Exh. JLB-16
Dockets UE-190529/UG-190530 and
UE-190274/UG-190275 (*consolidated*)
Witness: Jason L. Ball

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**DOCKETS UE-190529 and UG-190530 *(consolidated)***
In the Matter of the Petition of **PUGET SOUND ENERGY** **For an Order Authorizing Deferral Accounting and Ratemaking Treatment for Short-life UT/Technology Investment**	**DOCKETS UE-190274 and UG-190275 (*consolidated*)**

EXHIBIT TO TESTIMONY OF

Jason L. Ball

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

Flexibility for 21st Century Power Systems

November 22, 2019

OCTOBER 2019

Flexibility for the 21st Century Power System

Carl Linvill, Jim Lazar, David Littell, Jessica Shipley, and David Farnsworth

Introduction

Perhaps the most basic of electricity sector rules, one that has operated for over a century, is that electricity must be generated at precisely the same time it's consumed. For years, grid operators have determined load on a system and adjusted supply by adding available generators to meet it, first with the lowest-cost units, then adding more expensive ones until all of the electricity demand was satisfied.

Today, this fundamental rule has changed. New technologies on the supply side include fast-ramping and fast-cycling generation, new demand-side technologies like controlled water heating and storage, as well as improved transmission capabilities and system operations. This has created significant opportunity. For example, electric vehicles (EVs) or water heaters can charge during the night when power costs are low, or at mid-day when renewable generation is plentiful and may face curtailment. With those end uses, it doesn't matter whether your water was heated or your car battery charged five minutes or five hours before your shower or your drive.

Even though power systems have always had some ability to accommodate changes in supply and demand, flexibility will be "especially prized in twenty-first century power systems, with higher levels of grid-connected variable renewable energy (primarily, wind and solar)."[1] In 2018, the National Association of Regulatory Utility Commissioners' (NARUC) Electricity Committee and the Committee on Energy Resources and the Environment jointly moved passage of a resolution that calls on utilities and utility commissions to investigate the need for flexible resources and ensure that their capabilities are valued appropriately.[2]

This paper looks at various sources of flexibility available today and their potential for contributing to a more affordable, reliable and resilient power system capable of accommodating large amounts of variable renewable resources.

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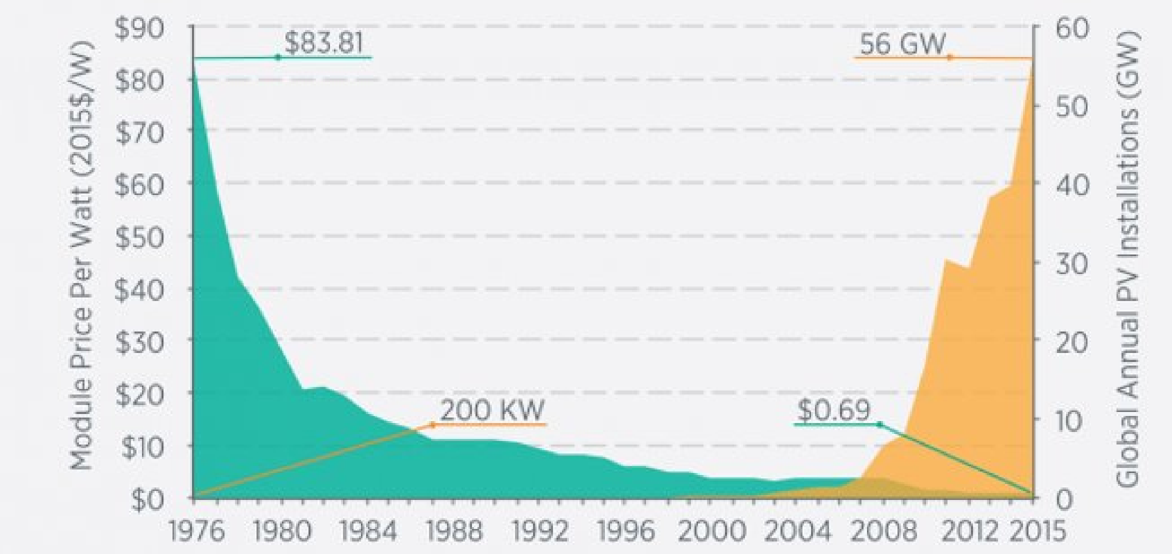
[1] Cochran, J., et al. (2014). *Flexibility in 21st Century Power Systems*. Washington, D.C.: National Renewable Energy Laboratory. Retrieved from https://www.nrel.gov/docs/fy14osti/61721.pdf.

[2] National Association of Regulatory Utility Commissioners (2018). *EL-4/ERE-1 Resolution on Modeling Energy Storage and Other Flexible Resources*. Washington, D.C. Author. Retrieved from https://pubs.naruc.org/pub/2BC7B6ED-C11C-31C9-21FC-EAF8B38A6EBF.

Changes in the Utility Sector

Over the last several years, the costs of key technologies, such as wind generation, have dropped dramatically. The cost of solar generation has dropped, too (see green in Figure 1), while the rate of installation has increased significantly (yellow).

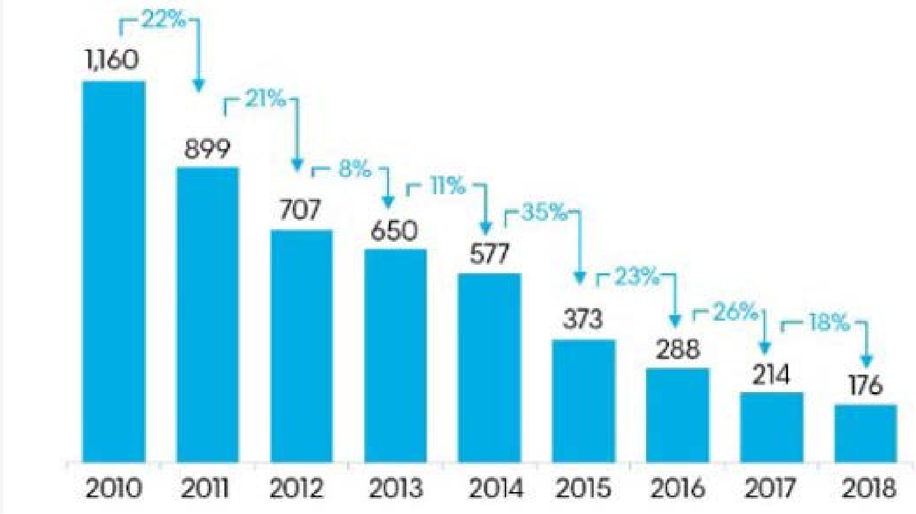
Figure 1. Price of solar vs. capacity of installations, 1976-2015



Source: SunShot, U.S. Department of Energy

The cost of electric storage also continues to drop, from $1,160 per kWh in 2010 to just $176 per kWh in 2018, lowering the cost of electric vehicles among other things (see Figure 2).

