient and inequitable, the DER policy will also be inefficient and inequitable. As we explained in the first two articles of our "Managing the Future of the Electricity Grid" series,[391] the societal value of a DER depends on time and location. Therefore, compensating a DER using net metering based on a flat volumetric rate would lead to over- or under-paying DERs, and is economically inefficient. And, because DER owners tend to be higher income, overpaying DERs without a corresponding societal benefit is also inequitable.[392]

Therefore, letting the short-term bill impacts on vulnerable populations, which, as discussed below,[393] are reversible with other complementary policies, to stop progress towards policies that could reduce the long-term, irreversible harm of bad rate design is not only economically irrational, but also, ironically, inequitable. Of course, promoting energy affordability and avoiding negative short-run financial impacts of policy reforms on low-income customers are also important goals, and should be taken into account as part of any policy reform.

However, the solution to this issue is not to avoid desirable price signals. Instead, efficient policy should be coupled with other programs that can ameliorate negative bill impacts on vulnerable populations in a non-distortionary manner. As we explained in Part I, economic efficiency depends on marginal price signals. Any fixed credit for low-income customers that is recovered by fixed charges from the rest of the customers, for example, would not affect economic efficiency because it would not change marginal incentives. Indeed, recent analysis shows that varying fixed charges based on certain characteristics such as customer income in a progressive manner, with low-income groups paying less and high-income groups paying more, can "preserve efficiency gains

390. Solomon Hsiang et al., *Estimating Economic Damage from Climate Change in the United States*, 356 SCIENCE 1362, 1363–64 (2017) (showing the spatial variation in economic damages from climate change).

391. *See* Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 103–04; Revesz & Unel, *Energy Storage and Greenhouse Gas Emissions*, *supra* note 7, at 159–61.

392. *See* Parth Vaishnav et al., *supra* note 320.

393. *See infra* Section V.C.

while mitigating undesirable distributional impacts."[394] Therefore, expanding already existing programs or designing new ones to directly address affordability to complement design reforms could help us move forward to a grid that is both more efficient and more equitable.

B. A Long-Term Vision

Once we leave the false dichotomy of efficiency versus equity behind, we can focus on the paradigm shift that is necessary to move forward. First, as we explained above, a technology-neutral framework that can granularly value electricity is necessary as we think about the architecture of the future grid. Second, this framework has to be forward-looking, taking long-run effects of policies into account.

1. A Technology-Neutral Framework

Today's state energy policies are a patchwork of reactive policies: net metering, renewable portfolio standards, energy efficiency incentives, demand response programs, electric vehicle tax credits, energy storage mandates, and even mandates for solar roofs. Each of these policies is obviously meant to address a need. However, this "one-problem-at-a-time" approach is not a sustainable framework for managing the future of the grid.

We neither know what technologies will be available in the future, nor can we assume that all those new technologies will be beneficial from a societal perspective. Therefore, it is important to shift to a framework that can accommodate any future technology based on its benefits and costs, and, hence, provide a level playing field for all technologies of the future. Doing that requires thinking about cost drivers in an unbundled way, with separate charges for energy, capacity, and externalities, and, then, basing the price signals on these cost drivers in a granular manner based on time and location.

Establishing this framework is especially important to level the field between technologies that can only reduce or modify consumers' demand and usage, and technologies that can actually generate and send electricity back to the grid. Technologies such as energy efficiency and demand response provide benefits by reducing use, and, therefore, the need for grid electricity at a given time and location. Consequently, these technologies avoid costs that would have been incurred to bring electricity to that location at that time. Technologies such as solar panels can provide benefits by generating electricity that consumers use instantly, and, hence, by reducing the need for grid electricity, as well as, by injecting excess electricity to the grid, and, again avoiding costs that would have been incurred to bring electricity to that location at that time.

394. Burger et al., *supra* note 359, at 4.

As a result, there is no logical reason why a technology that reduces consumer usage by one kWh and helps avoid the costs that are necessary to provide that kWh to that consumer should be compensated using a different framework than a technology that allows the same consumer to send the grid one kWh of electricity and helps avoid the costs for that kWh. Of course, the realized, numerical values of the formula could be different because, for example, a kWh injection actually has to go through the grid, and might thereby impose costs. But any difference in the framework to categorize and calculate these values would lead to distorted price signals, and inefficiently incentivize investments of one over another.

