Demand Response Programs Focusing upon SCE and ERCOT

Center for Energy and Environmental Policy
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Abstract

This paper examines the current literature of demand side management, focusing on the demand demand response aspects, before providing a comparative case study of current demand response programs in Southern California Edison and the Electric Reliability Council of Texas. The electrical grid faces severe challenges and both Texas and California have turned to demand response as a potential solution. Despite the two state's regulatory philosophy differences their demand response programs represent two sides of the same demand response coin. Both states need the benefits of demand response for the stability of their grids and doubtless will rely on them more and more heavily moving forward.

Introduction

Utilities, and the grid itself, are increasingly struggling with meeting the demand for electricity. This is especially pronounced during peak hours when demand is at its highest and the grid is stretched to the limits of its capacity (Energy.Gov, nd). Moreover supply is increasingly variable renewable generation rather than the traditional generators (Energy.gov 2015). A potential solution for these problems are demand response programs.

Demand response programs are an increasingly important part of the electricity system (Kolo, 2016). This paper will attempt to show both why that is and how it is happening. It will do that by first giving a brief overview of demand side management and why it is growing nationally, and then focusing in on the demand response programs of Southern California Edison (SCE), a utility in California, and the Electric Reliability Council of Texas (ERCOT), the Independent System Operator for the majority of Texas.

Nationally demand response has been growing over the last decade (Pittman, 2016). Particularly effective during peak hours it grew 15%, or 4096 megawatts between 2013 and 2014 (FERC, 2016). Demand response offers a cheaper alternative to building new power plants as well as with dealing with the increasing use of variable energy sources rather than traditional fossil fuel electricity generators (O'Donnel, 2016).

Despite its growth at the national level it is important to note, demand response is inherently a local tool. Programs must be matched to the needs and uses of that specific area. While, as will be gone over in depth later, air conditioning programs have proven effective in both SCE and ERCOT, it is highly unlikely these programs would be equally effective if transferred to different locales such as Vermont. Still Southern California Edison and the Electric Reliability Council of Texas are both innovative leaders in their field (Nadel, 2017) (ABACCUS, 2015), and their respective demand response programs have many key similarities and differences that make them worth studying and comparing.

Texas and California come from vastly different regulatory philosophies but both have decided that their respective electricity systems should make demand response an important part of grid stability. The two states are not as different in their electricity markets as many might assume, both have a glut of variable renewable sources at certain times of the day and are struggling to keep the grid stable as variable renewables push out older coal and natural gas fired plants (O'Donnel, 2016). For these, and other reasons, SCE and ERCOT have turned to a variety of demand response and demand side management programs to help stabilize their respective grids.

SCE, a utility, and ERCOT, a regulator, were picked so as to provide both the hands on utility and the regulators views of demand side management. Since demand response programs are often split between the two it is important to examine both utilities and regulators views and practices towards the programs. Regrettably due to practical considerations an analysis of both a regulator and utility in each state was not possible. Thus, it was decided to examine SCE and ERCOT, as a utility and a regulator respectively, and compare their programs. These provide an opportunity to understand both the differences between states, as well as to touch on the distinctions between regulators and the regulated in their approach to demand side management.

These programs will be gone over at some length and then compared using the six policy levers of demand side management developed by, Davito, Tai, and Uhlaner, in 2010. The levers will provide a framework to compare and contrast the demand response programs of the two utilities, a task made much simpler and more accessible by breaking the programs down into their component parts. The policies of SCE and ERCOT reflect the state's policy paradigms both in form and in how they are used.

The two's programs, despite their obvious regulatory philosophy differences, are far less different than one might imagine. Texas and California, as seen through the lens of demand response programs under SCE and ERCOT, are two sides of the same coin, not opposite ends of a spectrum.

Demand Side Management Overview

Demand-Side Management (DSM), also known as energy demand management, is increasingly being recognized as a major potential way to help mitigate climate change. First examined in the 1970's, DSM has grown and expanded as a field of study, especially in the last decade. With dozens of policy options for DSM, policymakers can tailor DSM solutions to their specific circumstances in order to help reduce overall demand and energy emissions.

Before we continue it is important to define demand-side management. This paper will use the same definition used in a study on the smart grid, it defines DSM as "A set of interconnected and flexible programs which allow customers a greater role in shifting their own demand for electricity during peak periods and reducing their energy consumption overall." (Davito, Tai, & Uhlaner, 2010). This definition is regarded as an expanded definition of DSM by writers in the field because it includes both load shifting and energy efficiency/conservation programs. Load shifting is often called demand response by utilities, though this depends upon the preferences of the company. For the purposes of this paper the two terms will be used interchangeably.

Grids

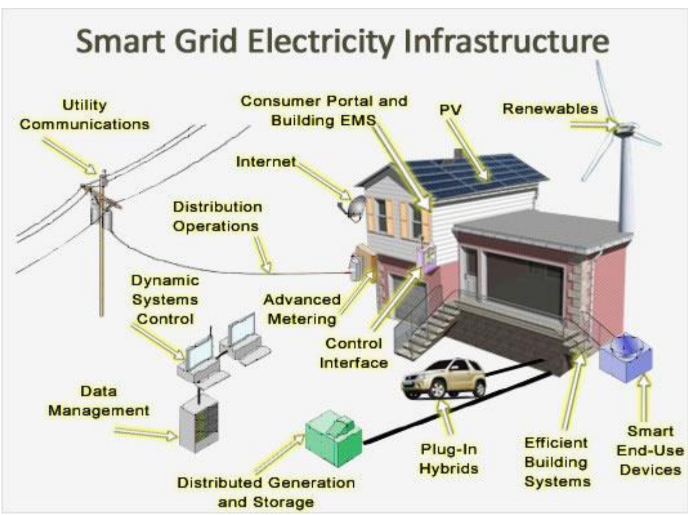
The current electrical transmission system is overloaded and outdated. It was designed for a different time with lesser energy demands and different forms of supply (EPRI, 2011). While utilities and various levels of government are slowly starting to address this issue, spending $18 billion between 2010 and 2014 (DOE, Smart Grid Systems Report, 2014), many authors believe more needs to be done in order to hasten the transition (Kennedy, 2011).

There are several different forms of grid based technologies that offer great promise for demand-side management, chief among them smart grids and microgrids. The two are not independent and many believe that the ideal future electrical grid will include both.

The grid aspect of demand-side management differs significantly from other forms of demand side management because it relies almost entirely upon the utilities and government policy with little or no control by the consumers. However, improved grids are a necessity in order for most forms of load shifting to take place as will be discussed later in this paper.