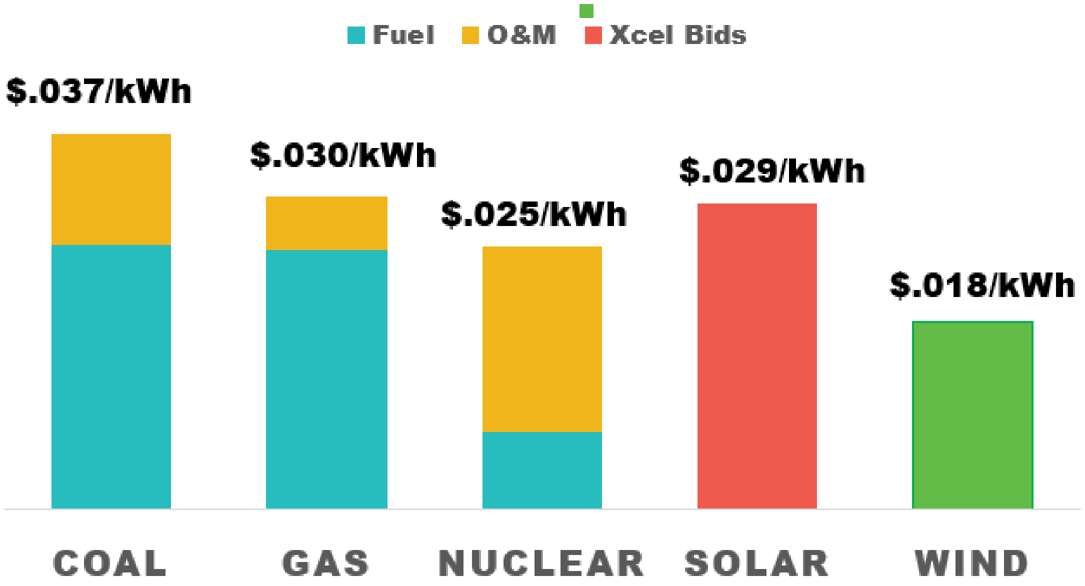
Figure 2: Battery pack price (real 2018 $/kWh)



Source: Bloomberg NEF. Data adjusted to be in real 2018 dollars.

At the end of 2017, Xcel in Colorado issued an all-source solicitation and received bids for wind and solar that are competitive with the operating costs of existing nuclear, coal and gas plants.

Figure 3: Existing plants vs. Xcel bids



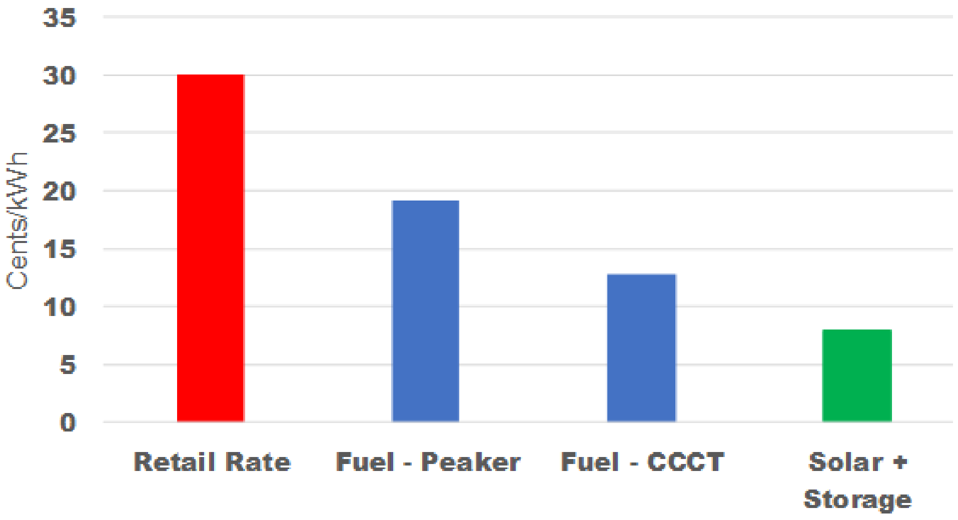
Source: USEIA Table 8.4 Electric Power Annual 2016

When Xcel submitted its proposed energy plan to the Colorado PUC at the end of 2018, it incorporated bids for these resources that were even lower: 1 cent per kWh for wind, 2 cents per kWh for solar, and 3 cents per kWh for solar plus storage. In light of these opportunities, Xcel proposed to close two coal units ten years ahead of schedule and to replace those resources with solar, wind and storage. Xcel estimates that the cost savings will be more than $200 million for ratepayers. While these prices may not be representative of renewables prices around the country, they do represent a general cost trend.

Similarly, in Hawaii — the first state to adopt a 100% renewables standard — Hawaiian Electric recently sought bids for solar plus storage, and submitted a portfolio of contracts for approval by the utility commission that would take the company from about 20% renewables to about 40% in one year. While costs are generally higher in Hawaii than on the mainland, each of these contracts was cost-effective compared with fuel costs alone for conventional resources in Hawaii.

When one compares these new contracts to existing rates and resources, it becomes readily apparent that they represent significant ratepayer savings. For example, as illustrated in Figure 4, Maui's average electricity price is about $.30/kWh. The average fuel cost for peaker power plants in Hawaii is about $.18/kWh, and the average fuel cost for the most efficient combined cycle plants is about $.13/kWh.

Figure 4: Maui electric rates, fuel, and new supply



Source: Data from Maui Electric Co.

By contrast, the proposed solar plus storage cost is only $.079/kWh, far below the operating cost of existing resources. Adding these resources should reduce both rates and bills for Hawaiian consumers.

Due to their low cost, such clean resources are good news for our economy and the environment. But, due to their relative variability, their adoption will increase the need for flexibility on the grid system. This greater flexibility makes it possible to schedule load to meet forecasted renewable energy generation. We describe these capabilities in the next two sections.

Supply-Side Flexibility

Increasing Resource and Geographic Diversity

In many cases over the last year, not only did renewable resources offer lower cost supply alternatives than existing resources, but their use in combination increased system flexibility as well. Figure 5 illustrates a case in Texas where wind resources (in two regions) and solar generation had different, but complementary, load capacity profiles.[3] In general, diverse renewable resources and a broader geographic footprint can complement each other, leveling system demand and reducing the need for flexible generation.

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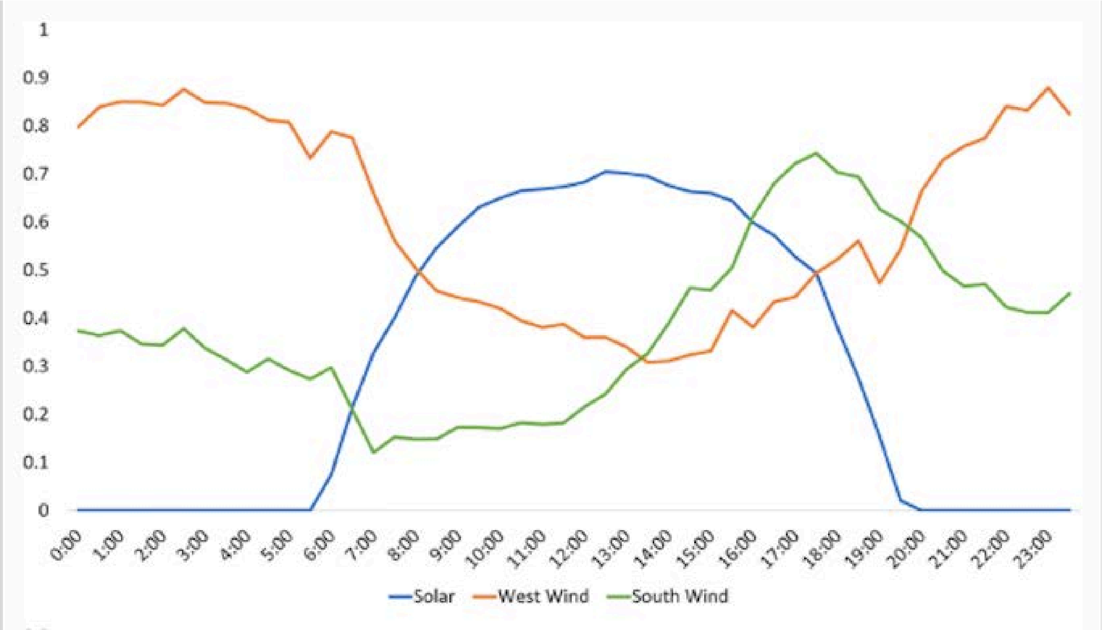
[3] Slusarewicz, J. and Cohen, D. (November 16, 2018). Assessing Solar and Wind Complementarity in Texas. *Renewables: Wind, Water and Solar*. Vol. 5, No. 7. Houston, TX. Department of Civil and Environmental Engineering, Rice University. Retrieved from https://jrenewables.springeropen.com/articles/10.1186/s40807-018-0054-3,

