WHITE PAPER

Aligning Retail Pricing and Grid Needs

INTRODUCTION TO A WHITE PAPER SERIES

By Debra Lew (ESIG), Erik Ela (EPRI), and Carl Linvill (RAP)

The decarbonization of energy systems will bring significant electrification of buildings, transportation, and industry along with high levels of wind and solar generation to provide clean energy at low cost. To balance supply and demand, the future grid will require a great deal of flexibility. Retail pricing, in addition to being a mechanism for utilities to recover their revenue requirement from consumers, is a way to signal the need for changes in consumption in order to better align demand and grid needs. Today, roughly three-fourths of U.S. households have advanced metering infrastructure, and control and communication technologies are available for everything from water heaters to space heating and cooling equipment to electric vehicles. What retail pricing structures will incentivize customer behavior to align with the reliability needs of the future grid? How do we unlock value for both the consumer and the grid in a practical manner without adverse impacts to customers who are disadvantaged or are unable to respond as well as others?

The Aligning Retail Pricing and Grid Needs Task Force examined this topic from the grid, consumer, economic, and regulatory perspectives. Seven white papers address different aspects of retail pricing and propose solutions or best practices. This introductory white paper provides context for the issues considered by the task force, offers insights from the white papers, and briefly summarizes each one.

Energy Systems Integration Group's
Aligning Retail Pricing and Grid Needs
Task Force

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ENERGY SYSTEMS INTEGRATION GROUP

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About ESIG

The Energy Systems Integration Group is a non-profit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. More information is available at https://www.esig.energy.

ESIG Publications Available Online

This paper and the accompanying white papers are available at https://www.esig.energy/aligning-retail-pricing-with-grid-needs. All ESIG publications can be found at https://www.esig.energy/reports-briefs.

Get in Touch

To learn more about the topics discussed in this white paper or for more information about the Energy Systems Integration Group, please send an email to info@esig.energy.

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Contents

Aligning Retail Pricing and Grid Needs

Introduction to a White Paper Series

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Introduction

Increasing levels of variable wind and solar generation create challenges for system operators to balance supply and demand and for system planners to ensure resource adequacy. Meanwhile, the electrification of transportation, buildings, and industry (which society is actively pursuing as a path to decarbonize these sectors) is increasing load and adding variability. The addition of these loads poses both a challenge and an opportunity. Unmanaged, they may stress all layers of the grid, from the bulk power system to the distribution system down to the premise level. This could lead to an overbuilt, unnecessarily expensive grid. But managed well, these loads can mitigate grid expenditures.

Responsive demand is demand that can be controlled by either the consumer or a signal to some end goal, and includes load reduction, load increases (such as during high solar output at midday), and even load following a signal to provide regulation reserves.[1] Managed well, loads have the potential to improve reliability and support grid needs. This white paper discusses flexible demand in general terms, but we recognize that it encompasses everything from sophisticated thermal batteries for industrial heat to fleet charging of electric vehicles to residential consumers manually turning on appliances during off-peak periods.

> **To both induce consumers to manage demand and avoid penalizing electrification, we need to move beyond traditional rate structures, while still recovering the revenue requirement.**

For regulated cost-of-service consumers, retail electricity prices need to recover the utility's revenue requirement. However, retail prices that do not vary with time do not induce consumers to manage demand. Volumetric, tiered prices (in which higher consumption costs more) can be a disincentive to electrification. To both induce consumers to manage demand and avoid penalizing electrification, we need to move beyond traditional rate structures, while still recovering the revenue requirement. Time-varying rate structures that set fixed-period time-of-use rates or more dynamic time-varying rates are an important alternative that promotes active load management and electrification.

Today, enabling technologies for control and communications are available at relatively low cost that can enable the management of some loads. Advanced metering infrastructure is now widely available across the U.S. and other developed nations, paving the way for time-varying rates and programs to better align consumer behavior with grid needs. But while managed demand has the potential to better support the grid,[2] an active debate persists regarding the relative effectiveness of pricing and distributed energy resource (DER) programs. While some actions, such as the U.S. Federal Energy Regulatory Commission (FERC) Order 2222,[3] have increased the attention on DER programs and

1 Regulation reserves respond to minute-to-minute variations to maintain power balance.

2 In an event held by ESIG in 2019 on the challenges of meeting a 100% zero-carbon electricity supply system, almost all of the workstreams determined that achieving this in a cost-effective manner with known technology will rely on the increased flexibility that can be provided by the demand side.

3 Federal Energy Regulatory Commission, *Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators,* Order No. 2222, 18 CFR Part 35, 172 FERC ¶ 61,247, September 2020.

The insights from the ESIG Task Force on Aligning Retail Pricing and Grid Needs and these white papers are intended to advance our understanding of the opportunities and challenges of using retail pricing and programs to meet the changing needs at all layers of the power system.

aggregators recently,[4] much less attention has been paid to retail pricing as a mechanism to align demand flexibility with bulk system needs.

In 2022, the Energy Systems Integration Group (ESIG) created a task force on Aligning Retail Pricing and Grid Needs, convening subject matter experts from three areas that inform pricing solutions—retail pricing, grid planning/operations, and consumer needs—and electricity regulation experts and representatives who specialize in wholesale markets, bulk power systems, distribution systems, retailer service, and consumer advocacy. The task force met monthly to level set key concepts and discuss relevant industry initiatives. Seven papers were drafted by members of the task force that highlight important challenges, and in some cases solutions, to the potential misalignment that exists today.

The white papers together with this introductory paper are intended for readers across many facets of the energy industry, from power systems engineering and grid operators to economists, consumer advocates, and regulators across the world. The insights from the task force and these white papers are intended to advance our understanding of the opportunities and challenges of using retail pricing and programs to meet the changing needs at all layers of the power system.

4 See, for example, ESIG's three-part series of DER integration into markets and operations at https://www.esig.energy/der-integration-series.

Grid Needs

Energy, supply capacity, transmission and distribution infrastructure, and ancillary services are needed to ensure reliable delivery of electricity service. Flexible demand that responds to pricing, controls, or dispatch signals can provide many of these services and offset infrastructure investments. Some services are agnostic to location (they can be provided by resources anywhere on the system), while others are location-dependent. In either case, grid needs change at different times of the day for different periods of the year. Most of these services are either a function of demand at a given time and location (for example, substation capacity to manage feeder loading, or generation and storage capacity during peak demand periods) or are driven by the need to balance supply against demand in real time (for example, energy arbitrage to manage both peak and off-peak periods).

Traditionally, bulk power system operators and wholesale markets have used supply-side resources to meet grid needs and generally viewed demand as fixed and inelastic. However, there is ample evidence that demand has considerable flexibility (WGLS, 2019; Zhou and Mai, 2021) and that the amount of flexibility will increase as we electrify other sectors (Hledik et al., 2019). Demand response programs are typically activated during emergencies and critical time periods. However, the magnitude is far lower than the flexibility that studies show may be inherent in demand, demand response is only one form of demand flexibility, and there may be additional ways to extract this flexibility. By using retail pricing to signal to consumers when load-shifting can serve grid needs, flexible demand can help defer transmission and distribution investments and assist with system balancing, providing more resources from which to react to the need.

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Impact of the Resource Mix and Load on Grid Needs

Grid needs depend on the resource mix. The amount of each service needed, and its value, will vary from one system to the next and will evolve as the resource mix evolves. For example, a traditional thermal fleet system may place a high value on peak shaving and the ability to reduce demand during those peak periods to avoid generation capacity additions and high fuel costs. A system that has high levels of solar may value energy arbitrage and the ability to shift demand from one period to another.

Grid needs also depend on the load. The magnitude and value of services will change as demand profiles are affected by electrification. Managing electrification load well is important because unmanaged electric vehicle charging and electrification of industrial heat, for example, draw high power, which can significantly increase the need for generation/storage and transmission and distribution investments, as well as increase the need for ancillary services. Because most distribution feeders tend

Because distribution feeders tend to be radial rather than networked, there is less diversity on those systems, and the stress of electrification is likely to occur there first—making location-specific flexible demand highly valuable.

to be radial rather than networked, there is less diversity on those systems, and the stress of electrification is likely to occur there first, making location-specific flexible demand highly valuable.