The Smart Grid

The smart grid is a catchall term for a more automated and computerized grid. It has no strict definition but is generally seen as involving smart meters in every home and computers running the grid that can react fast enough to real time events to either reduce or increase energy consumption as needed for the situation at hand. This computerization also helps the grid work more efficiently with variable renewable energy sources. The main purpose of the smart grid, though, is to increase the information and control at all points, both consumer and provider. The consumer can get real time electricity use information while the energy provider gets more detailed information on energy use and the ability to charge real time pricing. Moreover the smart grid allows for a two way flow of electricity as well as information allowing for easier managing of decentralized electricity generation (EPRI, 2011).



The smart grid involves many parts as can be seen on the picture on the left (Peri, nd). It is a result of the the huge increases in information technology being combined with the grid system, something that is long overdue as the current grid is over 25 years old in most places (Follet, 2016). The cost of upgrading the grid varies depending on the study and the level of new technology that is added to the grid. The Department of Energy in its 2014 report on it cites studies finding it costing between

$338-$476 billion over the next 20 years in order to complete the transition to a smart grid (DOE Smart Grid Systems Report, 2014). Unfortunately, to achieve this target would require spending approximately $17-20 billion annually, far above the $5.2 billion high it reached in 2011 (DOE Smart Grid Systems Report, 2014). Still the Electric Power Research Institute found that upgrading the grid would provide a benefit-cost ratio between 2.6 and six, mostly due to the costs of blackouts that are estimated to increase in number if the grid is not upgraded (EPRI, 2011). EPRI does admit that estimating costs for the smart grid can be complex and that they doubtless vary greatly across regions (EPRI, 2011).

Interestingly the Federal government actually has limited power over transitioning key parts of the smart grid, such as ensuring the spread of smart meters in people homes. While the federal government has been providing incentives for and encouraging the spread of smart meters since 2005 with the passing of the Energy Policy Act, this technically isn't mandatory and states can opt out (Rose, 2014). Still the incentives offered by the federal government through the American Recovery and Reinvestment Act are responsible for adding 15.5 million smart meters. Despite this, the lack of coordination between state and federal government is named as one of the greatest barriers to DSM and smart meters deployment (Rose, 2014).

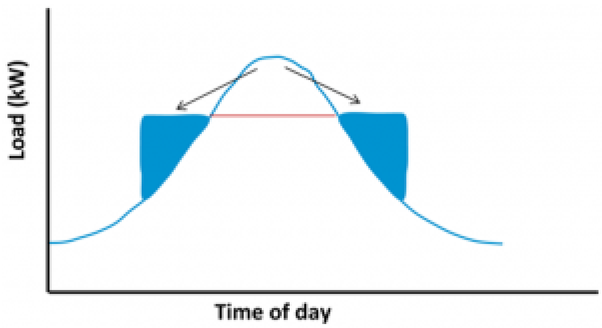
Microgrids

Microgrids are small localized grids that have the ability to disconnect from the main grid and operate autonomously. Traditionally the grid has been made up of giant electricity producers delivering electricity one way to often distant consumers. A microgrid focuses on local generation and transmission. This has the twofold benefit of reducing stress on the main grid and mitigating the effects of grid disturbances on consumers. While many microgrids cannot meet all their power needs on their own, in order to be deemed a microgrid they must be capable of meeting their critical electricity needs (KEMA, 2014). This is essentially for helping storm hit areas maintain necessary services even when the connections to the main grid are down. This could help reduce the estimated $18 to $33 billion a year in costs due to power outages caused by storms(PCEA, 2013). As you can see in the picture to the left to create a microgrid requires at least a partial transformation to a smart grid in order to run the interconnections to the main grid and to most effectively balance power within the microgrid (Galligan, 2016). Microgrids can be created so that their information and distribution systems best match the energy sources and demands for the area (Galvinpower, nd).

Microgrids truly shine when paired with other forms of demand-side management, such as loading shifting. One examination found that the optimal load shifting program would not be between the energy producer and all the consumers individually but through blocks of consumers that could coordinate between themselves rather than individually with the power generator (Mohsenian-Rad, Wong, et al, 2010).

Load Shifting/Demand Response

More than any other form of demand-side management, load shifting promises to shake up how consumers and producers use and sell electricity. It is often called

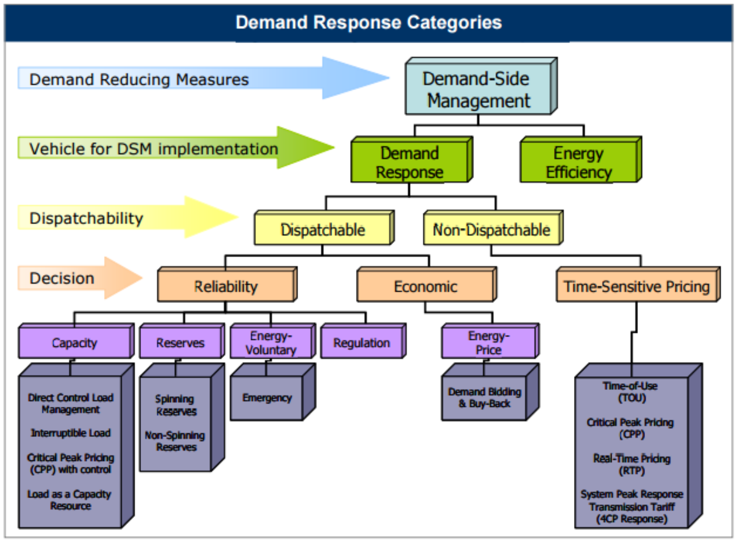


demand response when referring to the specific programs run by utilities. In order to be most effective it requires careful knowledge of the policy and a grid smart and strong enough to handle its requirements. Demand response also requires some of the most advanced technology and consumer input in order to be effective. Rather than reducing the total energy demand, load shifting involves moving when that demand is as can be seen on the graph above (Marsden Jacob Associates cited in EEX.gov,au, 2011). Many authors believe it will be a requirement in the future in order to make renewables as effective as traditional energy sources (Andersen, 2016)(Denholm, Hand, 2011).

Initially it may be unclear why load shifting would have positive benefits both for society and the consumer. Many generators are rarely run. In fact one study found that, in 2006, 15% of Pennsylvania, New Jersey, and Maryland's generation capacity was used for less than 1.1% of the time (Spees, Lave, 2008).These peak generators are turned on only to meet peak yearly demand, usually in the summer, and are less efficient, more costly, and more polluting generation sources than baseline generation sources, the plants that run year round. Load shifting could help reduce the need for these plants by shifting or reducing the load rather than increasing the generation. Demand response programs also help reduce costs of transmission and distribution by reducing peaks when the grid is often strained to its limit to meet demand. In fact one study found that demand response programs can reduce peak demand by 10% (Nadel, 2017). Load shifting may be achieved in several different ways, most of which could work together to help reduce energy peaks.

Nationally demand response is increasingly a major tool for utilities to reduce costs and still meet peak demand. Currently the majority, 53% of demand response comes from industrial customers, but residential and commercial are rising as resources (FERC, 2016). The same study found that currently most demand response programs are used in emergencies or as bidding resources in the electricity market. Emergency programs ares ones that are only called upon when the stability of the grid is in danger while bidding resources involve those few areas where demand response is allowed to be bid into the open market the same as supply side sources in order to meet the day's electrical requirements.