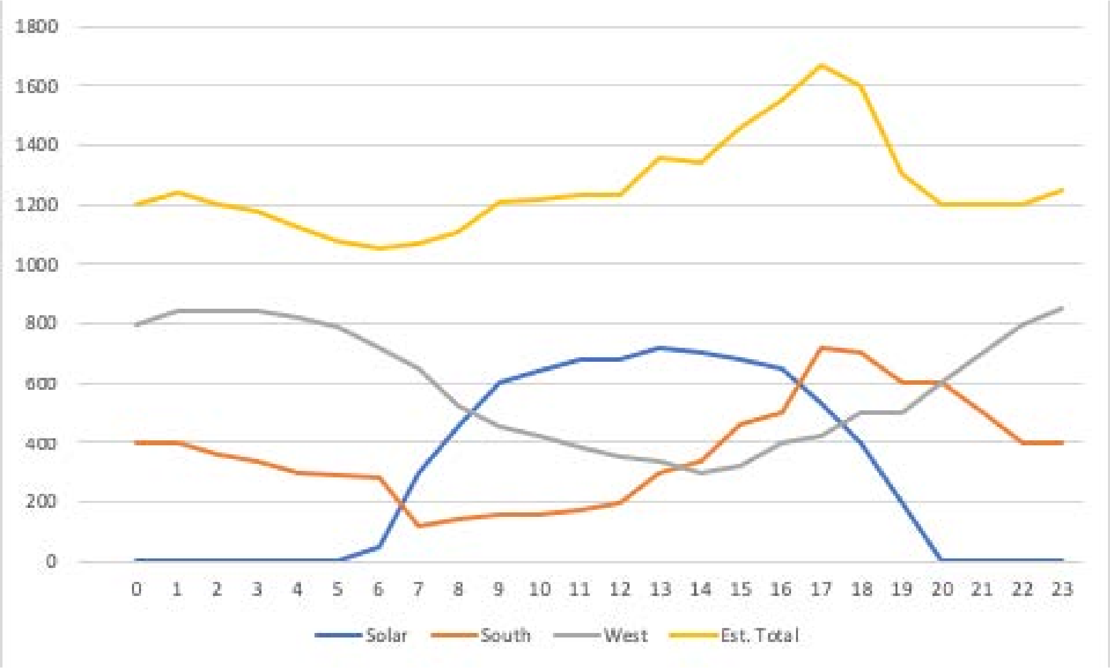
Figure 5: Texas wind resources and solar resources have complementary load capacity profiles



Source: Slusarewicz, J. H., & Cohen, D. S. (2018). Assessing Solar and Wind Complementarity in Texas. *Renewables: Wind, Water and Solar, 5* (7). Retrieved from https://jrenewables.springeropen.com/articles/10.1186/s40807-018-0054-3

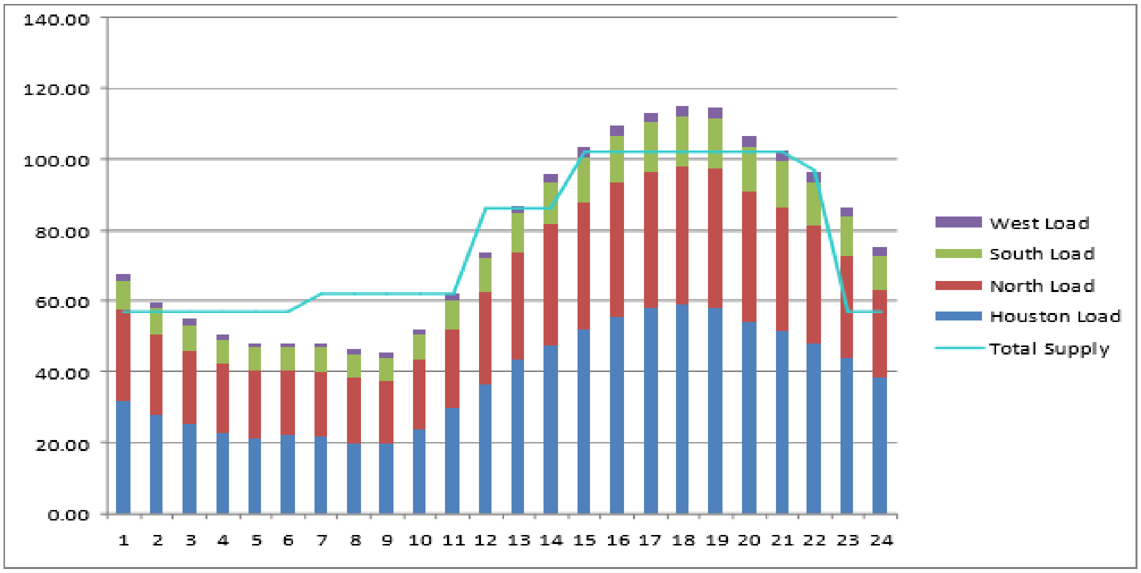
In combination, these resources can produce a smoother profile that more closely approximates system needs. For example, as the next two figures illustrate, if each profile (solar, west wind, and east wind) represented 1000 MW each (Figure 6), their combined capacity would approximate Texas' overall summer load profile (Figure 7).

Figure 6: Wind and solar summer production, 1000 MW of each of three resources



Source: Slusarewicz & Cohen, 2018

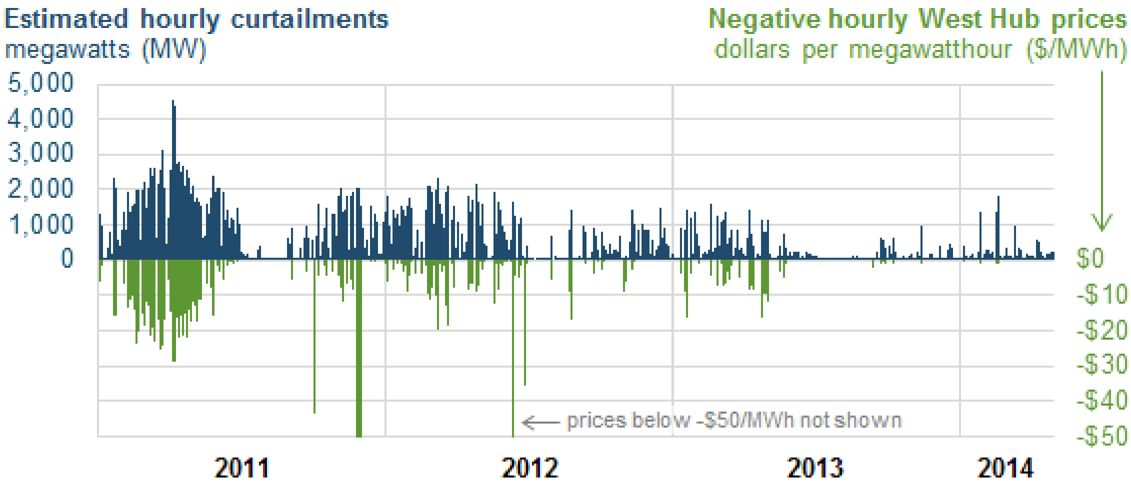
Figure 7: Texas summer load profile



Source: Sirius Solutions

Such a combination of generation supply would reduce the need for additional flexibility resources. Increasing resource and geographic diversity has not only reduced curtailments, as illustrated in Figure 8, it has also stabilized prices.[4] Reduced curtailment also helps to reduce carbon emissions in Texas.