There lies the importance of rate design reform to create a technology-neutral framework. Better pricing will automatically lead to behavior consistent with social welfare maximization. Consider a scenario in which, following a transition to efficient pricing, the price signal a consumer sees becomes the full cost impact of additional demand or use, and the consumer then chooses to consume less energy than previously. That would mean that the marginal benefit to that consumer was lower than the social marginal cost, and that this consumer was previously over-consuming. In contrast, if this consumer chooses to continue using the same amount of electricity following the policy, that would mean that the marginal benefit to that consumer was at least as high as the social marginal cost, and that the prior use was socially beneficial.

Furthermore, because the rates would now be forward-looking and based on avoidable costs, any reduction in revenue due to reduced use would indeed correspond to only the avoided costs. So, for example, a customer with a solar panel would pay lower energy charges because the solar generation reduces the need for electricity from the grid, and avoids related costs such as fuel costs and losses. In addition, this customer would pay lower demand charges only to the extent that the solar panel helps reduce the customer's coincident peak demand. And, because that coincident-peak demand charge would be set based on avoidable marginal capacity costs, the reduction in customer bill would correspond to truly avoided costs, and not to already incurred, non-avoidable costs.

As a result, consumers' investment decisions would also be socially beneficial. Essentially, any action that leads to a reduction in the need for capacity, whether it is because of energy efficiency, distributed generation, or demand reductions as a result of price signals would be rewarded using a similar framework. Therefore, consumers would be able to better understand the true value of using more efficient air-conditioners on hot summer afternoons, or whether investing in weatherization or LED light bulbs would be more useful, and to invest accordingly. And, even with the net metering framework, better prices would result in compensation based on the true social benefits of both use reductions and injections, and direct DER investment where it is more valuable.

Finally, a DER that can reduce the need for energy generation from fossil-fuel-fired plants would get rewarded for avoiding costly air pollution regardless of whether it reduces the amount of withdrawals from the grid, or whether it directly injects to the grid. Compensating DERs that can inject to the grid for avoiding emissions, but not doing the same for DERs that can avoid emissions by reducing the electricity needed from the grid would lead to an economically inefficient portfolio of DERs. And, because externalities are reflected in prices, the potential for perverse consequences such as energy storage inefficiently increasing emissions would be eliminated.

Therefore, a rate design based on the principles we outlined in Part I can serve as the basis of a comprehensive framework that can value "all energy resources to provide the right signals for a socially desirable outcome, regardless of whether they are centralized or distributed; small scale or utility scale; or emitting or non-emitting" and help us "move beyond narrow and short-sighted debates that may inefficiently favor one low-carbon resource over another."[395]

2. *Decision-Making with a Long-Term Focus*

The second shift relates to the time frame of decision-making. As the discussion in Part III shows, most stakeholders are focused on short-term impacts of policies, and especially the short-term bill impacts. The same is true for regulators. For example, even New York, a state that is considered to be a leader in the clean energy transition, decided that "[l]onger term effects that require significant capital investment by a consumer, a prosumer, or that impact utility capital investment programs will not be examined [when calculating bill impacts.]"[396]

However, this short-sighted approach disregards two important long-term benefits of the transition toward a cleaner and a more modern grid. First, as we mentioned, avoiding or delaying the need for capacity expansions would save costs to society. And understanding whether or by how much a particular rate design would save future capacity costs, and hence will eventually affect bills, is important to both efficiency and equity.

Second, the impacts of air pollution are felt in a longer time period. Local pollutants cause or exacerbate chronic illnesses that last a lifetime, or cause premature mortality. Similarly, greenhouse gas emissions stay in the atmosphere for hundreds of years, contributing to climate change. And the effects of climate change will be felt for decades to come. None of these negative externalities can be fully captured in short-term analyses spanning only a few years.

Using a short-term framework, therefore, is likely to lead to price signals and investments that discount significant efficiency and equity gains that can be achieved by avoiding consequences that materialized in a longer time frame.

---

395. Revesz & Unel, *Distributed Generation and Net Metering*, *supra* note 3, at 108.

396. N.Y. State Dep't of Pub. Serv., *supra* note 279.

And a longer-term focus is necessary at this junction when we are making significant longer-term investments to move toward a clean and modern grid.

C. Necessary Complementary Policies

As we discussed throughout the Article, achieving an efficient and an equitable modern grid is not possible without better price signals. However, we recognize that better pricing is only a necessary condition for successfully modernizing the grid, but by itself it is not sufficient. Complementary policies are necessary to ensure social equity.