Demand response programs can be split into two main types of programs Dispatchable and non-dispatchable programs, as can be seen one the graph below produced by the North American Electric Reliability Council (2013). Dispatchable programs involve programs that the utility or grid operators can activate as needed for the stability of the grid or due to economic considerations. Non-dispatchable programs give consumers more control over their demand allowing them full control over it instead providing them an incentive to reduce or increase demand but not requiring any changes.



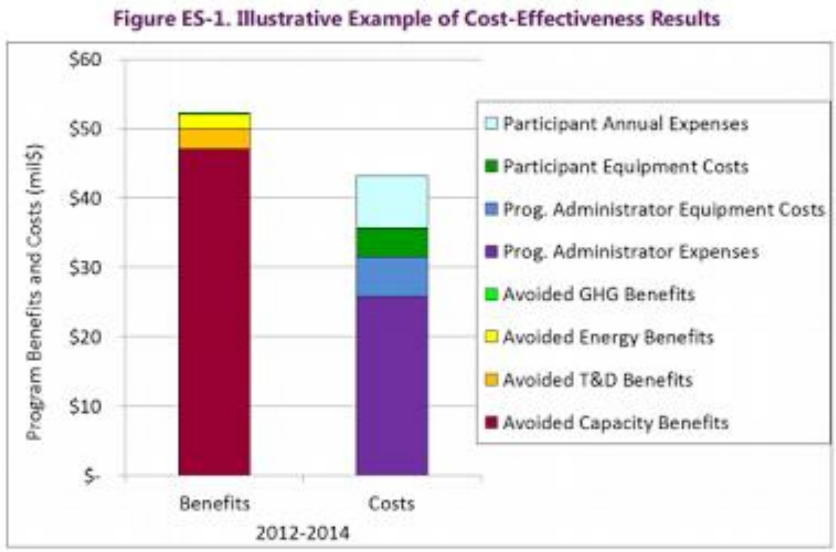
A primary form of demand response involves shifting the use of certain appliances around the house so that they will not be running at peak hours. This could be more easily achieved if there is a smart grid to help provide real time information as well as real time rates for energy use, both of whose benefits were explained earlier in this paper. Appliances such as dryers could be set to run overnight when electricity is cheap thus flattening out the demand curve reducing the expense of and need for peak energy while increasing the flexibility and stability of the grid (Davito, Tai, Uhlaner, 2010). Studies have shown that load shifting programs can be run in ways that do not affect the consumer's lifestyle yet are still cheaper for the utility than generating the power would be (Anderson, 2016).

Energy storage also can be used to shift loads. For example California is experimenting with so called “permanent load shifting” which involves building objects that can change the energy use times of a building such as through using ice cooling systems which freeze the ice overnight when energy prices are low (Maccracken, 2013). Another exciting opportunity for DSM load storage can be found in hybrid and electric cars. The number of electric vehicles has been rising sharply over the years and there are some who hope that they could be used as a source of energy for when the grid needs it (Xu, Liu, Ding, Zeng & Pan, 2014). There is also the potential for them as a store of energy for when variable renewables are producing large amounts of power but there is little demand. One study found that electric vehicles when combined with a smart grid could theoretically reduce deviations from the average energy use by 70% (Lopez, Torre, Martin, & Aguado, 2015). This amount of flexibility in grid demand will be crucial as the economy shifts more towards variable renewable sources and away from fossil fuels.

In the next section the case studies of Southern California Edison and the Electric Reliability Council of Texas examined in depth. Besides the obvious locational differences between the two it is important to note that Southern California Edison is a profit driven utility while the Electric Reliability Council of Texas is a nonprofit regulator. Utilities are most concerned with meeting their customers needs and earning a profit while regulators need to be concerned with the stability of the overarching grid, especially trying to meet peak demand. While many of these concerns overlap There are key differences that will appear in how they view and use demand response programs.

Introduction to Southern California Edison

Before we continue, Southern California Edison (SCE) needs to be introduced. SCE is a subsidiary of Edison International, a profit driven energy giant with several energy companies under it and an operating revenue of $11.5 billion (Edison.com, nd). One of the larger electric utilities in the United State SCE serves approximately 15 million people. Founded in 1887 SCE has been in business for almost 130 years(SCE fact sheet, nd). Yet, probably due to California's energy market restructuring, the company only generates 16% of its electricity with most of its electricity being bought from the electricity market (SCE fact sheet). California has been a leader in demand side management programs for years and as a utility within that state the SCE has been involved as well (Kohansal & Mohsenian-Rad, 2015). In fact California was one of the first states to get involved in demand response programs which it first started in the 1990's (Jarred, 2014). Moreover the SCE is in the top five utilities when looking at peak shaving, reducing demand during peak hours according to the ACEEE (Nadel, 2017). It helps that, as can be seen on the graph below, demand response programs have been proven to be cost effective in California (Woolf et al, 2013). It has also been upgrading changing and evolving new demand response programs relatively quickly.



As discussed previously transitioning to a smart grid is an integral part that is needed for any demand response programs to become widespread. By the end of 2012 SCE planned to finished its transition to its SmartConnect meters with everyone who did not opt out getting a SmartConnect meter installed (SCE Smart Meter FAQ, nd). The meters provide a two way flow of information about current consumption to both the utility and the homeowner. These meters also provide the ability, when paired with an additional device, for customers to create an area network that the various devices in the home can connect with. So smart devices in the area could be configured to reduce energy use when prices are high or to only use electricity when the price is below a certain threshold (SCE HAN FAQ, nd).

Southern California Edison's demand response programs focus upon large business customers rather than residential consumers. For most of the programs residential and other low demand customers are only available for demand response programs if they are willing to aggregate their demand (Churchwell, 2015).

California's Public Utility Commision, which SCE must report its programs to, defines demand response as,

> “Changes in electricity use by customers from their normal consumption pattern in response to changes in the price of electricity, financial incentives to reduce consumption, changes in wholesale market prices, or changes in grid conditions.” (quoted in Jarred, 2014).

Notice how only decreasing consumption is specifically mentioned as a tool. The wording of this definition may help explain the focus of SCE’s programs. Currently SCE website lists thirteen different demand response programs while its reports on its demand response capacity include several more. Almost all of them focus on reducing demand during peak hours (SCE.com DRP, nd). The programs this report shall be examining are listed below.

- Agricultural and Pumping Interruptible Program,
- Permanent Load Shifting
- Time-of-Use Base Interruptible Program
- Capacity Bidding Program
- Demand Bidding Program
- Aggregator Managed Portfolio (AMP) Program
- Summer Advantage Incentive (also known as Critical Peak Pricing)
- Optional Binding Mandatory Curtailment
- Summer Discount Plan
- Real-Time Pricing

Each of these programs targets slightly different sections of the markets and the wide variety gives the SCE options in dealing with the various grid events that may happen.