Figure 8: Texas (ERCOT) wind curtailments vs. negative West Hub real-time electricity prices



Source: U.S. Energy Information Administration, data from ERCOT and SNL Energy

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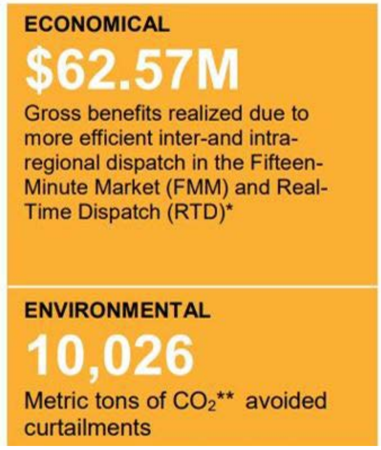
[4] Lee, A. (June 24, 2014). *Today in Energy: Fewer wind curtailments and negative power prices seen in Texas after major grid expansion*. Washington, D.C. U.S. Energy Information Association. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=16831.

The Western Energy Imbalance Market (EIM) is a real-time balancing market in the Western Interconnection with a larger geographic footprint that creates greater resource diversity for those who have joined.[5] Because members' flexible resources can be shared to meet needs across the entire footprint, the reserves required of each member have declined.

Figure 9 shows the benefits enjoyed quarterly by EIM participants. In the fourth quarter of 2018, EIM benefits exceeded $62 million and avoided more than 10,000 metric tons of greenhouse gas (GHG) emission through reduced curtailments.[6]

Figure 9: EIM benefits, fourth quarter of 2018



ECONOMICAL

$62.57M

Gross benefits realized due to more efficient inter-and intra-regional dispatch in the Fifteen-Minute Market (FMM) and Real-Time Dispatch (RTD)*

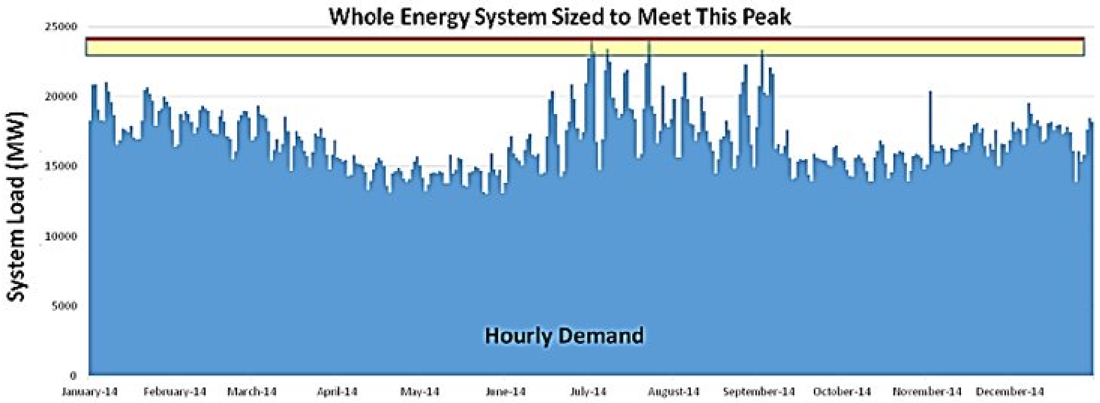
ENVIRONMENTAL

10,026

Metric tons of CO_2** avoided curtailments

Enlarging the geographic footprint of available resources creates the opportunity to take advantage of a greater diversity of resources. Larger markets, however, can also produce unnecessary costs at a large scale, which could be reduced by greater flexibility. For example, New England's grid, like many large wholesale markets, is built to serve peak loads, and the "need to size all grid infrastructure to the highest peak results in system inefficiencies, underutilization of assets, and high cost to ratepayers."[7] Between 2013 and 2015, on average, the top 1% of hours per year (87) constituted 8% of Massachusetts ratepayers' electricity costs, while the top 10% of hours accounted for 40% (over $3 billion) of their annual electricity spend.

Figure 10: Demand vs. size of energy system



Source: *State of Charge: Massachusetts Energy Storage Initiative*

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[5] Nine entities (ISOs and utilities) are current members with eight more set to join in the coming two years.

[6] Western Energy Imbalance Market. (January 31, 2019). *Western EIM Benefits Report, Fourth Quarter 2018*. Author. Folsom, CA. Retrieved from https://www.westerneim.com/Documents/ISO-EIMBenefitsReportQ4-2018.pdf.

[7] Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. (2017). *State of Charge: Massachusetts Energy Storage Initiative*. Boston, MA. Author. Retrieved from https://www.mass.gov/files/2017-07/state-of-charge-report.pdf.

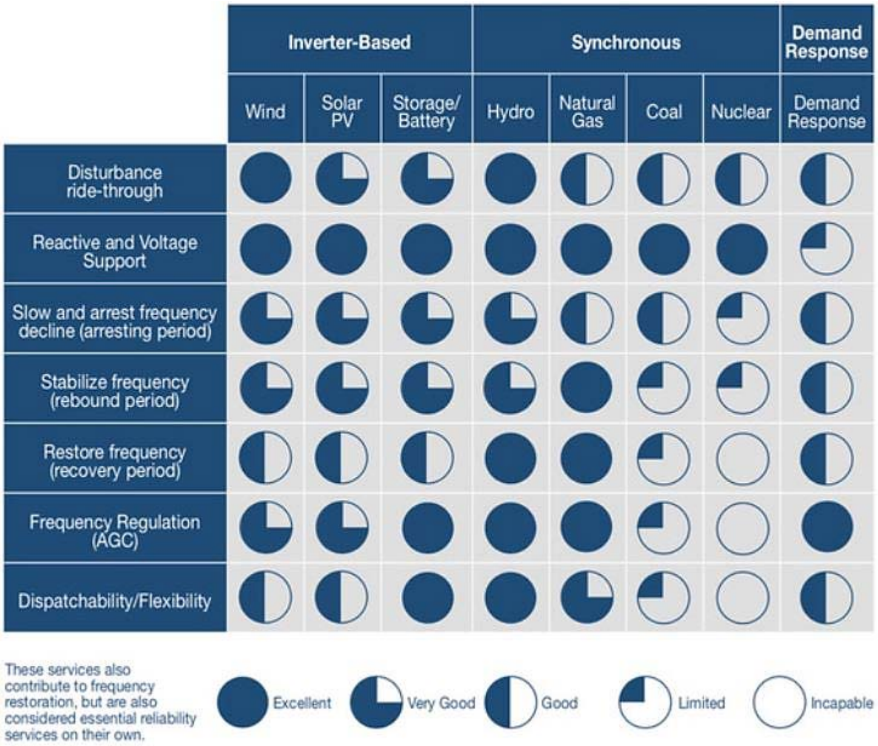
Building generation, transmission and distribution, and the associated natural gas pipelines to serve just a few system peak hours each year is an expensive way to do business, especially with new advanced technologies and other approaches that offer operational flexibility to reduce peak hours and provide reserve capabilities. Electric storage through batteries, older pumped hydro units hedging with low-cost energy, and electricity charging when the price is low and the entire system is not stressed all can replace high-cost electricity and reduce system stress — given the right set of rules.

Supply-Side Inverter-Based Capabilities

Supply-side advanced technologies like inverter-based wind, solar, and batteries can provide the grid with important capabilities today, but in many places these resources are underutilized.