Today, the most common service provided by flexible demand is the curtailment of consumption during emergencies and very high-cost periods. However, there are other time periods and services where modern load control technologies could greatly support the power system if the market operators and consumers saw the value and enabled the opportunities for consumers to provide such support. As integrated DERs and electrified loads grow in number, the range of services and the quantity of service is expected to grow substantially. Table 1 describes the main grid needs.

Retail pricing provides a signal to consumers, and it is important to consider the types of loads that are responding to the signal, how that signal is communicated (automation vs. manual), how far in advance the signal can be provided, and how accurate the signal is. Some price signals may occur too quickly with too many rapid changes for meaningful response from demand that is not automated. When prices incentivize consumer response, and conditions (which may include renewable resource forecasts or the larger-than-expected consumer response itself) render those prices inaccurate, then those responses can have a negative impact on the grid. While price response approaches need to be managed well to avoid perverse outcomes, price responsiveness

TABLE 1
Grid Needs

Grid Need	Description
Energy and Supply Capacity	
Energy at time and location	Adjusting energy or demand in the place and at the time where it is needed to maintain power balance
Supply capacity / adequacy	The installed MW capacity to provide energy when it is most needed
Infrastructure Maintenance and Investment	
Transmission capacity	The installed MW capacity to deliver energy across the bulk power system when and where it is most needed
Distribution capacity	The installed MW capacity to deliver energy across the distribution system when and where it is most needed
Essential Reliability Services	
Operating reserve	Having supply capacity held back to respond in case of emergency conditions
Frequency response	Quickly responding to frequency deviations to stabilize system frequency
Regulation reserve	Responding to minute-to-minute variations to maintain power balance
Voltage regulation	Responding to voltage changes to maintain local voltage within range
Black start	Supporting the system restoration to bring a power system back following a black out or separation

Source: Energy Systems Integration Group.

TABLE 2

Overview of Grid Needs and How They Would Be Signaled for Supply and Demand That Is Providing (or Could Provide) the Service

Grid Need	Signal on Supply	Signal on Wholesale Demand	Signal on Retail Demand
Energy/Shaping	Locational marginal pricing, dispatch	Locational marginal pricing	Time-of-use rates, variable peak pricing, dynamic rates
Supply capacity (defer generation)	Capacity price or scarcity price, contract	Capacity price or scarcity price	Demand charge, critical peak pricing, peak time rebates, dynamic rates
Distribution upgrade deferral	Agreed-upon contract	Agreed-upon payment	Demand charge, critical peak pricing, peak time rebates, dynamic rates
Transmission upgrade deferral	Congestion prices, agreed-upon contract	Congestion prices, agreed-upon payment, e.g., ERCOT's 4CP program	Demand charge, critical peak pricing, peak time rebates, dynamic rates
Ramping reserve	Ancillary service price	Load-ratio allocation	N/A
Spinning reserve	Ancillary service price, operator call	Load-ratio allocation	N/A
Regulation reserve	Ancillary service price, automatic generation control signal	Load-ratio allocation	N/A
Frequency response/ Inertia	No incentive, autonomous control	N/A	N/A
Voltage regulation	Cost recovery, automated or manual dispatch	None	N/A
Black start	Cost recovery, operator call	N/A	N/A

Notes: ERCOT = Electric Reliability Council of Texas; 4CP = Four Coincident Peak; N/A = not applicable.

Source: Energy Systems Integration Group.

is a valuable tool to ensure reliability and control cost. Table 2 shows how different grid needs are or can be signaled for supply and demand. This information may help different jurisdictions evaluate whether certain changes to retail rates may create better incentives for the different types of services that demand can potentially provide.

Today, key value streams for flexible demand are likely to be in avoiding generation capacity on the bulk power system, supporting the grid during peak periods, and energy arbitrage. In the future, avoiding new or upgraded distribution facilities will also become important due to increasing electrification. Flexible demand will increasingly provide ancillary services such as operating reserves as well, possibly through large consumers responding to prices, but likely through aggregations of demand enrolled through programs or contracts.

Supply Capacity/Infrastructure Needs as a Key Driver for Price-Responsive Demand

Increased levels of variable renewables will likely increase the needs for flexibility in energy, for supply capacity to ensure resource adequacy, and for transmission capacity. Increased electrification will likely increase the needs for distribution capacity as well. Flexible demand is used today to reduce levels of generation and storage capacity. It can also be used to reduce levels of transmission and distribution capacity, as discussed in white papers in this series including "'Why Is the Smart Grid So Dumb?': Missing Incentives in Regulatory Policy for an Active Demand Side in the Electricity Sector" by Travis Kavulla; "Rate Design for the Energy Transition: Getting the Most out of Flexible Loads on a Changing Grid" by Olson et al.; and "Tapping the Mother Lode: Employing

Price-Responsive Demand to Reduce the Investment Challenge" by Michael Hogan (Kavulla, 2023; Olson et al., 2023; Hogan, 2022).

On the distribution system, location-specific services are necessary to relieve congestion in specific areas of the system. Traditionally, distribution congestion has been resolved through infrastructure upgrades, but flexible demand can provide this service if location-specific signals can be sent, thus helping to avoid or defer the large capital costs of traditional infrastructure upgrades and potentially addressing these needs at a lower cost.

If retail pricing is to obviate needs for capacity and infrastructure in the planning time frame, it would need to be used to reduce demand forecasts in the resource, transmission, and/or distribution planning processes. We note that the reduction of demand can provide outsized value because it can also remove the need for planning reserve margin for that amount of demand. In conventional resource planning with a planning reserve margin of, say, 15%, the reduction of peak demand by 100 MW through retail pricing could yield a reduction of supply capacity needs of 115 MW due to the planning reserve margin associated with the peak demand reduction.

Retail Electricity Pricing

Retail pricing occurs within a larger context where other factors interact with it to substantially affect how well consumer choices align with grid needs. For example, utility and public purpose consumer programs interact with retail pricing and affect alignment of consumer choices with grid needs at each layer of the grid. On the distribution system, these programs affect the placement and use of storage, which can in turn affect distribution system needs. On the bulk system, settlement procedures and wholesale market design, either through organized electricity market auctions or bilateral arrangements, affect the alignment of consumer choices with bulk system needs. While these factors and others have an effect on how well consumer choices align with grid needs, this task force focused specifically on retail pricing itself and how retail pricing design aligns with grid needs at each layer of the grid.

A Brief Overview of Wholesale Pricing

Wholesale pricing in organized markets is simpler than retail pricing, but a quick review of how wholesale pricing meets bulk system grid needs is helpful background before considering the additional complexities that come with retail pricing design. Ensuring reliability at least cost for consumers is an objective at every layer of the electricity system, but meeting the objective on the bulk system is easier because centralized market dispatch ensures that bulk system resources and bulk system needs are identified and met within the context of an optimized market system dispatch. Ensuring reliability at least cost on the premise and distribution system layers depends on designing a pricing incentive structure that induces consumer choices that lead to meeting needs on those layers reliably and as cost-effectively as possible. Retail pricing would be simpler if an optimized dispatch could be implemented to meet needs all the way down to the premise level, but distribution systems are not operated that way today.

Ensuring reliability at least cost on the bulk system is easier than on the premise and distribution system layers because centralized market dispatch ensures that bulk system resources and bulk system needs are identified and met within the context of an optimized market system dispatch.

On the bulk system, grid operators dispatch generation to balance supply and demand using wholesale prices that send appropriate signals to the generators on the bulk system. This is especially true in the United States, where wholesale markets use transmission network–constrained economic dispatch, locational marginal prices for energy, and ancillary service auctions co-optimized with energy. Flexible demand sometimes participates in the balancing of supply and demand and bulk system reliability overall, but the availability of flexible demand has historically been limited.

The cost of producing and distributing electricity on the bulk system has large locational and temporal differences. The market operators (or host utilities) use complex software programs to determine the quantity and price of these services with locational and temporal detail and to determine which resources should be used to meet those needs at least cost. In most countries, marginal cost pricing is typically used to set the price for energy and most ancillary services.