Overview of the Southern California Edison Company's Demand Response Programs

SCE categorizes its demand response programs into five categories, emergency, price responsive, demand response aggregator-managed, SmartConnect□-enabled programs, and non-event based programs (Churchwell, 2015). Each of the categories can be dispatched separately and can be used to handle different types of events that may occur. Interestingly these programs as listed in the SCE Executive Summary Report on SCEs "2015-2025 Demand Response Portfolio" published in 2015 include more than the thirteen currently listed on demand response section of the website. However the SmartConnect□ enabled programs were discontinued and so will not be discussed in this paper (SCE Save Power Days, nd).

SCE's Emergency Demand Response Program

The Emergency demand response programs are designed to be used in the case of negative events that threaten the stability of the grid. They are to be used to help stabilize and reduce stress on the grid during emergency situations. The Base Interruptible Program and the Agricultural and Pumping Interruptible Program are the two programs designed for this run by the SCE (Churchwell, 2015). There is also a third program called the Optional Binding Mandatory Curtailment Program that, while not considered a demand response resource, and so is excluded from their reports on demand response(Churchwell, 2015), is still listed on SCE's website as a demand response program.

The first of these the Base Interruptible Program is described as “a tariff-based, emergency-triggered demand response program” used by both SCE and the California Independent System Operator (CAISO) as a method of dealing with system emergencies (Churchwell, 2015). The program is only open to customers whose demand, either individually or aggregated with other customers, meets or exceeds 200 kW(SCE Schedule TOU-BIP 2016). Customers during sign up choose a Firm Service Level, the base of electricity that they cannot or will not cut and still stay operational, and then they choose which group they want to be put into, the 15 minute warning or the 30 minute warning group. This determines how much time the customer is given to comply to any order to reduce demand. They then make a commitment about how much they will cut, it must be at least 15% of their total demand and the amount must be greater than 100 kW (SCE Time-of-Use Base Interruptible Program, 2010). In exchange for doing all this customers receive monthly credits, regardless of whether or not there was an interruption that month, that apply against each month's electricity bill. They are also given credits according to how much they reduced demand, their Firm Service Level, and the season the event takes place in. There are also excess energy charges for those who fail to reduce demand in time.

The second of the two emergency demand response programs is the Agricultural and Pumping Interruptible Program. While California's drought has been getting better the southern part of the state especially remains dry (Daniels, 2017). What many do not realize is that the agricultural sector uses 17.5% more electricity during droughts due, mostly, to the need to pump water up from groundwater sources rather than relying on surface sources (Kotin, 2015). The Agricultural and Pumping Interruptible Program attempts to harness this demand as a resource for use during emergency events on the electrical grid. The program provides credits to eligible agricultural pumping customers who allow SCE to automatically shut off the electricity to the pumps when needed by CAISO or the SCE. The program is open to those with a demand of over 37 kW or over 50 horsepower. In exchange the customers get credits that reduce their electricity bills (SCE Agricultural and Pumping Interruptible Program, 2010).

The third demand response program is the confusingly named Optional Binding Mandatory Curtailment Program (SCE.com DR section, 2017). Even more so than the previous two programs it is a program of last resort (Churchwell, 2015). The program provides an opportunity for customers to exempt themselves from rolling outages in exchange for significantly cutting their demand during those such events (SCE OBMCP, 2010). Unlike most demand response programs the program provides no incentives to participate beyond the certainty of not having one’s power cut off during rolling outages, instead merely a 15% reduction of electricity use is required (SCE OBMCP, 2010). The program benefits SCE by reducing demand during critical moments and benefits customers who require a steady flow of energy.

Price-Responsive Programs

Price-Responsive Programs are dispatched by the SCE or CAISO but purely on economic reasons rather than exclusively for emergencies, though they are often called upon to help with emergencies as well. SCE lists four of its demand response programs as price-responsive programs, the Summer Discount Plan, split into two separate programs for commercial and residential, Critical Peak Pricing, and the Demand Bidding Program (Churchwell, 2015).

The two Summer Discount Plans are similar but can be dispatched separately (SCE Demand Response Event Status, 2017). The Plans involve the cycling of air conditioners to reduce or lower demand during peak moments of the summer. There are different levels the customer can sign up for which vary whether the utility can entirely shut off AC or merely cycle it as well as an option for the customer to override the cycling (SCE Summer Discount Plan, nd). Depending upon which combination of options residential customers sign up for they can earn between $50-$200 worth of credits. Commercial customers can earn up to $20-$250 per AC unit they have if they agree to sign up for the programs.

Critical Peak Pricing, also known as the Summer Advantage Incentive is another price responsive demand response program and it relies upon a dynamic pricing program that charge them according to time-of-use-rates. All customers with demands of over 200 kW are automatically signed up for it and moving forward into 2017 SCE plans on defaulting smaller commercial customers into the program as well (Churchwell, 2015). It works by offering credits during the summer and in exchange SCE can call 12 events on any non-holiday weekday notifying customers of the event the day before (SCE Schedule CPP, 2016). During those events the electricity prices become time-of-use and are considerably higher than average, thus incentivizing the customer to reduce its electricity use (SCE SAI, 2013).

The last of the price-responsive programs is the Demand Bidding Program. While most of the SCE's programs are being integrated to work with the CAISO market the

Demand Bidding Program will not due to the difficulty of integrating it (Combs, Morales, 2016). Demand Bidding is hard to integrate into the wider market because so much uncertainty surrounds it. Demand bidding is exactly what it sounds like in that customers may bid the day before Demand Response Events to reduce their energy use by at least 1 kW and for at least 2 hours. Rather than requiring customers to lower their energy usage however it is entirely optional and they are not held to their bids. In fact they even still receive some credits even if they only reduce their energy consumption by 50% of their original bid (DBP Factsheet, 2015). The credits earned are around 50 cents per kWh of power reduction. There is even the ability to creating a “standing bid” so you automatically bid a certain amount every time there’s an event and can decide the day of the event whether or not to actually carry through with your bid. Obviously this can make it difficult for the utility as they cannot properly account for how much demand will be reduced as it may vary considerably depending on how many customers decide to honor their bids. This make it difficult to account for in the wider market (Combs, Morales, 2016).

Demand Response Aggregator-managed Programs

Demand response aggregator-managed programs are a subset of price-responsive programs but differ in that rather than individuals signing up with the utility typically there is an aggregator middle man that they sign up with instead and that aggregator is the one that signs up with the utility for ones of its demand response programs (Churchwell, 2015). These aggregators provide options for smaller customers to be able to be signed up for demand response programs as it aggregates enough of them to reach the electricity minimums required for SCE’s demand response programs.