Table 1 illustrates numerous capabilities of inverter-based and synchronous technologies.[8] Solar photovoltaic generation and electric batteries have always been inverter-based, while wind has become inverter-based over time in order to perform similarly. But all these resources are especially useful in managing the grid because they excel at responding quickly.

Table 1: Capabilities of Inverter-Based and Synchronous Technologies



	Inverter-Based			Synchronous				Demand Response
	Wind	Solar PV	Storage/ Battery	Hydro	Natural Gas	Coal	Nuclear	Demand Response
Disturbance ride-through	●	◕	◕	●	◑	◑	◑	◑
Reactive and Voltage Support	●	●	●	●	●	●	●	◔
Slow and arrest frequency decline (arresting period)	◕	◕	◕	◕	◑	◑	◔	◑
Stabilize frequency (rebound period)	◕	◕	◕	◕	●	◔	◔	◑
Restore frequency (recovery period)	◑	◑	◑	●	●	◔	○	◑
Frequency Regulation (AGC)	◕	◕	●	●	●	◔	○	●
Dispatchability/Flexibility	◑	◑	●	●	◕	◔	○	◑

These services also contribute to frequency restoration, but are also considered essential reliability services on their own.

● Excellent ◕ Very Good ◑ Good ◔ Limited ○ Incapable

Source: Milligan Grid Solutions

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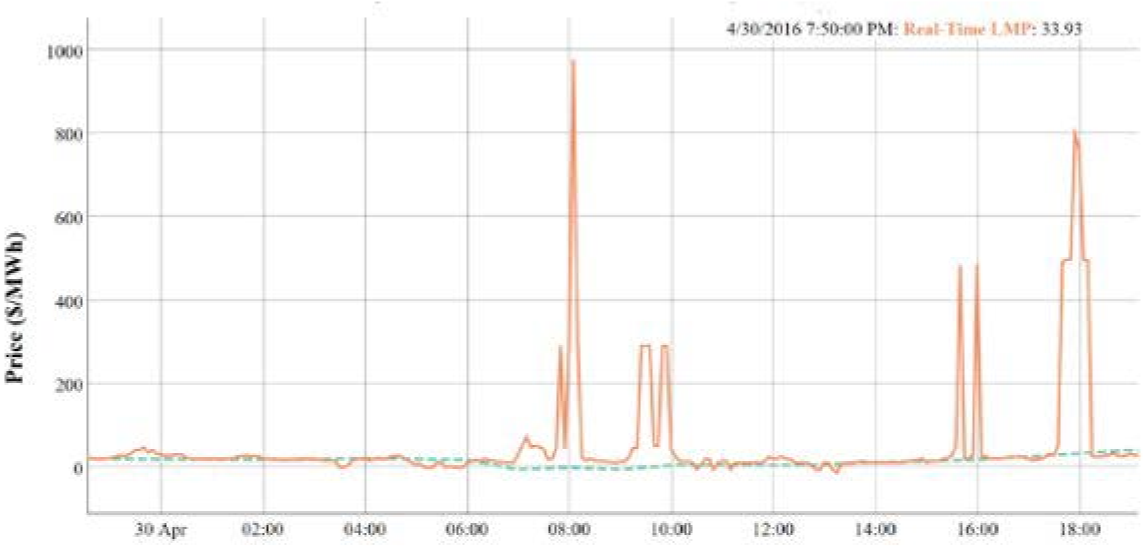
[8] Milligan, M. (2018). Fact Sheet: Sources of Grid Reliability Services. Milligan Grid Solutions. Retrieved from http://www.milligangridsolutions.com/Sources%20of%20Essential%20Reliability%20Grid%20Services%20Fact%20Sheet.pdf.

Figure 11 illustrates pricing patterns over the course of 20 hours in the CAISO in April 2016. It exemplifies the typical challenges posed by grids with both variable energy resources and variable loads.[9] Real-time change (e.g., the price spikes at 8:00 and 18:00) require fast-responding resources, exactly the capabilities offered by inverter-based technologies.

Figure 11: Pricing in CAISO, April 30, 2016



Source: Gary Dorris, Ascend Analytics, with data from CAISO

Demand-Side Flexibility

Rather than dispatching supply to meet uncontrolled demand, technology advances now allow management of the demand side to meet available supply. Demand response (DR) is not new, but traditional demand response programs simply focused on shedding load during periods of grid stress. Today, the DR includes the ability to be responsive to other grid needs. In articulating the various services that DR can now provide, Lawrence Berkeley National Laboratory (LBNL) adopted useful terminology illustrating how DR can be used to *shape, shift, shed and shimmy* load.[10] We discuss each of these below.

Shape

Figure 12 show the commonly-cited California ISO "duck curve," which illustrates ready opportunities to shape load. Time-of-use rates can move loads away from expensive peaks times, such as between the hours of 4 and 8 p.m. Energy efficiency and appliance standards can help shape load as well. For example, energy efficiency targeted to water heating, dishwashing, and

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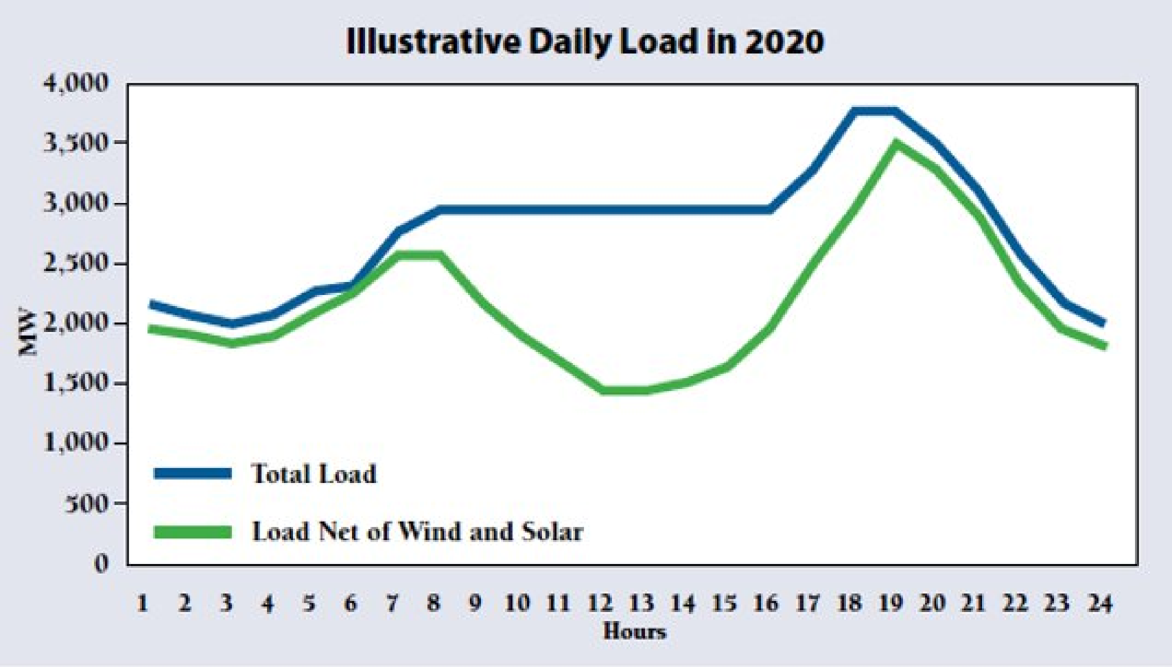
[9] This graphic acquired from Gary Dorris with Ascend Analytics shows pricing patterns at the CAISO in April of 2016.