Organized wholesale markets seek to meet demand at least cost to consumers while keeping the grid within reliability standards. Energy and wholesale service pricing are set by market mechanisms and regulations that seek to align market participant purchase choices with the energy and reliability service needs of the bulk system grid. Wholesale energy constitutes the largest expense for market participants, so wholesale prices drive the majority of market participant behavior. Wholesale prices in the United States are established from day-ahead down to a 5-minute granularity, prices vary locationally down to the level of a generator substation, and these energy prices are formed simultaneously with prices for three to six additional interrelated ancillary services. While there are several ways that the electric power industry might improve wholesale markets, these markets already function in a way that seeks to align incentives with bulk system grid needs in as granular a way as possible given other constraints.

Organized wholesale markets seek to meet demand at least cost to consumers while keeping the grid within reliability standards. Energy and wholesale service pricing are set by market mechanisms and regulations that aim to align market participant purchase choices with the energy and reliability service needs of the bulk system grid.

In addition to the price signals from system and market operations (wholesale energy and ancillary services prices), we also need to consider decisions made in system planning to build supply capacity and transmission and distribution infrastructure. With the notable exception of the Electric Reliability Council of Texas' (ERCOT's) energy-only market, most U.S. balancing authorities must meet some supply capacity obligation to ensure resource adequacy, typically through a resource planning process or through a wholesale capacity market. Transmission and distribution planning processes study the need for new, upgraded, or replacement infrastructure. The economic or reliability signals for new supply capacity, transmission, or distribution infrastructure do not necessarily come out of wholesale energy and ancillary service prices, but rather through these various system planning processes. Because retail pricing can obviate the need for this capacity/infrastructure, it is important to note the mechanism through which this benefit is realized. Today's system planning processes start with a demand forecast, traditionally for system peak, but modern practices include 8760 demand profiles. Retail rate structures, combined with estimated or measured price sensitivity (price-responsiveness) of consumers, can be used to adjust the demand forecast. For example, a time-of-use rate with a certain price ratio between peak and off-peak rates may result in a shifting of a certain amount of MW of demand from peak to off-peak periods. This adjusted demand forecast may then help to reduce the amount of supply capacity or transmission and distribution infrastructure needs that are identified in the planning processes. Importantly, system planners need some level of certainty about the price-responsiveness of consumption in order to rely on this reduced demand, especially for parts of the system such as radial distribution systems where there are few other resources that can help if price-responsiveness does not occur.

Retail prices are set to recover wholesale prices as well as all other costs of service. As noted, wholesale prices are established to meet bulk system needs, thus constituting one important price signal that reflects a subset of the grid needs. However, needs at the premise and distribution system level are not reflected in wholesale prices, and these needs are not expressed and met through an organized market dispatch on the distribution system level. Retail pricing should thus recognize wholesale pricing, but should not be solely aligned with wholesale pricing, because this would effectively ignore needs on the premise and distribution system levels of the electricity system. Some level of locational pricing on distribution systems would be helpful in aligning consumer choices with local grid needs, but this refined granularity of locational pricing is at the pilot stage at best.

Alignment Between Retail Pricing and Grid Needs

Distribution utilities and other load-serving entities and retailers sell the electricity purchased in the wholesale market to end-use retail consumers—residential, industrial,

The combination of flat retail rates together with distribution utilities' and load-serving entities' obligation to serve load can lead to potentially dramatic overbuilding of the system. Consumers' flat rates during times of scarcity do nothing to guide a shift in consumption to less risky hours on the system and thus lower the peak demand. Instead, the system must increase its generation capacity to serve the unmitigated peak load.

and commercial—at retail rates. Distribution utilities and load-serving entities also have an obligation to ensure a high level of reliability; however, the retail pricing structures are less granular than those in the wholesale markets (varying much less in time or space) and are much less linked to meeting specific grid needs. The combination of flat retail rates together with the obligation to serve load can lead to potentially dramatic overbuilding of the system: consumers' flat rates during times of scarcity do nothing to guide a shift in consumption to less risky (less expensive) hours on the system and thus lower the peak demand that must be served. Instead, the system must increase its generation capacity to serve the unmitigated peak load—an expensive proposition, borne by consumers themselves—which could have been avoided if consumer demand had been able to be shifted to time periods with less reliability risk.

In addition to retail rates not reflecting energy and ancillary service costs, they may also not reflect transmission and distribution infrastructure costs. For example, costs for transmission infrastructure on the bulk power system may be reflected in a non-coincident peak demand charge that may not align with stress periods on the bulk power system, or these costs may be reflected in a fixed charge that does not align with any time period. The same issue arises for distribution system costs, which do not have granular needs assigned with any time period.

While large commercial and industrial consumers may participate directly in wholesale markets and respond to wholesale price signals, small commercial and residential retail consumers typically see an aggregated price that does not show temporal or locational wholesale system prices. Many utilities and retailers do offer time-varying rates, but participation in time-varying rate tariffs is generally low (unless these rates are default rates). Moreover, prices established in time-varying rates may reflect how wholesale prices differ on average between peak and off-peak periods, but unless they are dynamic rates tied to real-time energy prices, they cannot reflect real-time scarcities or surpluses. As a result, since the vast majority of small commercial and residential utility consumers and some large commercial and industrial consumers do not see wholesale price signals, they lack an important tool with which to align their consumption choices with needs of a reliable grid.

How Retail Rates Are Determined

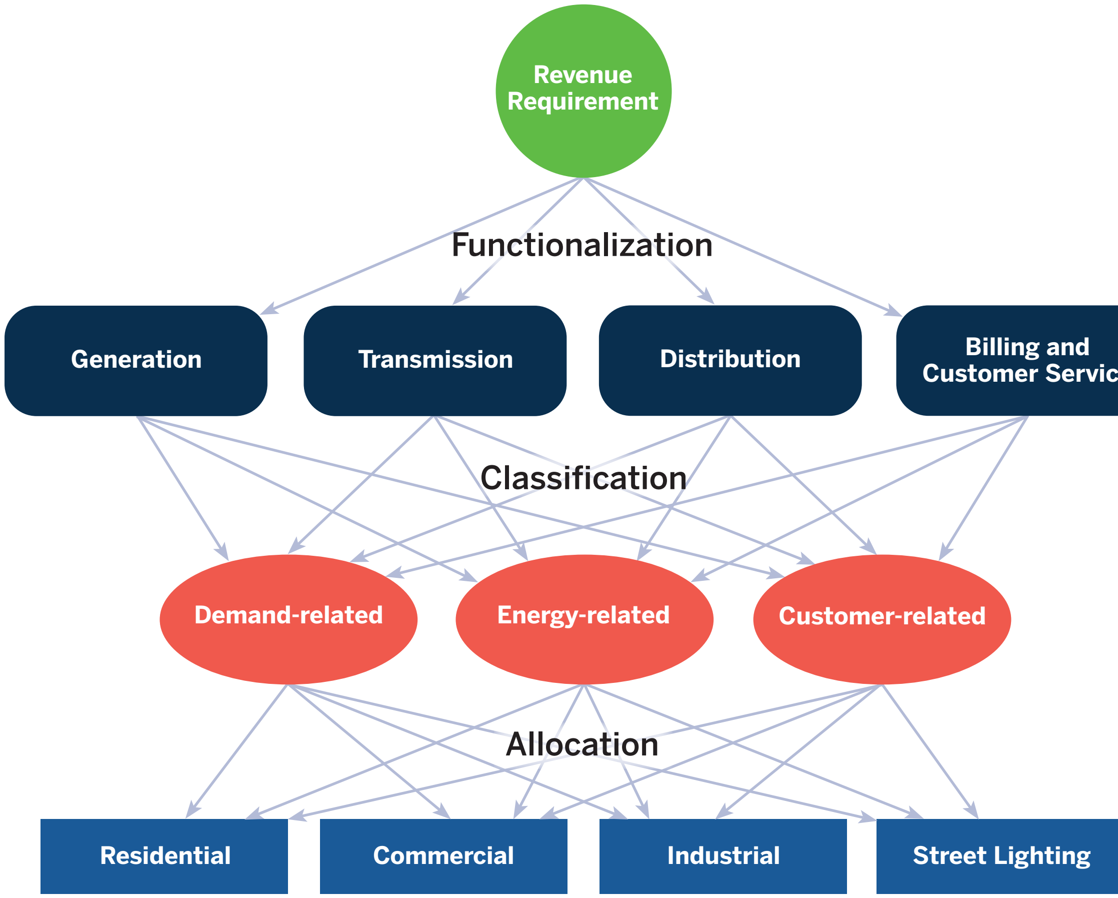
Whereas wholesale rates are determined in wholesale electricity markets, retail rates are administratively determined—by a utility commission for investor-owned utilities and by an oversight board for publicly owned utilities and cooperatives. For brevity, we describe here the administrative process used by utility commissions.