This helps the utility by expanding the reach of demand response programs thus helping the utility achieve grid stability. SCE has two of these programs the Capacity Bidding Program and the Aggregator Managed Portfolio Programs (Aggregator Demand Response Programs, 2014).

The Capacity Bidding Program can be either large customers, labeled self-aggregators, or through third party aggregators for smaller customers. Similar to many of the earlier plans SCE can call event days on any non holiday weekday between 1-7 pm with a maximum of 30 hours per month. While the plan lasts for a year each month entrees are allowed to change their demand reduction bids (SCE CBP, 2017). With financial incentives to comply and penalties for those who do not (SCE CBP, 2017) the Capacity Bidding Program provides a wider tool for the utility to use to shift demand during peak hours as well as times of crisis in the grid.

The Aggregator Managed Portfolio Program is similar to the Capacity Bidding Program but each of the third party aggregators runs its own programs and manages itself almost entirely without the utilities direct input. SCE can call on these aggregators to participate in events and the aggregators then have to provide their promised load reduction. Unlike the Capacity Bidding Program though each aggregator has a different contract with different event lengths, number of events, and hours available (SCE Demand Response Programs, 2017). This gives the aggregators a lot of flexibility in who they sign up and what levels of commitment they are willing to offer bringing even more customers into the demand response market.

Non-event Based Programs

Unlike all the previous demand response programs this set of programs does not require the utility to call for specific events during critical or peak moments of the year, instead they are always active trying to trim demand away from peak hours and towards lower priced times.

The Real-Time Pricing Program run by SCE changes the price of electricity by the hour to reflect the cost of electricity during that time. The program is open to any business or agricultural customer with a smart meter who is willing a sign a twelve month contract and once signed up the prices vary on the hour for the entire term of the contract (SCE RTP FAQ, 2013). Prices are determined according to the previous day's temperature and so the consumer knows the day ahead what the prices will be for the next day and so can reduce their consumption plans accordingly (SCE RTP hourly savings yearly benefits, 2013). Interestly this means that despite the name this is not actually real-time pricing, as the prices do not perfectly represent to the current price of electricity. This makes sense from a business perspective but might reduce the economic efficiency gains from real time pricing (Borenstein, 2010) especially during transition times of the year when the weather changes quickly from hot to cold or cold to hot. Still in general electricity prices are much higher during the days in summer and are cheaper at night when there is far less demand so depending on how much the customer can shift their electricity usage they can reduce their electricity bills (SCE RTP hourly savings yearly benefits, 2013). Customers with inflexible demand would probably end up paying higher costs overall as chances are their highest moments of demand would also be during peak times.

SCE’s Time-of-Use Program is similar to the real time pricing program but with less variability in the prices. All small and medium business and agricultural customers have been required to sign up for it. Like with the real time pricing program electricity prices change throughout the the day however there are only three blocks of prices, off-peak, mid-peak, and on-peak, and the prices and times of those blocks are set ahead of time (SCE Time-of-Use Rates for business, nd). Time-of-rates were designed by SCE to have a relatively small effects on the bills of the customers on the net with more than 90% of the new, mandatory, customers expected to have less than $100 change in their bill (Churchwell, 2015). The purpose of the program was not to raise additional funds for SCE but to try and slowly shift demand away from peak hours by letting businesses and agricultural customers find their own ways to shift their demand to reduce bills once they got used to the new system. Residents with smart meters can also sign up for several different options with time-of-use rates but it is optional and they are allowed to switch off the plan if they find it too difficult or expensive (SCE Time-of-Use Residential, nd).

Permanent Load Shifting

The last form of Demand Response run by SCE involves trying to permanently shift a customer's load away from peak hours by providing incentives for thermal energy storage. Thermal energy storage systems creates cooling during off peak hours, when rates are lower, and then distributes it during on-peak hours to minimize peak energy usage (SCE Permanent Load Shifting, nd). SCE attempts to incentivize these systems by providing reimbursements and incentives for companies that install the systems.

SCE's Policy Paradigms and Reasoning for Demand Response Programs

Southern California Edison offers several reasons for its support for demand response programs. SCE offers the benefits to both consumers and the utility as reasons for participating in demand response programs, as well as promoting the positive effects on the environment as another factor (SCE Demand Response Programs, nd).

The positive effects of demand response for the grid and consumers have been discussed previously, however, it is important to note that SCE is in dire need of its demand response programs. In 2016 the Aliso Canyon Gas Storage Facility, had to shut down and remains closed to injections today with only minimal withdrawals. This has drastically reduced natural gas supplies and margins in SCE territory (Penn, 2017). In response to this regulators granted extra funding to SCE's demand response programs in order to help make up the gap in supply (Bade. 2016).

It is interesting to note that while the main page on demand response programs on SCE's website lists the environmental as one of the benefits from demand response programs most of the individual program flyer descriptions do not (SCE Demand Response Programs, nd). Yet the grid stability and financial benefits to the customers are mentioned for all of them. The exceptions to this, at least among the programs with online flyers, are the Demand Bidding Program (DBP Factsheet, 2015), and the Optional Binding Mandatory Curtailment Program (SCE OBMCP, 2010). This is interesting as neither of them have much in common nor do they appeal particularly to residential users, the group one would assume would care most about the environmental benefits.

Impact on Demand

It is important to note at least one paper has shown demand to be relatively inelastic in the overall California Independent System Operators market, of which the SCE is an important part and one of the largest demand bidders (Kohansal, Mohsenian-Rad, 2016). This means that a 10% drop in price would result in less than 10% drop in electricity use by the demand side bidders. However this applies to the utilities themselves making the bids not the individual customers. To learn more about the root causes and a fuller explanation of this read "A Closer Look at Demand Bids in California ISO Energy Market" by Kohansal, Mohsenian-Rad, 2016. Regardless this demand inelasticity in California does not mean that demand response is ineffective but it does mean that, at least with the current tech, there is a limit to what a pure monetary incentive can provide for demand response.