[10] Lawrence Berkeley National Laboratory. (March 1, 2017). 2025 California Demand Response Potential Study: Charting California's Demand Response Future. Berkeley, CA. Author. Retrieved from http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442452698.

kitchen lighting loads that contribute to evening peak demand can have a big impact on load shape over the long term.[11]

Figure 12: Illustrative daily load in 2020



Source: Lazar, J. (2016). *Teaching the Duck to Fly.* Montpelier, VT: Regulatory Assistance Project

Shift

Load-side resources can also shift demand to more advantageous times of the day, e.g., when surplus renewable power is available and energy is less expensive. Figure 13 illustrates circumstances experienced in many power systems: periods with an abundance of renewable energy.

Load-side resources can also help shift demand away from more expensive times to hours where prices are very low, thus helping to avoid curtailing renewables. Switches, radio controls, and smart thermostats can turn a building into a thermal battery: pre-cooling or pre-heating its spaces and water supply. EV charging and the use of storage – either as future load or future supply – can be managed in a similar way. Demand-side resources, like an Ice Bear air conditioner, can provide cooling while effectively shifting load (see sidebar).

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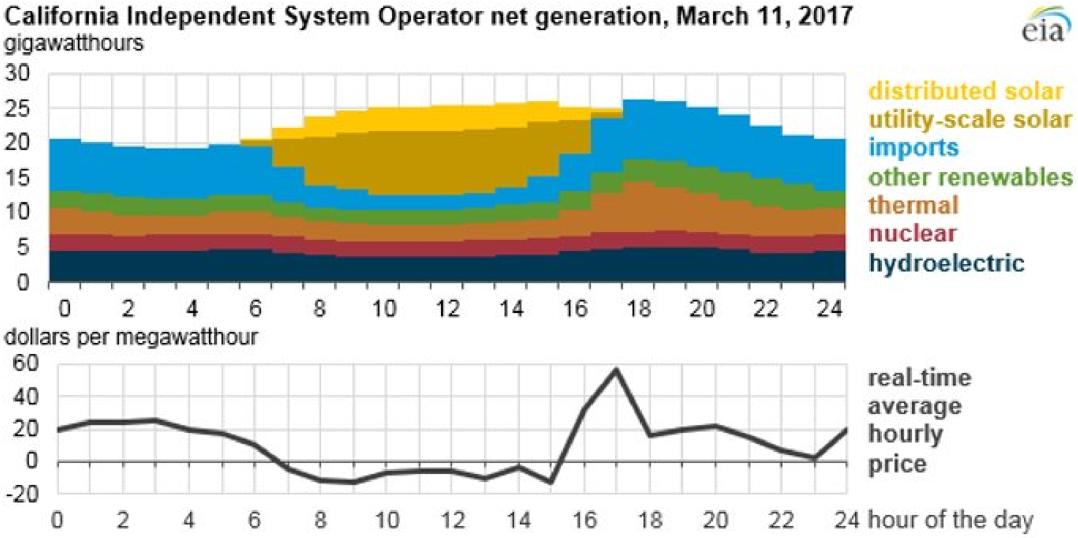
[11] Lazar, J. (2016.) *Teaching the "Duck" to Fly, Second Edition*. Page 12. Montpelier, VT: The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/7956

Figure 13: Load-side resources can "shift" demand



Source: Energy Information Administration

Shed

The next category of demand-side flexibility concerns loads that can be shed, or curtailed, occasionally. Shedding is consistent with the traditional definition of DR. Suitable technologies include advanced lighting, interruptible processes, air conditioning cycling, and storage, among others. Figure 14 illustrates how shedding load can reduce system peaks, avoiding the costs and often the development of generation resources. Similar to Figure 10, Figure 14 shows that Rhode Island ratepayers spent 9% of their electricity expenses on 1% of their demand in 2016, and 26% of their total spend was for only 10% of their demand.

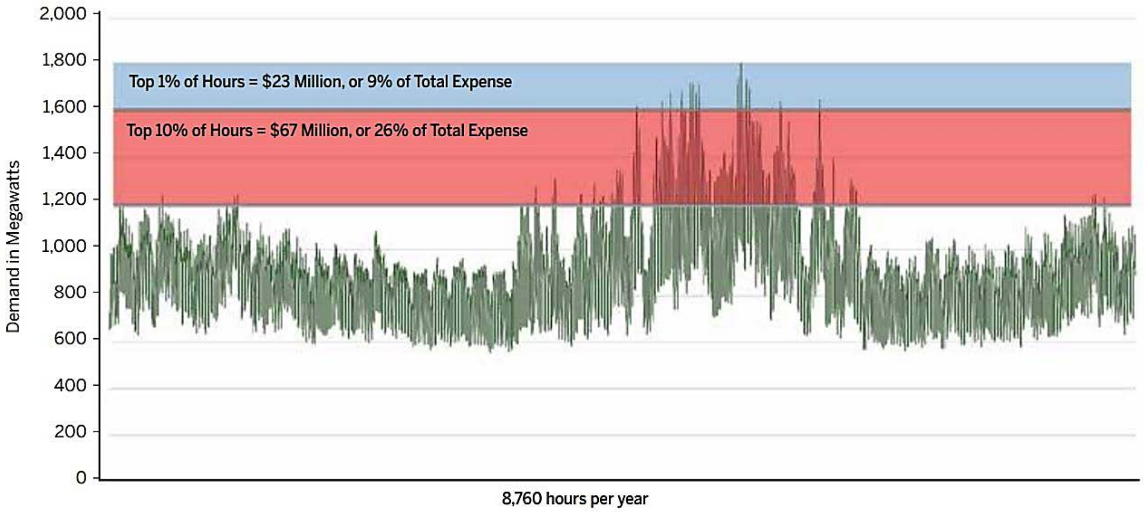
SIDEBAR

The Ice Bear

Ice storage air conditioning is an important flexibility demand-side resource to consider. These systems make ice or chilled water while power is cheap, then use it to provide air conditioning when the air is hot. This can help move the peak load into low-cost hours: the only power consumption at the time the cooling is being delivered to the building is for pumps and fans, not the energy-intensive compressor or chiller. There are thousands of ice storage systems operating today, but there are tens of millions of air conditioning systems that do NOT utilize ice storage. So this is a great opportunity.

Given such high costs for so few hours, shedding strategies could significantly decrease costs to the whole system by reducing load during those few critical hours. Shedding also helps reduce emissions from the dirtiest power plants that otherwise would need to run during those critical peak hours.

Figure 14: Spending on peak demand in Rhode Island



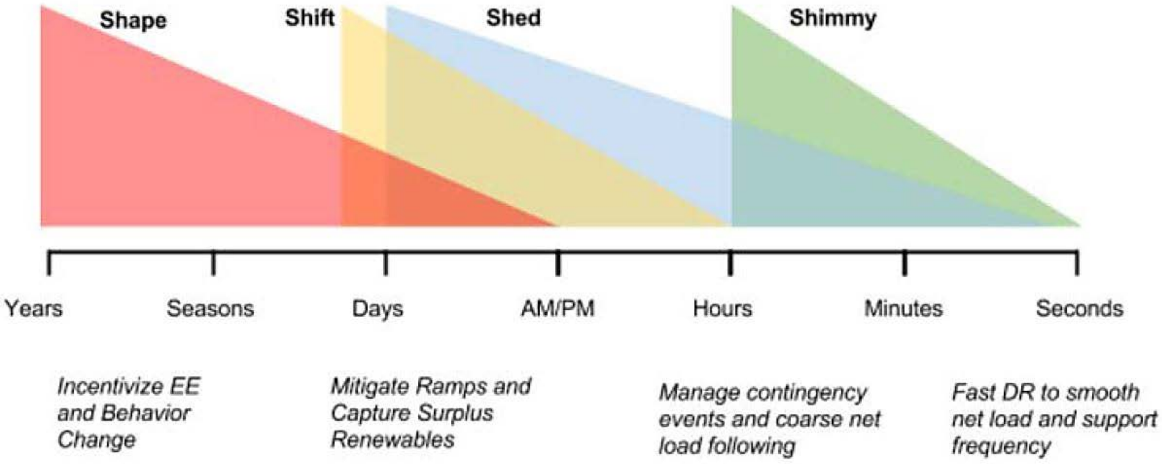
Source: Rhode Island Division of Public Utilities & Carriers, Office of Energy Resources, and Public Utilities Commission. (2017). Rhode Island Power Sector Transformation: Phase One Report to Governor Gina M. Raimondo.