Determination of rates starts with an assessment of the revenues required to operate. Costs have historically been allocated to functional categories, from which they are put into three buckets—demand (peak)-related, energy-related, and consumer-related, as shown in Figure 1. Demand-related costs are those related to consumption during system peak demand, and energy-related costs

Since the vast majority of small commercial and residential utility consumers and some large commercial and industrial consumers do not see wholesale price signals, they lack an important tool with which to align their consumption choices with the needs of a reliable grid.

FIGURE 1

Traditional Embedded Cost of Service Study



Costs have historically been allocated to functional categories, from which they are put into three buckets: demand (peak)-related, energy-related, and consumer-related. Demand-related costs are those related to consumption during system peak demand, and energy-related costs are related to the quantity of energy delivered, regardless of system conditions at any particular time or place. Consumer-related costs are allocated to consumers by type of consumer.

Source: LeBel et al. (2021); Regulatory Assistance Project.

are related to the quantity of energy delivered, regardless of system conditions at any particular time or place. Consumer-related costs are allocated to consumers by type of consumer.[5] For example, for residential consumers, the consumer cost typically includes the cost of the meter, the line drop to the consumer, and sometimes a portion of the cost of the nearest transformer.

In an era dominated by traditional generation, this cost allocation approach was somewhat aligned with grid needs; however, for systems with increasing levels of variable renewable energy and increasing bi-directional flows on distribution systems, it is rapidly becoming out of date. Today's grid has become a 24/7 grid, with grid needs arising in many different hours of the year, not only during predictable, peak hours. With today's grid, limiting allocation to the demand-related, energy-related, and consumer-related buckets shown in Figure 1 produces retail prices that may be severely unaligned with premise and distribution system grid needs. In response to this new reality, a more granular paradigm for allocating costs has been proposed that suggests at least four

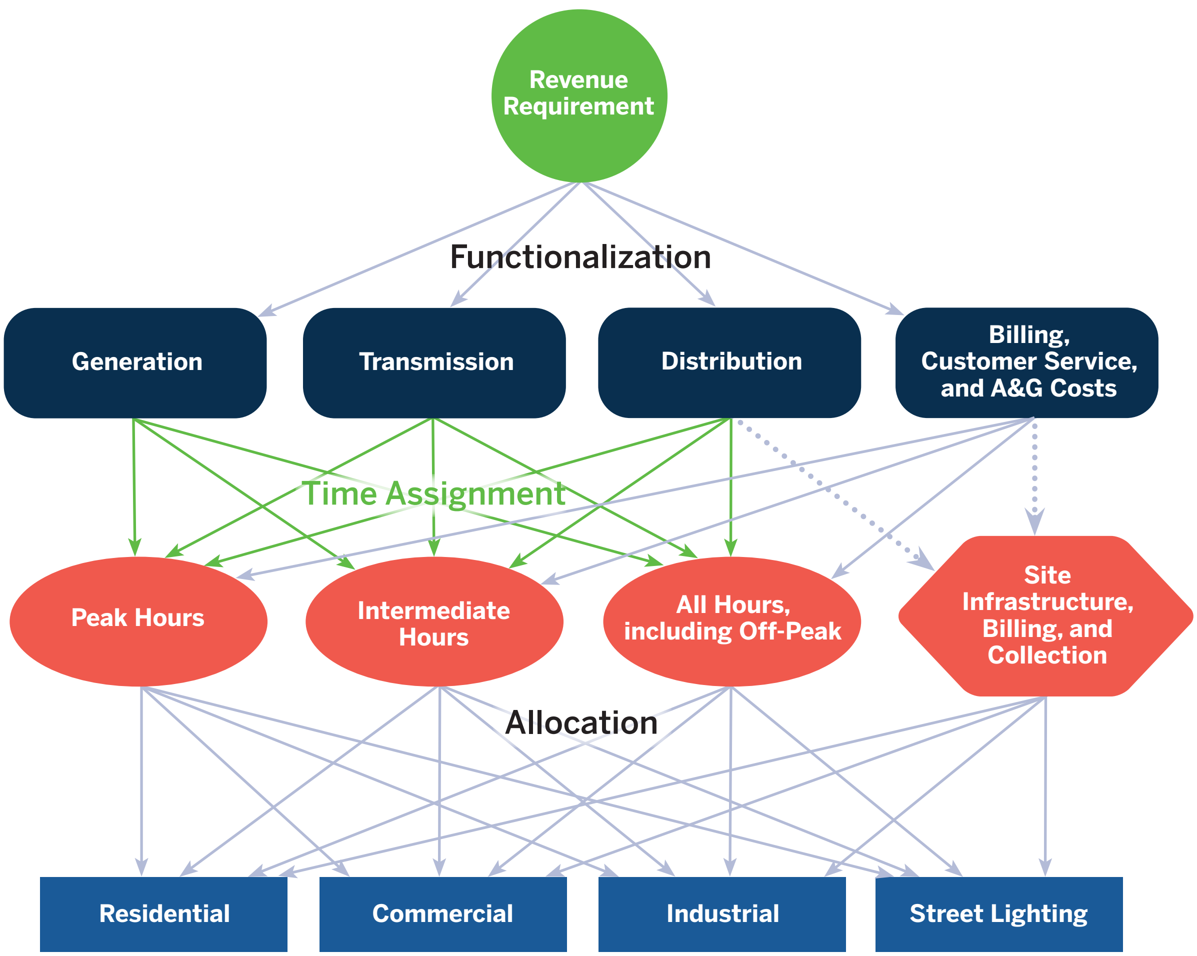
5 An excellent overview to cost allocation by the Regulatory Assistance Project can be found in Lazar et al. (2020).

discrete time assignment buckets, as shown in Figure 2. Further disaggregation into more granular time assignments is desirable and will become possible as data improvements and information technology advances allow.

Once costs are allocated, retail rates are set that recover the utility's costs of service. Ensuring that the utility has the opportunity to recover authorized costs of service is always important. Fairly allocating costs among consumers and setting rates are additional primary concerns of the regulator. A fair rate design considers several principles. Since the early 1960s, the retail rate design has been based on Bonbright's principles of cost causation, encouragement of efficient outcomes, fair value, consumer orientation, stability, equity, gradualism, and economic sustainability (Bonbright, 1961) (see Table 3, p. 12).

These principles do not produce a single answer: there is tension between some principles such that, depending on how each one is weighted, very different rate designs can result. It is often said that rate design is as much art as it is science. The aim of the task force was to identify how rate design can better meet existing and emerging grid needs while still meeting the goals of the other principles where applicable. While grid reliability is included in some of the principles indirectly, it is not listed explicitly.

FIGURE 2
Modern Embedded Cost of Service Study



The grid needs emerging today are occurring over many different hours of the year, not merely system peak and off-peak. In response to this new reality, a more granular paradigm for allocating costs is needed, as shown here.

Note: A&G = administrative and general.

Source: LeBel et al. (2021); Regulatory Assistance Project.

TABLE 3

Bonbright's Principles

Principle	Objective
1. Cost causation	Rates should reflect cost causation, including embedded costs, long-run marginal and future costs, and the fixed-cost nature of delivering electricity.
2. Encourage efficient outcomes	Rates should encourage economically efficient and market-enabled decision-making, for both efficient use of the grid by customers and new investments.
3. Fair value	Customers and utility should both be paid the fair value for the grid services they provide.
4. Customer orientation	Rates should aspire for simplicity while providing customer choices.
5. Stability	Customer bills should be relatively stable.
6. Equity	Electricity should remain affordable and accessible for vulnerable sub-populations.
7. Gradualism	Rate changes should be implemented in a manner which would not cause any large bill impacts.
8. Economic stability	Rate design should reflect a long-term approach to price signals, remain neutral to any particular technology or business cycle, and avoid cross-subsidies and prevent abuse/gaming/arbitrage.

Bonbright's principles have been used since the 1960s to guide rate design in the United States.