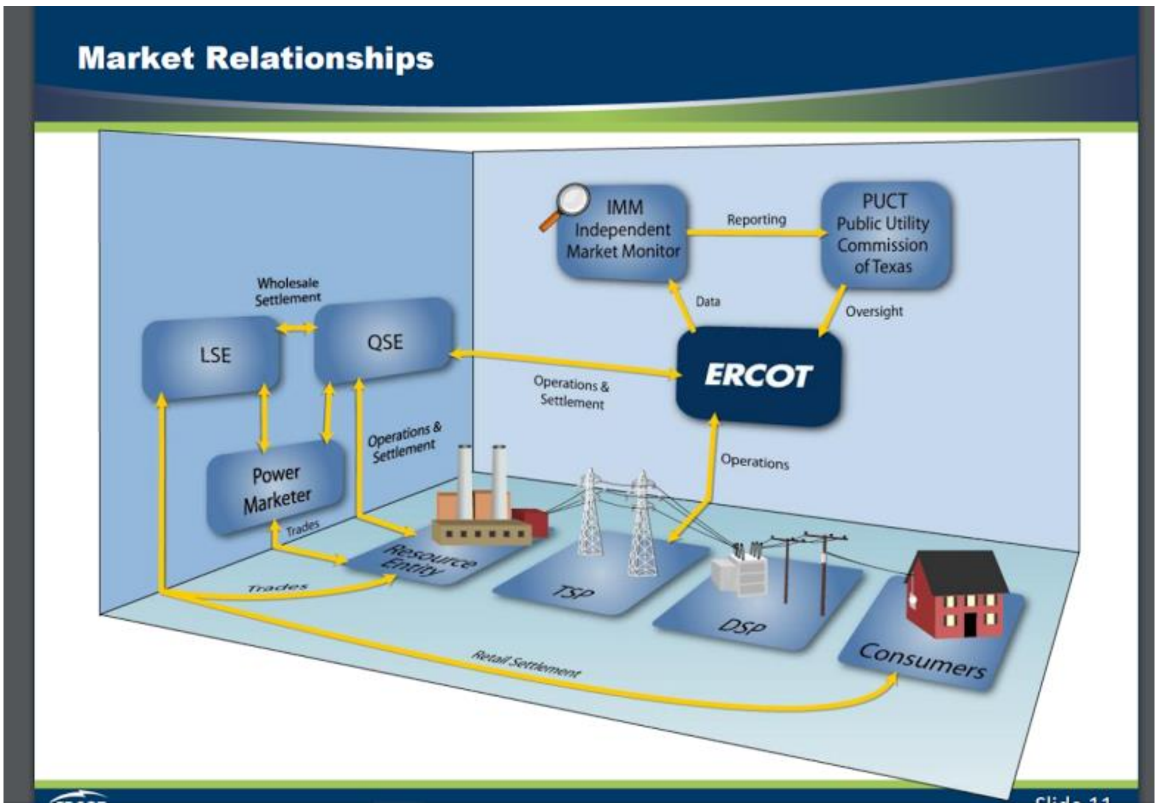
Introduction to the Electric Reliability Council of Texas

The Electric Reliability Council of Texas (ERCOT) is an independent system operator that controls 90% of the state's electric load (ERCOT, nd). Unlike SCE ERCOT is not profit driven. Officially formed in 1970 ERCOT's members range from electric utilities to generators to consumers. ERCOT serves over 24 million consumers and prides itself on over 75% of its load being made up of competitive choice customers, so the customers have a choice towards who provides their energy (Ercot.com quick facts sheet). ERCOT has been so successful at this that Texas has been listed as the most competitive residential electricity market for 8 years (ABACCUS, 2015). ERCOT has four primary responsibilities,

1. System reliability: planning and operations
2. Wholesale market settlement for electricity production and delivery
3. Retail switching process for customer choice
4. Open access to transmission

ERCOT’s territory has a rather complex setup as can be seen in the diagram below (ERCOT_Nodal Market Guide, 2010). Starting in 1999 the utilities were broken up into generation, transmission, retail; the market was opened up so new entrants were allowed (Baddour, 2016). The important entities for this paper will be touched on here and then discussed in how they relate to the demand response programs in the programs respective sections. Qualified Scheduling Entities (QSEs) submit the bids to buy or sell energy in both the Day-Ahead Market and the Real-Time Market (ERCOT QSE, nd). Load Serving Entities (LSEs) are the retailers sell the electricity to the final customers (ERCOT LSE, nd). The Resource Entity can be either demand or supply side the market does not differentiate the value of their bid. They and their assets are registered and are represented by QSE's (ERCOT RE, nd).

ERCOT has a unique electricity market structure (Gross, 2015). As the independent system operator ERCOT must maintain the balance between supply and the demand on the grid within its territory.



It manages electricity within its territory with three different markets, a day ahead market, and real time pricing market, and an ancillary services market (FERC, 2016). Participants in the day ahead market buy or sell electricity for the next day and are bound to those prices. The real time market is picked both by lowest price and by where it makes most sense to have the production, as, if it is too concentrated the grid in the area might not be able to handle transporting it elsewhere (Gross, 2015).

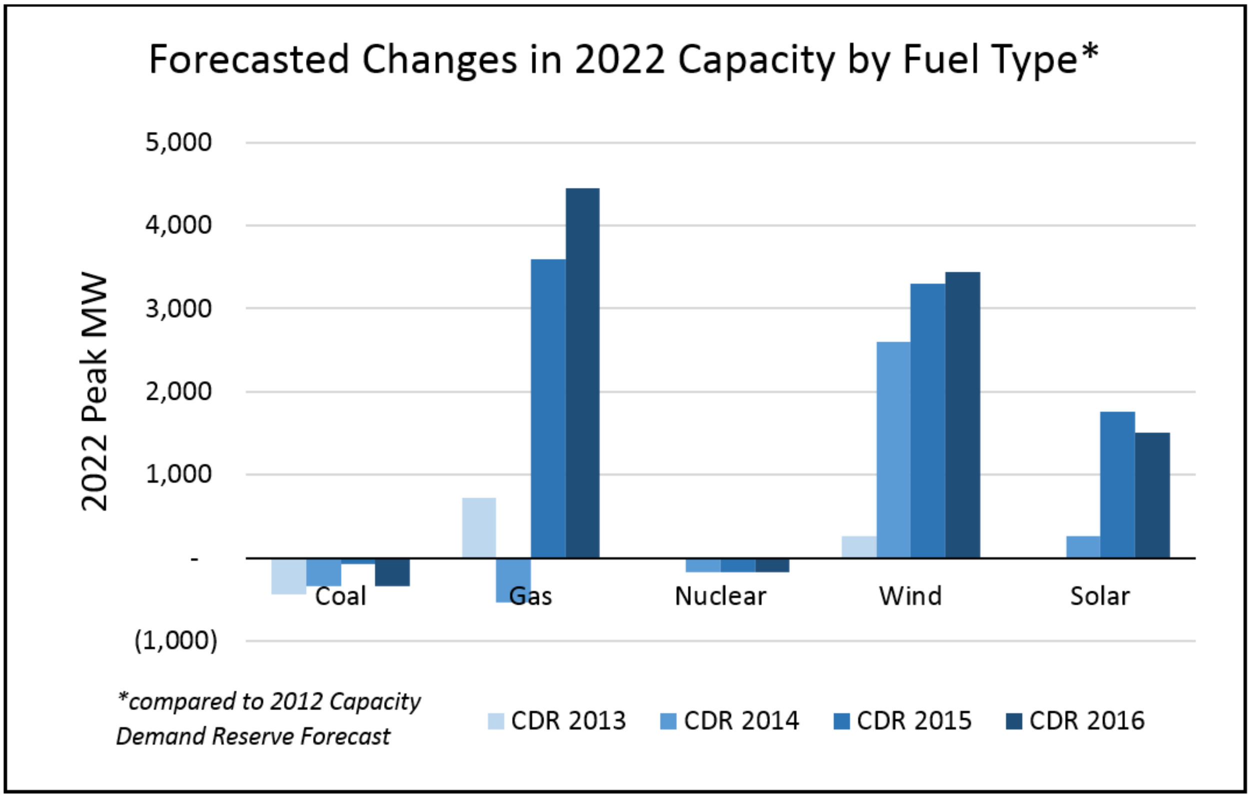
ERCOT is also unique in that it has no forward capacity market using an energy only market. Since it was estimated to take around 5 billion a year for a capacity market ERCOT instead Instead it has an operational reserve demand curve which lets the generating companies take the financial risks (Gimon, 2016). It has been suggested that one reason why ERCOT never developed a capacity market is due to a reluctance to do anything that could signify supply and demand in an energy-only market (Zarnikau, 2013).