A pricing scheme that is consistent with the principles we described in Part I, would necessarily increase prices for some consumers at certain locations for usage at certain times. And, because we would be moving away from flat, volumetric rates, some types of users would necessarily pay more than they were paying before, whereas other types of users would pay less. As we explained above, that outcome is not necessarily inequitable based on cost causation principles because it would eliminate existing cross-subsidies. But, nonetheless, some of the people who would have to pay higher bills might indeed belong to low-income or minority groups, or to groups that cannot easily change their consumption such as elderly and sick people. As many families are already living in "energy poverty," spending an unsustainable portion of their income on energy bills and even sacrificing consumption of other basic necessities,[397] this potential for higher bills increases social inequity and energy poverty concerns.

But any such inequity based on social principles can, and should, be remedied by complementary programs that directly address affordability concerns. Electricity is not the only setting in which concerns are raised about efficient pricing. For example, congestion pricing on highways, where economic efficiency principles suggest a higher price during when there is congestion, also leads to similar equity concerns. However, the discussions on congestion pricing show that it is possible to have efficient congestion pricing, while also providing equitable relief.[398]

In the electricity sector, there are already many low-income assistance programs, with various designs, offered by utilities. Some utilities give eligible customers discounts on their entire energy bill, others give a flat percentage discount on monthly energy charges,[399] and yet others cap bills at a certain per-

397. Welton, *supra* note 339, at 632 n.278.

398. *See* Jonathan Remy Nash, *Economic Efficiency Versus Public Choice: The Case of Property Rights in Road Traffic Management*, 49 B.C. L. Rev. 673, 730 (2008).

399. All Massachusetts utilities fall into this category, and many California utilities do as well. *See* Lee Hansen, Conn. Gen. Assembly Office of Legislative Research, Utility Rate Discounts for Low-Income Customers in Other States 2–5 (2018), https://perma.cc/LUY5-ZHEW (summarizing utility rate discount programs for low-income cus-

centage of household income depending on income level.[400] A few utilities give different types of discounts for fixed and volumetric charges.[401] And some utilities in deregulated states use different types of discount structures for charges that are recovering distribution level costs, and generation and transmission level costs.[402]

These programs can be expanded to address any potential energy poverty problems that may arise with new rate designs. However, it is important that programs aimed at reducing energy poverty are designed in a manner that does not distort price signals. Direct bill credits for these groups based on income would reduce the total bill the customer have to pay, while still providing signals about when energy, capacity, and externality costs are the highest. But, reducing the volumetric charge, or giving different levels of discounts for different charges would distort marginal price signals, and hinder efficiency. Affordability programs should also be reformed in a manner that does not negatively affect efficiency.

Conclusion

As a confluence of factors such as advancing energy technology, increasing DER penetration, and climate change concerns are forcing a transformation of the power grid, properly designing rates to manage this transformation is becoming an urgent endeavor. In this Article, we first describe basic economic efficiency principles that should govern any rate design reforms. Then, we summarize how rates have evolved in the United States to show the very limited role of economic efficiency principles throughout this history. We overview the most influential stakeholder positions in the rate design debate, explaining certain misperceptions of these positions. Then, we discuss the shortcomings of current or proposed rate designs to provide economically efficient price signals for socially beneficial electricity consumption, as well as investment in both traditional resources and DERs.

Finally, we outline a long-term, technology-neutral vision that should guide rate design reforms, and argue that this vision would improve both efficiency and equity compared to the status quo. Price signals that reflect the underlying costs of providing electricity to consumers, including capacity costs and externalities related to air pollution, in a time-, location-, and demand-

---

tomers). Two New York utilities, Consolidated Edison and National Grid, have a tiered monthly electric discount structure that varies by service type. *See id.*

400. Many New Hampshire and Pennsylvania utilities follow this model. *See id.* at 4, 6–7.

401. The Long Island Power Authority's rate is a 97.5% discount on the daily service charge and a 25% discount on the first 250 kWhs used. *Id.* at 5.

402. Rhode Island's National Grid's low-income assistance program removes the monthly $5 customer charge and gives low-income consumers a 31% discount on their distribution charge, but does not discount supply charges. *Id.* at 8.

variant basis, can form a technology-neutral framework that can properly value all types of energy resources. Only then can we efficiently and equitably unlock the future that modern technology promises us.