Source: Sergici (2022). Adapted from Bonbright (1961).

The principles of most immediate interest for mitigating and meeting grid needs are cost causation and encouraging efficient outcomes; addressing grid needs has associated costs, and using consumer resources to meet grid needs can be an efficient outcome. However, it is still necessary to engage all principles to arrive at a fair rate design, because all of the principles are relevant in ensuring rates that effectively engage consumer interest and protect consumers from unfair burdens.

Common Alternatives to Traditional Retail Rate Design

Traditional residential rate design in the era before active demand, electrification, and variable generation was typically limited to a fixed charge and a time-invariant volumetric rate—one that varies according to volume of use but not time of use. Traditional residential rate design is not well aligned with the grid needs that have emerged in the modern era, so alternatives that remedy the deficiencies have emerged.

Common alternatives to the traditional residential rate design include time-of-use, critical peak pricing, peak time rebates, variable peak pricing, demand charges, real-time pricing, and two-part real-time pricing (based off a diurnal profile) (Table 4, p.13). There are variations on these. For example, demand charges may be based on coincident peak or non-coincident peak, real-time prices might be based on day-ahead market prices or real-time market prices, and real-time prices could have guardrails to prevent issues such as Griddy consumers being charged $90/kWh for days during the rolling blackout in ERCOT in February 2021. In addition, competitive retail markets have illuminated the potential for innovative new designs that may be attractive to consumers including subscription rates (a fixed bill with separate payments), free nights and weekends when consumers are not charged for consumption, and others.

Historically, volumetric, tiered rates (also known as inclining block rates in which rates increased for higher consumption) that did not change during the day were

TABLE 4
Common Alternative Retail Rate Designs

Rate Type	Definition
1. Time-of-use rates	The day is divided into peak and off-peak time periods. Prices are higher during the peak period hours to reflect the higher cost of supplying energy during that period.
2. Critical peak pricing	Customers pay higher prices during critical events when system costs are highest or when the power grid is severely stressed.
3. Peak time rebates	Customers are paid for load reductions on critical days, estimated relative to a forecast of what the customer would have otherwise consumed (their "baseline").
4. Variable peak pricing	During alternative peak days, customers pay a rate that varies by day to reflect dynamic variations in cost of electricity.
5. Real-time pricing	Customer pay prices that vary by the hour to reflect the actual cost of electricity.
6. Two-part, real-time pricing	Customer's current rate applies to a baseline level of consumption. A second, marginal cost–based price applies to deviations from the baseline consumption.
7. Three-part rates	In addition to a volumetric energy charge and fixed charge, customers are also charged based on peak demand, typically measured over a span of 15, 30, or 60 minutes.
8. Fixed bill with incentives	Customers pay a fixed monthly bill accompanied with tools for lowering the bill (such as incentives for lowering peak usage).

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viewed as a signal to encourage energy efficiency during all hours. For a system with expensive fossil-fueled generation on the margin, this type of rate helped to reduce fuel use, but it did not discern between expensive peak and inexpensive off-peak periods. Additionally, this rate discourages increased electricity consumption due to electrification of heating or transportation, as described in the white paper in this series titled "Heat Pump–Friendly Cost-Based Rate Designs" by Sergici et al. (2022).

Time-of-use rates provide a signal to encourage investments and behavior focused on shifting demand from peak to off-peak periods. In this way, they have a similar effect on the power system as a storage resource that charges during off-peak and discharges during peak. However, increased variability in resources and loads are making fixed-time-period rates less effective because time-of-use periods are established months or years in advance and thus may not keep pace as electrification and net consumption variability increase. The advantage of fixed period time-of-use rates is that they are easy for consumers to understand and plan consumption choices accordingly.

Pricing that can reflect these real-time needs can help to address the mismatch between time-of-use periods and increasing variability in periods of grid stress, but can be a bit more challenging for customers to understand. Critical peak pricing, variable peak pricing, real-time pricing, and peak time rebates are options to address time-varying needs more dynamically than time-of-use pricing. By reflecting a high price during a peak event, these rates can have a similar effect on the grid as a peaker resource that runs only during high-stress periods.

The various alternative rates may work well for some grid services but not others. Table 5 (p. 14) provides an example of how well these retail pricing options may be able to meet a range of grid needs, with green indicating more potential, yellow indicating modest potential, and orange indicating little potential. The light green indicates the potential to meet these grid needs if there is the capability for locationally specific price signals. In all cases, the implementation of the pricing approach matters, and so simply adopting a pricing approach that is green relative to a specific grid need does not guarantee that need will be met. For example, weaker price signals may result in less customer response; longer peak periods or calls that are too frequent may result in consumer fatigue. Addressing distribution system needs could require locationally specific, real-time forecasts and loading data and communications that most systems do not have. In selecting a rate design, considering the most critical grid needs in play on the utility system and the infrastructure needs is an important first step toward identifying rate designs that are more likely to mitigate those key needs.

In addition to pricing, real-time needs can be reflected in DER programs. Pricing and programs can be complementary if designed well. For example, Hines et al. (forthcoming) discusses how Arizona Public Service (APS) uses time-of-use rates and demand charges as a coarse tool to shape demand, with DER programs layered on top to provide a precise tool in real time to manage demand. Pricing and programs are also complementary in that pricing is needed to help provide an investment signal for DER program infrastructure and aggregators. Without retail pricing signals, DER aggregators' only source of income is from arbitrage and other services in the wholesale markets, which is often not sufficient to cover their costs and attract consumer participation. Time-varying retail prices give the consumer and aggregator another value stream.

Grid needs originate at each layer of the grid: at the premise, on the distribution system, and on the bulk system. Similar to issues with DER integration into wholesale markets, perfectly aligning retail pricing with wholesale market prices could potentially exacerbate grid needs on the distribution system when wholesale market conditions are not well aligned with local distribution conditions. Local distribution constraints should likely take precedence over bulk power system needs simply because there are fewer resources and options available to manage local demand.

A consumer's location on the grid network and the nature of the consumer's demand matter. Consider, for

TABLE 5

An Example Mapping of Rate Designs to Their Suitability for Meeting Specific Grid Needs

Pricing	Energy	Capacity	Distribution Capacity	Transmission Capacity	Ramping	Spinning
Flat volumetric rates	Yellow	Orange	Orange	Orange	Orange	Orange
Time-of-use rates	Green	Yellow	Yellow	Yellow	Orange	Orange
Critical peak pricing	Orange	Green	Light green	Light green	Orange	Orange
Peak time rebates	Orange	Green	Light green	Light green	Orange	Orange
Variable peak pricing	Orange	Green	Light green	Light green	Orange	Orange
Real-time pricing	Green	Green	Light green	Light green	Green	Green
Two-part, real-time pricing	Green	Green	Light green	Light green	Green	Green
Demand charge	Yellow	Green	Light green	Light green	Orange	Orange

An example of how well these retail pricing options may be able to meet a range of grid needs, with green indicating more potential, yellow indicating modest potential, and orange indicating little potential. The light green indicates the potential to meet these grid needs if there is the capability for locationally specific price signals.

Source: Energy Systems Integration Group.

example, a consumer with significant on-site electric vehicle charging infrastructure. A strong alignment with wholesale market pricing may make sense if they are connected at the transmission level or connected to a distribution feeder and substation with ample margin. But an alignment with local distribution grid conditions may make more sense if they are deep in the distribution network on a radial feeder that has little margin. The white paper in this series by Olson et al., "Rate Design for the Energy Transition: Getting the Most out of Flexible Loads on a Changing Grid," discusses a pricing approach for addressing needs related to stresses at the bulk power system level, transmission level, and local distribution level. In aligning retail rates with grid needs, the utility and the regulator need to consider the range of grid needs in play and make a conscious choice about which grid needs should be the focus in setting a time-varying rate structure for particular customers and classes of customers.

Using Wholesale Market Design to Inform Retail Price Structures

Based on the discussions thus far, one might simply ask, why not use the locational prices for energy and grid services that are aligned with grid needs at the wholesale market level, and communicate and charge these rates to all consumers? While not everyone may agree on all aspects of wholesale electricity markets, there is general consensus in the industry that the short-term wholesale energy markets with bid-based locational marginal pricing have been successful in driving operational decisions of suppliers. They were designed in theory to incentivize suppliers and consumers in an equal manner.