Demand programs in ERCOT's territory are far more centralized under ERCOT than California's programs are under CAISO. While the individual utilities and providers do have a few programs, they tend to be more focused on increasing energy efficiency, which then reduces peak load, rather than in load shifting. As opposed to the many programs in California, Texas has focused in on fewer programs with each utility offering only one or two load management programs (the Texan utilities prefered term from a quick review of their websites, though ERCOT primarily uses demand response), (AEP TNC, nd) (Centerpoint Energey, nd), with the major programs being run by ERCOT through the Retail Electricity Providers (Energy.gov EIP Texas, 2015). The 2015 Annual Report of Demand Response in the ERCOT Region, created by ERCOT itself, categorizes and groups its demand response resources.

- Load Resources
- Emergency Response Services
- TDSP Load Management Programs
- 4CP Load Reduction
- Price Response Demand Response Products

- ○ Block & Index
- ○ Critical Peak Pricing
- ○ Peak Rebates
- ○ Real-Time Pricing
- ○ Time of Use Pricing
- ○ (Annual Report on ERCOT DR, 2016)

Each of these programs is designed for different needs that ERCOT may face and each focuses on different parts of the market and different levels of response(ERCOT ERS, nd). ERCOT's demand response programs are available to residential customers as well as business and industry (Lie, Lee, Lee, 2014). In fact, since 2011 ERCOT is required by Senate Bill 1125 to allow residential as well as commercial and industrial consumers to partake in load participation programs (Load Participation in ERCOT, 2015). ERCOT needs this demand response capacity because, as can be seen on the graph below (Gimon. 2016), variable renewable sources are growing fast there and are expected to be a significant portion of total energy by 2022. In 2009 FERC estimated that by 2019 Texas would have an estimated 18 gigawatts of demand response potential (quoted in Wattles, 2012). This capacity could help ERCOT deal with the variability of that comes with increased wind and solar capacity.



Overview of The Electric Reliability Council of Texas's Demand Response Programs

The Electric Reliability Council of Texas runs fewer programs than SCE. This reflects Texas's commitment to the free market with many of its demand response programs being based around giving consumers maximum freedom in their choices. As opposed to SCE's multiple dispatchable programs most of the programs in ERCOT's territory are automatic. Most, though not all, of the programs are run through ERCOT and for all of them it has the power to use them if it is needed for the stability of the grid (Annual Report on ERCOT DR, 2016). The demand response programs can be categorized in five different groups, load resources, emergency response services, Transmission/Distribution Service Providers (TDSP) Load Management Programs, 4CP Load Reduction, and Price Responsive Demand Response Products.

Load Resources

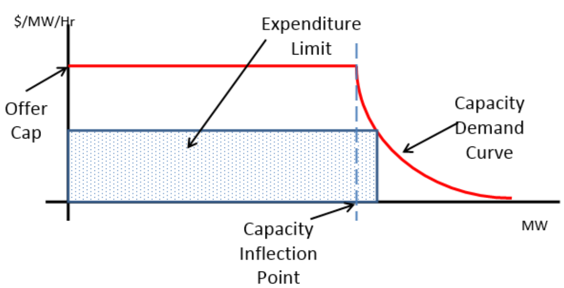
ERCOT's load resources rules provide an opportunity for demand response to compete on an equal level with supply side resources. For its real time and ancillary market, qualified customers may registers as Load Resources and may bid to reduce their energy through Qualified Service Entities. All that matters is the price of their bid, the bids, technically defined as buying less, are treated the same as supply increases by ERCOT in choosing what to use to keep the market balanced. So if the market reaches the level of the bid then they are required to fulfill their promised market capacity (ERCOT Load Resource Participation, nd). ERCOT provides some flexibility with these bids as they may be either a single price or a curve. The real time market moves in five minute blocks and so they may be required to adjust their usage quickly (ERCOT DSWG Loads in SCED, 2014). Load Resource not in the real time market can decide on different time spans of response that the loads can commit to, from 5 minutes to 30 minutes for the required demand drop (ERCOT Load Participation, 2015). Some of the resources are automatically activated if the frequency on the grid gets too low which can help keep the grid stable (ERCOT_Demand Response) If the Load Resources were picked in the day ahead ancillary market than they receive a payment regardless of whether or not they were actually called upon (ERCOT Load Resource Participation, nd). Overall Load Resources, are a very market based approach to encouraging demand response that takes little or no direct control from ERCOT or the utilities instead allowing the Load Resources to determine their own prices and times at which they will operate. The estimated maximum capacity of Load Resources was 3253.22 MW at the beginning of 2015 with the average for each month being between 1300 and 1600 MW (Annual Report on ERCOT DR, 2016).

Emergency Response Service

ERCOT's Emergency Response Service is designed for situations where fast responses are necessary in order to keep the grid working at full capacity. Created in 2008 (Wattles, 2012) it is split into four smaller programs, 10 and 30 minute programs for either weather or non-weather sensitive programs. Designed for both the demand and supply side the program lasts for four month and gives only 30 or 10 minutes warning, depending on which program was signed up for, before requiring action (ERCOT ERS, 2017), this time is often needed as unlike Load Resources these customers often aren't expecting to have to change their energy use. Customers can only qualify for ERCOT's Emergency Response Service program through Qualified Scheduling Entities (QSE's), groups that meet certain qualifications and can submit bids to ERCOT (ERCOT Abbreviated Qualification guide paper, 2006). The bids can promise any time or just specific time periods when the demand reductions can be achieved (ERCOT Load Participation, 2015). These QSE's then submit a bid price to ERCOT for the 'price' of their emergency response. A price is set by a prearranged capacity demand curve that is calculated to get the highest possible procurement of demand response with the minimum expenditure. During an event everyone involved is paid at the highest bidders price, so long as they are within the cost bounds, and carry out their bid successfully when called upon. This is illustrated in the graph above from ERCOT's Emergency Response Service Procurement Methodology Report (2016). Each four month session of the four different program types tended to attract between 300 and 600 MW of demand response (Annual Report on ERCOT DR, 2016).