Shimmy

Responsive load can also "shimmy" back and forth to meet short-term grid needs. This can help deal with short-term ramps and disturbances on the system. EV charging is an example of technology that can provide shimmy services, because it can occur all at once or can be turned on and off as the need arises.

There are a wide variety of flexibility services that the demand side can provide, and they span a number of timescales. See Figure 15. It is useful to think about these types of flexibility in terms of the time frames over which they can operate. Moving from the longest time frame of years and days for shaping, down to timeframes of minutes and even seconds for shimmying.

Figure 15: Shape, shift, shed and shimmy — timeframes



Source: LBNL. (2016, November). 2015 California Demand Response Potential Study

Optimizing Flexibility

We have taken a look at the types of resources that can provide flexibility. In the following discussion, we look at how to take advantage of these opportunities and consider several types of tools to optimize flexibility: retail pricing and price-responsive demand, controlled loads, and opening up planning and market processes.

Retail Pricing

Relevant utilities are quickly finding that demand charges are an unstable form of revenue, and that customers may pursue alternatives to avoid paying them. Demand charges are only an approximation of a customer's contribution to system capacity costs, because they measure the customer's highest usage during the course of a month without considering whether that usage was coincident with a system peak.[12] Customers' usage patterns vary more widely than can be accurately captured by a demand charge. Furthermore, the impact on low-use customers and apartment dwellers is disproportionate. A time-varying rate design allocates costs more equitably, makes bills more predictable and is easier for customers to understand.[13]

In California, the Extended Stay America motel chain has teamed with STEM to install batteries and energy management systems at 68 of Extended Stay's properties.[14] STEM operates the system to minimize the demand charges to the hotels, and also operates it as a "virtual power plant" to provide services to the utility system. This system can be operated remotely using artificial intelligence to build smart algorithms. It can cut billing demand and save money for customers like Extended Stay America.

Without storage, the demand charges for a motel using the STEM automated battery system would be set by the highest 15-minute usage in the month. Just a few periods during the month will set this part of the bill for the entire month. However, by installing storage to cover the highest hours of usage — about 100 kWhs out of 28,000 — the motel is able to reduce its demand charges by nearly 20%, from 68 kW to 56 kW, without any impact to motel guests.

Utilities pursuing smarter rate design are moving away from demand charges in favor of time-of-use (TOU) energy rates, and dozens of pricing pilots have shown that ratepayers respond to pricing.[15] The municipal utility in Fort Collins, Colorado, recently adopted what may be the best-designed residential rate in America. They moved all residential customers to TOU rates, as

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[12] Farnsworth, D., Shipley, J., Sliger, J., and Lazar, J. (January 30, 2019). Beneficial Electrification of Transportation. Montpelier, VT Regulatory Assistance Project. Retrieved from https://www.raponline.org/wp-content/uploads/2019/01/rap-farnsworth-shipley-sliger-lazar-beneficial-electrification-transportation-2019-january-final.pdf.

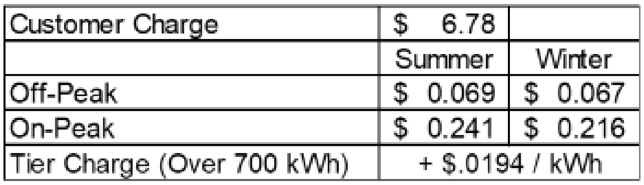
[13] Lazar, J. and Gonzalez, W. (2015). *Smart Rate Design for a Smart Future.* Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-gonzalez-smart-rate-design-july2015.pdf.

[14] Ko, T. (November 16, 2017). How California demand response has opened up to energy storage, virtual power plants. Energy Storage News. Retrieved from https://www.energy-storage.news/blogs/how-california-demand-response-has-opened-up-to-energy-storage-virtual-powe.

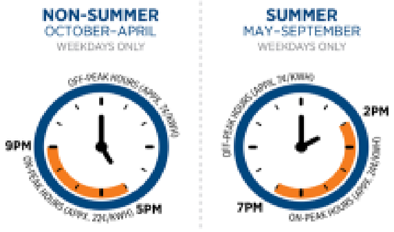
[15] Faruqui, A., Hledik, R., and Palmer, J. (2012). *Time-Varying and Dynamic Rate Design*. Montpelier, VT: Regulatory Assistance Project. Retrieved from https://www.raponline.org/wp-content/uploads/2016/05/rap-faruquihledikpalmer-timevaryingdynamicratedesign-2012-jul-23.pdf.

illustrated in Figure 16. The standard rate has the following features: First, a low customer charge for recovering billing and collection costs. Second, a very low off-peak rate. Third, a rate during peak hours that is three times as high as the off-peak rate. And finally, they have a "tier charge" that applies to all usage over 700 kWh/month, retaining an energy conservation incentive from their former inclining block rate.

Figure 16: Smart residential rate in Fort Collins, Colo.



Customer Charge	$ 6.78	
	Summer	Winter
Off-Peak	$ 0.069	$ 0.067
On-Peak	$ 0.241	$ 0.216
Tier Charge (Over 700 kWh)	+ $.0194 / kWh	



Perhaps most important, the on-peak period is only four hours long in the non-summer period, and five hours long in summer, short enough that people really can schedule laundry, dishes and other usage to avoid high-cost hours. By setting an electric vehicle to charge after the end of the high-cost period, this rate design allows Fort Collins residents to fuel their cars at an effective cost of less than $1/gallon of gasoline equivalent.

Controlled Loads

Today, the capabilities of electrical end uses make them an effective and low-cost way of integrating higher levels of variable renewable resources. This can enable lower-cost management of resources, save consumers money and reduce total associated power emissions. To illustrate the capabilities, we could consider what some call the "Smart House of the Future," as illustrated in the text box on the following page, and the impact some of these innovative technologies can have on peak usage of that house. [16]

First, a thermally efficient building will mean lower overall energy usage, and in particular will help limit the energy needed to provide space conditioning, which is a key strategy for making electric space heating more economical for consumers. Heat pumps are becoming ever more efficient and modular, and have the potential to contribute about 4 kW to a household peak. Similarly, cooling can contribute about 4 kW to peak. (As mentioned earlier, ice storage is becoming an economical option to help shift cooling to less expensive times to power cooling service; ice can be made at

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[16] We emphasize that the "Smart House" is intended to illustrate what is technologically possible, as opposed to reflecting the typical American housing unit.

lower-cost times and stored to cool a home using less energy during the system peak.)

Smart thermostats make it possible for heating and cooling uses to participate in programs like Nests' "Rush Hour Rewards," which provide incentives to customers that let their thermostat automatically be turned down by a very small amount during peak times.

SIDEBAR

Minimizing Usage: The Smart House

If household loads all occurred on or near a system peak, they would add significant costs to the system and contribute to the need to acquire more supply to meet this load.

However, virtually all major household uses can be shifted away from the peak period using smart, responsive technologies. Exploiting this flexibility can dramatically cut peak demand usage.