However, it may not be simple to force locational marginal pricing on all residential consumers all of the time. For technological, comfort, equity, and other reasons, these designs may not be feasible without alteration on the retail side. However, given the attention to detail and consensus of wholesale market design efficiency, the wholesale market designs could be used as a starting point when evaluating changes to retail rate design. A decision chart similar to that shown in Figure 3 (p. 16) could potentially be used to determine how a particular service (such as energy, supply capacity, transmission, or ancillary grid services) can be incentivized through retail rates. By looking at how prices are formed for the particular service in the wholesale market (if applicable), if the design has been efficient and successful, rate designers could evaluate whether it can be used at the retail level, and if not, why. This would allow them to move ahead with a practical design that shares some of the benefits but is free of the limitations that were found with pushing the original design at the retail level.

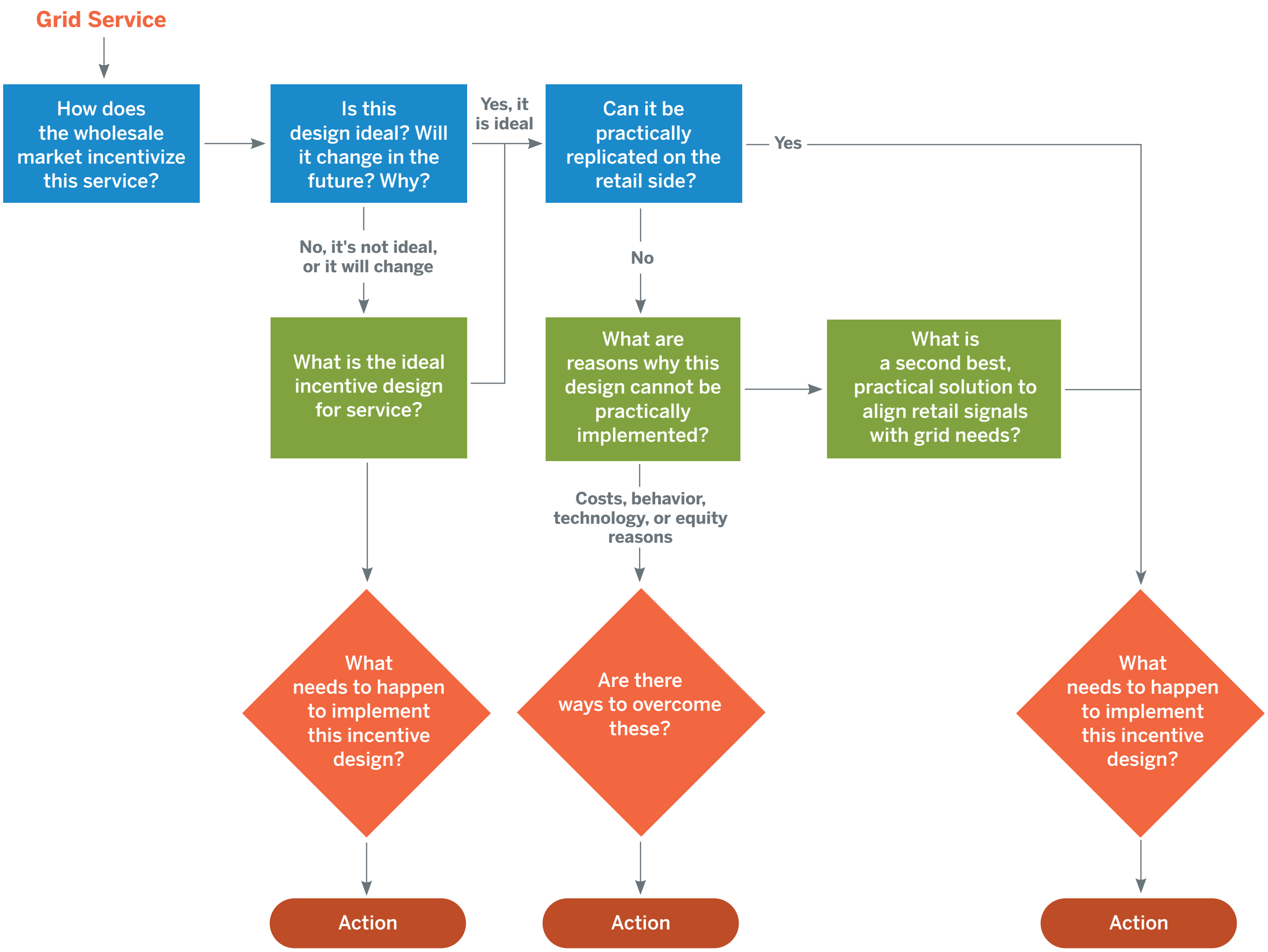
Given the attention to detail and consensus of wholesale market design efficiency, the wholesale market designs could be used as a starting point when evaluating changes to retail rate design.

Energy supplied or consumed at a time and location, can provide a helpful example. First, how does the wholesale market incentivize this service? In U.S. electricity markets it does so through hourly day-ahead and 5-minute real-time wholesale locational marginal prices. Many believe that this design is efficient for wholesale suppliers to supply efficient energy when and where it is needed. Can this be practically replicated on the retail side? The answer today is "possibly," and retail designers may need to review the reasons that could limit its practical application. Five-minute prices may be too granular to get most residential consumers to react unless they own very sophisticated automation technology. In addition, high and volatile prices may be too extreme for certain customer classes. A modified version of this design may be more practical, such as a regional price from the day-ahead market at an hourly resolution (most real-time pricing designs) with other options available for consumers' choosing.

An ancillary service, such as regulation service, and how to incentivize consumers to provide this service or reduce the need for it, may look very different to retail rate designers when going through this process. Many of these ancillary services have similar granular prices in the wholesale market to wholesale energy markets, which may not be very practical at all to replicate in retail rates with today's technology, and so second-best, practical solutions must be designed to meet these grid needs through retail pricing as best they can. For the example of regulation ancillary service, this option could involve a retail customer participating in the wholesale market directly through an aggregator, such as what has been proposed through FERC Order 2222 and existing demand-side ancillary service programs. The process outlined in Figure 3 may also be helpful for analyzing how rate design can improve other grid services not offered in wholesale markets, such as distribution services, by reviewing analogous services that are in place (such as transmission congestion management). Ultimately, it will be important for wholesale market designers and retail rate designers to collaborate and coordinate on effective designs, as the products and services that they are designing markets for are ultimately the same.

FIGURE 3

Process for Determining Whether Features of a Service in the Wholesale Market May Be Useful in Retail Rate Design



This process can help to determine whether features of a service in the wholesale market may be useful in retail rate design. In regions outside of independent system operators' or regional transmission organizations' territories, "wholesale market" can mean how a utility incentivizes the service from independent power producers in its region. The assumption is that the ideal solution for incentivizing a service on the wholesale side is also the ideal on the retail side, but this process can be used in either case.

Source: Energy Systems Integration Group.

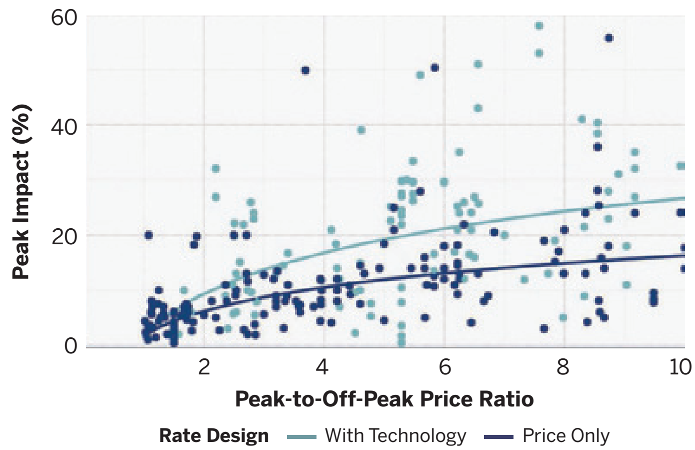
Consumer Needs

Consumers' Responsiveness to Prices

Whereas pricing on the wholesale market is mostly driven by market forces, pricing on retail systems has to accommodate diverse consumers with diverse objectives, including socio-economic concerns and the fact that electricity is a basic need. As discussed above, historically, retail rates have not varied temporally or locationally at anywhere close to the variation seen on wholesale markets. These costs are also not separately reflected in consumer rates in most states and for most utilities, so consumers have no price signal that induces a response that helps mitigate or resolve distribution system or bulk system needs. However, increasing digitization, decentralization, and electrification has begun producing more variable rate designs for utility consumers. Traditionally, retail consumer demand has been assumed to be generally inelastic, meaning that demand is assumed to be insensitive to prices. However, meta-studies of hundreds of pricing experiments demonstrate otherwise: Figure 4 shows greater reductions in peak electricity demand as peak to off-peak price ratios increase, with even greater reductions when enabling technology is used (Faruqui and Bourbonnais, 2020; Faruqui, Sergici, and Warner, 2017). Pricing is quickly becoming another tool in the toolbox for grid management as APS (Hines, 2021), Sacramento Municipal Utility District (SMUD) (SRP, 2023), Ontario (Navigant, 2013; Ipsos Public Affairs, 2014), ERCOT (ERCOT, 2023), and many others have found.

Consumers typically have no price signal that induces a response that helps mitigate or resolve distribution system or bulk system needs.

FIGURE 4
Price Responsiveness Under Dynamic Pricing Experiments



Greater reductions in peak electricity demand are seen as peak to off-peak price ratios increase, with even greater reductions when enabling technology is used.

Source: © 2022 IEEE. Reprinted with permission from Faruqui and Bourbonnais (2020) (https://ieeexplore.ieee.org/document/9069846).

Ratemaking principles need to consider consumer behavior. For example, if average costs during peak periods are only modestly higher than average costs during off-peak periods, cost causation might suggest that peak to off-peak ratios of a time-of-use rate should likewise be modest. However, consumers given peak and off-peak prices that are only modestly different may not be sufficiently incentivized to change their behavior. A larger price signal may be needed to change their behavior, even if that larger price signal does not match the average peak to off-peak wholesale price ratio.

TABLE 6

Three-Dimensional Grid Needs and Retail Challenge

Grid Needs	Incentives	Consumer Loads
• Energy • Supply capacity / adequacy • Deferred transmission and distribution upgrades • Congestion management • Ramping reserve • Regulation reserve • Spinning reserve • Frequency response • Voltage regulation • Black start	• Time-of-use rates • Critical peak pricing • Peak time rebates • Variable peak pricing • Real-time pricing • Two-part real-time pricing • Three-part rates • Fixed bill with incentives (subscription) • Demand charge	• Electric vehicles • Heating, ventilation, and air conditioning, and heat pumps • Water/other heaters • Water/other pumps • Data centers • Cryptocurrency mining • Industrial heat • Hydrogen production • Compressors • Aerators • Fans/dryers • Cooling towers • Behind-the-meter batteries

It is important to understand the flexible load potential in a particular service territory and be aware of the three-dimensional matching among grid needs, incentives, and consumer loads so as to promote the right incentive for the right grid need that will be able to get the right response out of demand flexibility.

Source: Energy Systems Integration Group.

Different load technologies and devices will also have distinct capabilities and responsiveness. The various types of consumer loads will be able to provide different services at different performance levels. Similarly, different retail rate incentives may be more or less useful for particular load technologies or particular grid services. While it is important that any design be technology-agnostic as best it can, it is also essential to understand the flexible load potential in a particular service territory and be aware of this three-dimensional matching in order to promote the right incentive for the right grid need that will be able to get the right response out of demand flexibility (see Table 6).

Ability of Retail Prices to Encourage or Discourage Electrification

Because the electricity sector has a more cost-effective pathway toward decarbonization than other energy sectors used by transportation, buildings, and industry, it is widely acknowledged electrification—combined with decarbonizing the electricity sector—is the best pathway to economy-wide decarbonization. Rate design has a large impact on whether consumers are incentivized or penalized when electrifying various end uses. Typical residential rates in which most of the utility costs are recovered through flat volumetric rates may be financially penalizing consumers who purchase electric vehicles or heat pumps, especially if these rates are tiered with higher rates for greater consumption. It may not be financially beneficial for them to use electricity during the time periods or locations where it is at lowest cost or lowest carbon emissions. This may become a greater issue when large loads, such as the production of industrial heat or steam, seek to electrify.

ESIG's Aligning Retail Pricing and Grid Needs Task Force explored how rate design needs to evolve as the timing, location, and nature of grid needs change and as the broader electrification of the economy proceeds. Recovering a greater portion of the cost of service through fixed charges is one option, proposed in white papers by Sergici et al. (2022) and Olson et al. (2023). However, there is great debate over fixed charges in general, as they may not incent consumers to change day-to-day behavior. White papers by Kavulla (2023) and Hogan (2022), for example, suggest more dynamic rates to incentivize consumers to shift demand to times when the price of energy is low.

Bridging the Gap

Given the needs of the grid, the needs of consumers, and the principles behind rate-making, how can retail pricing help prepare for a future with increased variable renewables and increased electrification? There are several dimensions to the evolution of retail pricing.

First, we recognize that retail prices start with consumers. Designing prices with a consumer-first approach is key to consumer adoption, satisfaction, and retainment. Hines et al. (forthcoming), explains APS's customer-centric approach for its prices and programs as well as the interaction between the two. A consumer's APS bill tells them how much money they would have saved over the past several months if they had been on a different pricing plan, providing them with some certainty about the value proposition. And consumers are not monolithic. Choices are essential to offer because not all consumers have the interest or ability to understand and adapt (or invest in technology to adapt) to more complex or more dynamic pricing. Kavulla (2023) makes a good case for both giving choices and having time-of-use rates be the default option.

Second, the future grid requires flexibility, and if we only consider flexibility from generation resources, we are missing half of the equation. If we want flexibility from demand, as Kavulla explains, we need to expose someone—whether consumers or retailers or load-serving entities—to price signals that better reflect cost causation and grid needs. These price signals are not just for wholesale energy, but also supply capacity, transmission and distribution, or even grid services. In fact, Hogan discusses that supply capacity, transmission, and distribution may likely end up being the larger value streams.

Designing prices with a consumer-first approach is key to consumer adoption, satisfaction, and retainment.

Third, while time-of-use rates are a good place to start, we note that they largely address the energy-shifting need and, to some degree, the supply capacity need. They may not always align to address transmission or distribution infrastructure needs. If supply capacity, transmission, and distribution are the larger value streams to be captured, Olson et al. (2023) present a rate that addresses all of these. Sergici et al. (2022) present options that also focus on not penalizing electrification while still recovering utility revenue requirements.

In addition, the grid may need more dynamic interaction than existing time-of-use rates because these rates cannot reflect real-time grid conditions. This does not mean that all consumers need to be on real-time pricing. Rather, increasing the number of consumers on more dynamic rates will be helpful for the grid. Olson et al. (2023) propose a dynamic hourly energy charge aligned to long-run marginal costs. O'Neill, Lew, and Ela (2023) make the case for demand, especially large commercial and industrial consumers, to respond to day-ahead and real-time wholesale prices to deliver benefits to both the grid and the consumer. As an example, Chen's white paper, "Leveraging Locational and Temporal Flexibility in Transportation Electrification to Benefit Power Systems," discusses potential DC fast-charging stations interconnected directly onto the transmission system and responding to wholesale prices (Chen, 2023). Hogan (2022) explains that we need to start treating demand as demand rather than treating reduced demand as supply. Consumers responding to day-ahead and real-time prices, and reducing demand during scarcity events when prices are high, achieves this goal. This approach also eliminates the need for complex monitoring and verification, which is necessary in demand response, when reduced demand is treated as supply.

Fourth, retail pricing can be more than just a way to recover revenue requirements. It can be a tool for resource planning and can provide grid services similar to what storage or a peaking plant can provide. Better retail pricing can reduce total system costs—the costs that ultimately are borne by all consumers. It can enhance grid reliability by managing demand.

Fifth, it is important to understand the certainty, or reliability or predictability, of a response from any resource. System operators need confidence in price-responsive demand if they are to depend on it in their operational forecasts and unit commitment and economic dispatch decisions. System planners need confidence if they are to rely on reduced demand forecasts as they determine supply, transmission, and distribution needs and investments. As an industry, more data and analysis are needed to understand consumer responsiveness.