And, in homes with on-site storage, smart rate design would encourage homeowners to use batteries to make up the difference.

Electric vehicles are another form of controllable load. A level 2 charger would contribute about 6.6 kW to peak demand if not controlled.

Grid-integrated water heaters likewise can respond to signals from the utility or an aggregator and turn themselves down when prices are high. They can contribute about 4.4 kW to peak.

And finally, major appliances in the home like the refrigerator, dishwasher and washer/dryer (3 kW) can either be grid-interactive or scheduled using timers that are standard with these technologies today.

As illustrated in the sidebar, if left uncontrolled and occurring all during the system peak, this load could add significant costs and potentially more fossil generation to the system. However, given its flexibility, the load could be moved to different times of the day when power is cheaper and also cleaner

Planning and Market Processes

Planning and market processes are a third category of tool for adding flexibility to the power system. For example, regulators could support plans that benefit from market procurement of solar, wind and storage resources. In its 2016 Integrated Resource Plan, Xcel Energy received a large number and diversity of wind, solar and battery bids at very low prices.[17] For example, they received 96 bids for more than 40,000 MW of wind with a median price of less than 2 cents per kWh and more than 150 bids for solar with a median price of less than 3 cents per kWh. Wind, solar and battery combined was slightly over 3 cents per kWh.

Utility companies are not the only ones capable of using market processes to acquire flexible resources. Regulators can make a difference by soliciting cost-effective solar and storage bids, as in the case of Nevada, illustrated in Figure 17. Note that the solar photovoltaic cost per kWh is less than the operating costs of coal and gas, and storage is cheaper than the demand charges faced by commercial customers.

These low costs for renewable energy and storage mean that raw energy costs are not a big challenge. But ensuring that supply and demand stay in balance at all times is a challenge that will require the tools we have discussed so far.

Opening wholesale markets to aggregated distributed energy resources and storage like they have done in California is another example. The California ISO initiated the Electricity Storage and Distributed Energy Resources (ESDER) Initiative in 2014, designed to enhance the ability of ISO-connected and distribution-connected resources to participate in ISO markets. The third phase of the ESDER initiative was completed in 2018 and is pending approval at FERC. It provides for a bidding mechanism that allows aggregated behind-the-meter resources to offer load-using and load-curtailing service.

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[17] Minnesota Public Utilities Commission. (April 26, 2018). Docket No. E002/M-17-694. In the Matter of Xcel Energy's Petition for Approval of the Acquisition of 302.4 MW Dakota Range Wind Project. Retrieved from https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId=%7B307EDE62-0000-CC15-9E79-31803D369388%7D&documentTitle=20184-142111-01.

Figure 17: Soliciting cost-effective solar and storage bids in Nevada

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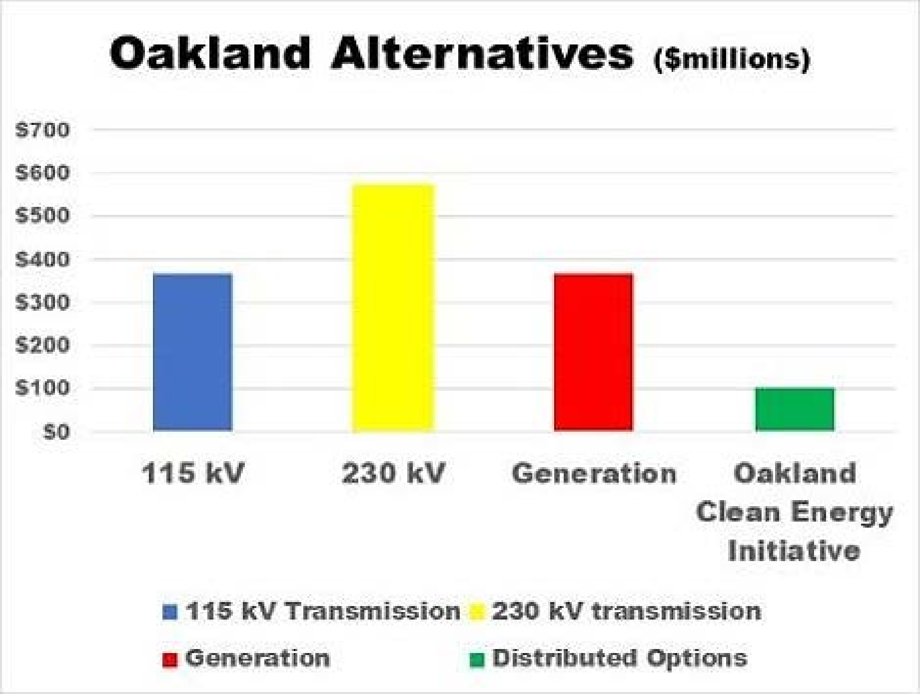
Regulators can also make a difference by inviting advanced technology alternatives when fossil plants retire. The PG&E and East Bay Clean Energy Project, the Oakland Clean Energy Initiative or "OCEI," replaced a retiring 165 MW gas peaking generating station and avoids the need for new transmission. The resulting project is comprised of a mix of energy efficiency, demand response and photovoltaic distributed generation, electric storage, substation upgrades and line re-ratings. This strategy saved ratepayers money and reduced air emissions, avoiding transmission and generation solutions totaling $300-600 million with a combined DER solution price tag of only $102 million (see Figure 18).

Demand-side solutions can also be used to manage seasonal loads. Oklahoma Gas and Electric, for example, has a very effective demand response program using their version of smart meters. Maryland utilities, likewise, have been successful using air conditioning cycling and straight demand response. Wholesale market rules, however, matter in this context. PJM, the country's largest wholesale market operator, has put forward rule changes that have been adopted and eliminate the ability of these resources to receive capacity market payments for seasonal demand response. This is significant because this is how the Maryland utilities, for example, have funded their demand response programs.

Figure 18: Alternatives in Oakland, Calif.



Pricing can be designed to reflect grid management needs at regional, utility, zonal, nodal and even circuit levels. To provide an example of how these needs vary, we looked at data showing pricing across the New England ISO on a particular day: November 14, 2018. Pricing on that day ranged from negative figures per MWh in Maine (-$15.62) to high numbers of $116.58 in the Boston area, illustrating that different customer responses are necessary in different parts of the system, and that pricing in the wholesale market can provide part of that signal but not all of it. Negative pricing in Maine suggests that there is excess generation and not necessarily that the lines are loaded. Pricing can be designed to respond to those situations by encouraging demand through advanced batteries and electric vehicles when pricing is low, and discouraging these “shiftable” loads when prices are high.

What market designers and stakeholders need to do is develop markets on each scale that reward innovative solutions to provide energy and use transmission and distribution lines efficiently. Providing capacity alone is almost meaningless, because that only establishes a promise to be available, while energy and reserves are what are necessary to run the grid. Either the energy is there or it’s not, regardless of the promised capacity to show up. During the well-known polar vortex of 2014, for example, much of the capacity that had cost consumers billions failed to show up when needed. Thus, fuel security discussions that focus on generation capacity miss the point. Instead, regulators and policymakers can design markets and utility responses to take advantage of advanced technologies in nondiscriminatory ways, and can harness innovation to reduce consumer costs and improve reliability and system resiliency.

Conclusion

This discussion has been an effort to illustrate how power grids can be made more flexible and, thus, more capable of accommodating greater amounts of variable renewable resources. The 20th century is over; today, we have many different technologies and innovative solutions at multiple scales that can meet these needs at much lower cost. Flexible generation, transmission capabilities, system operations and managed demand-side resources can all contribute to the system flexibility we have been describing. This is an opportunity for regulators to provide policy guidance to help realize the many benefits of a more flexible grid.

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