Finally, distribution systems are going to be increasingly stressed with electrification, but today, we do not have any type of pricing on the distribution system analogous to the bulk system and wholesale market to signal consumers to react and support the distribution network. Wholesale locational marginal prices have proven an effective signal for managing the bulk power system, and expanding these prices to distribution systems may offer similar benefits to the distribution system. Olson et al. (2023) discuss the potential for coincident peak demand charges on distribution systems as a way to manage congestion. Even before sophisticated distribution locational marginal pricing can be realized, the implementation of a coincident peak demand charge, a peak time rebate, or a critical peak price on the distribution system can be a way to reduce demand using today's technology.

Task Force White Paper Series

There are many perspectives from which to examine the use of retail pricing to incentivize flexible loads to support power system needs. Seven members of ESIG's Aligning Retail Prices and Grid Needs Task Force led the development of a series of seven white papers that examine some of these perspectives with specific applications. The task force provided substantial feedback and direction to the effort. The papers are introduced below with links to each of the published pieces, the culmination of a year-long discussion on the topic of retail pricing with key experts from across the industry.

"'Why is the Smart Grid So Dumb?': Missing Incentives in Regulatory Policy for an Active Demand Side in the Electricity Sector," by Travis Kavulla (NRG Energy) https://www.esig.energy/missing-incentives-in-regulatory-policy-for-active-demand-side/

Travis Kavulla examines the unfulfilled promise of the smart grid: the low use of time-varying rates relative to the deployment of advanced metering infrastructure (Kavulla, 2023). He focuses on two utility business models—cost-of-service utilities and competitive retailers—and compares their exposure to price risk including generation, transmission, and distribution costs. He discusses many ways in which consumers are shielded from price risk and concludes that we cannot extract demand flexibility until we expose consumers—or, in many cases, their wholesale providers—to generation, transmission, and distribution costs. This can be done by making time-varying rates the default for regulated utilities, by ensuring that competitive retailers are exposed to all relevant marginal costs (including transmission costs), and by bolstering public investment in and standardizing automated devices.

"Treating Demand Equivalent to Supply in Wholesale Markets: An Opportunity for Customer, Market, and Social Benefits," by Richard O'Neill (Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy), Debra Lew (Energy Systems Integration Group), and Erik Ela (Electric Power Research Institute) https://www.esig.energy/treating-demand-equivalent-to-supply-in-wholesale-markets-an-opportunity-for-customer-market-and-social-benefits/

Richard O'Neill, Debra Lew, and Erik Ela discuss how efficient markets are two-sided—with both supply and demand responding to price—but that wholesale electricity markets are unusual in that demand is considered to be price-inelastic (O'Neill, Lew, and Ela, 2023). Like other papers in this series, they argue that demand is elastic, and the need is to create mechanisms and incentives for demand to respond to wholesale prices by bidding into the wholesale market as generators do. Consumers could bid in offers to wholesale day-ahead markets and receive a schedule. Then, in real time, depending on market rules, they could adjust their demand based on real-time prices or they could bid into the real-time market and receive 5-minute dispatch signals for their demand. The ability to bid in demand would put consumers on equal footing as generators; expose consumers to energy and ancillary market prices, thus allowing them to save money when they help the grid; eliminate baselining, benefit valuation, and monitoring and verification issues that plague demand response today; and reduce overbuilding in supply infrastructure.

"Tapping the Mother Lode: Employing Price-Responsive Demand to Reduce the Investment Challenge," by Michael Hogan (Regulatory Assistance Project) https://www.esig.energy/price-responsive-demand-to-reduce-investment-challenge/

Michael Hogan finds the principal sources of value from flexible demand to be infrastructure for generation, transmission, and distribution capacity (Hogan, 2022). He shows how elastic demand curves (price-sensitive demand) can provide financial benefits to consumers, and how reserve shortage pricing can further increase those gains. He argues that markets typically force-fit demand into mimicking supply; that is, they treat demand reductions as generation, which has shortcomings compared to treating demand as demand in a full two-sided market. He discusses how we over-procure supply due to differences in how shortages are priced in long-term supply capacity markets versus reserve shortage pricing in real-time markets. He offers as solutions: more dynamic retail pricing and more retail service options offered by competitive third-party providers akin to options offered in jurisdictions that have competitive retail service providers, addressing price discrimination for shortages, and internalizing flexible demand into planning and procurement of infrastructure.

"Rate Design for the Energy Transition: Getting the Most out of Flexible Loads on a Changing Grid," by Arne Olson, Eric Cutter, Lindsay Bertrand, Vignesh Venugopal, Sierra Spencer, Karl Walter, and Aryeh Gold-Parker (Energy and Environmental Economics (E3)) https://www.esig.energy/price-responsive-demand-to-reduce-investment-challenge/

Arne Olson and colleagues discuss the nature of low-carbon grids that are dominated by long-term fixed investments, and decarbonization through increased electrification which should not be penalized in retail pricing (Olson et al., 2023). They argue that demand flexibility can provide high value by avoiding long-term fixed investments in generation, transmission, and distribution infrastructure and in dynamic load-shifting to match variable renewables. They discuss how more granular multi-part rates could include an hourly energy rate that is low in most hours when zero/low-variable-cost resources are abundant, a size-based charge that encourages load reductions during the small number of hours driving infrastructure investments, and non-bypassable consumer charges designed for equity that recover utility embedded and unavoidable fixed costs.

"Leveraging Locational Temporal Flexibility in Transportation Electrification to Benefit Power Systems," by Jennifer Chen (World Resources Institute) https://www.esig.energy/leveraging-locational-and-temporal-flexibility-in-transportation-electrification-to-benefit-power-systems/

While most retail pricing focuses on temporal flexibility, Jennifer Chen examines locational flexibility, in particular, how locational marginal prices may be considered in the siting of electric vehicle (EV) charging facilities (Chen, 2023). She explores how EVs' ability to charge where and when electricity is cheaper on the bulk power system can help to lower system costs, improve renewable integration, and improve system reliability. Charging station siting and rates that take into account the locational and temporal values of electricity could allow drivers to react to EV charging prices, similar to how consumers react to gasoline prices today. Large EV fleets could be sited away from congested distribution grids and account for transmission bottlenecks to reduce infrastructure needs.

"Heat Pump–Friendly Cost-Based Rate Designs," by Sanem Sergici, Akhilesh Ramakrishnan, Goksin Kavlak, Adam Bigelow, and Megan Diehl (Brattle Group) https://www.esig.energy/heat-pump-friendly-rate-designs/

Sergici and colleagues examine retail rate design that can encourage the electrification of the building sector (Sergici et al., 2022). With a focus on the use of heat pumps for space heating, they examine the impact of three new rate designs on 80 sample residential customers. Each rate is designed to be revenue neutral so that electrification is not subsidized. They calculate how rate designs affect these customers' heating bills after heat pumps are installed, and find that under default rates, energy costs for heating are higher for all 80 customers, but under any of the three alternative rates studied, energy costs for heating are lower for all 80 customers.

"Orchestrating Customer Programs and Rates For a Customer-centric Path to Clean Energy," by Thomas Hines et al. (Arizona Public Service (APS)) (Forthcoming)

Hines and colleagues describe how APS, an Arizona utility, has some of the longest and most utilized experience with time-of-use and demand rates in the United States, has rapidly growing DER programs, and is gaining experience with coordinating the two approaches. They discuss how providing consumers with time-of-use and demand rate options can send consistent, technology-neutral price signals that better align overall grid needs with individual consumer benefits. The offering of easy-to-adopt demand-side management programs to consumers that are coordinated with these rates encourages consumers to increase their partnership with the utility. The time-of-use rates provide clear price signals that encourage consumer technology adoption which can be leveraged to increase the scale of the demand response programs. APS designs and schedules the demand response events around time-of-use rate periods so that consumers see savings from both the time-of-use rates and the demand response program.

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Aligning Retail Prices and Grid Needs

A White Paper from the Energy Systems Integration Group's Aligning Retail Pricing and Grid Needs Task Force

By Debra Lew, Erik Ela, and Carl Linvill

This white paper and the accompanying white papers are available at https://www.esig.energy/aligning-retail-pricing-with-grid-needs.

To learn more about the topics discussed in this white paper, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. More information is available at https://www.esig.energy.

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