TDSP Load Management Programs

Transmission/Distribution Service Providers are the closest things to utilities within ERCOT's territory. They are allowed to offer demand response programs within their areas that involve paying customers to reduce their demand during peak hours of the year. This paper will not be going in depth on the specifics of these as they are not run by ERCOT however it is important to note that ERCOT can call upon these to be deployed during specific emergency conditions. As of the beginning of 2015 these programs capacity was estimated at 180 MWs (Annual Report on ERCOT DR, 2016).



4CP Load Reduction Programs

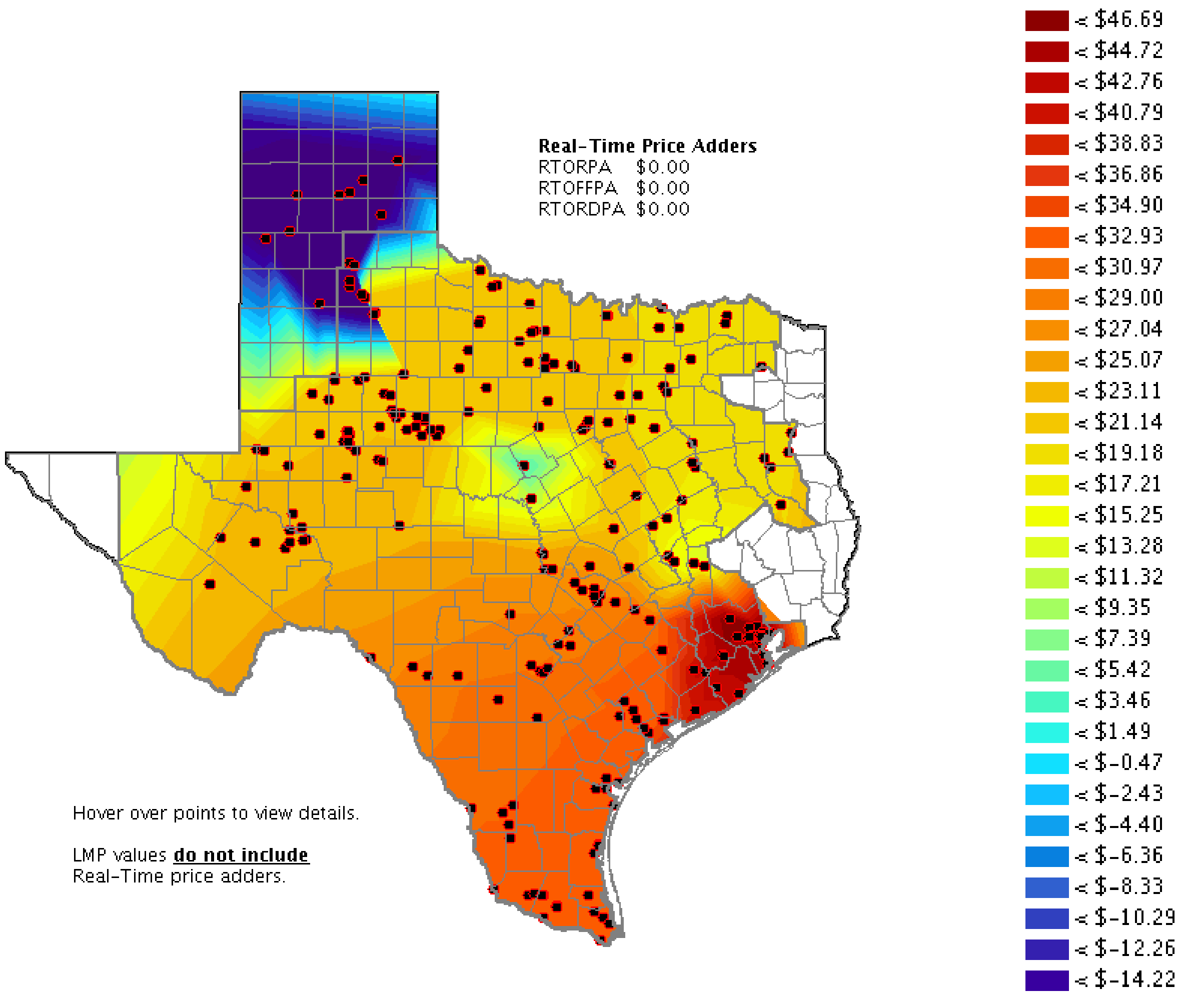
4CP stands for Four Coincident Peak. For each month in the summer, June, July, August, and September, the highest 15 minute peak is discovered. The 4CP program charges large scale customers with interval data recorders for their use of the transmissions systems based on how much they contributed to each of the peaks in the summer. These charges are then recouped from the users by adding a monthly charge to their electricity bill for the next calendar year (Zarnikau, 2013). This incentivizes companies to attempt to predict when those peaks will be and reduce their energy consumption ahead of them so that their charges will be lower the following year (Depaolo, and Brown, 2016). Ironically enough if enough of the large customers reduce their demand what would have been the highest peak for the month becomes just a rather high peak. so it flattens peaks out as each company tries to avoid the peaks in order to save money on their bill for the entirety of the following year. There was an estimated 840 - 985 MW response from this program in 2014 (Annual Report on ERCOT DR, 2016).

Price Responsive Demand Response Products

Price Responsive Demand Response Products are similar to the non event based pricing section of the SCE's portion. They are made up of several different programs each of which handles the cost of electricity and requirements for the program slightly differently. These tend to be run by the Retail Electricity Providers (REP's) not ERCOT, although ERCOT is often involved in the pricing. These programs are Block & Index, Critical Peak Pricing, Peak Rebates, Real-Time Pricing, Time of Use Pricing, Other Load Control Programs, Other Voluntary Demand Response Product, NOIE Load Control. These programs were estimated to give an estimated 472-761 MW of demand response due to them, although this data is missing time of use as its data had not yet been compiled (Annual Report on ERCOT DR, 2016).

Real Time Pricing

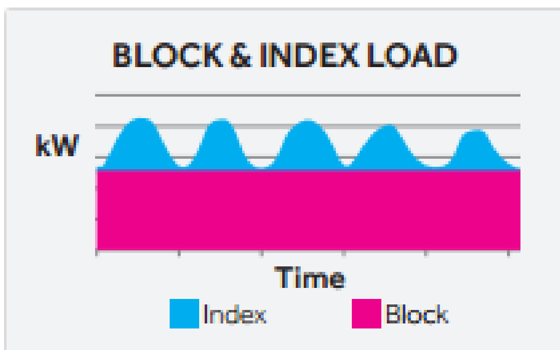
ERCOT's real time pricing market reflects the true costs of electricity at that moment in that section of the system. The system is a nodal wholesale market which applies transmissions costs not from various zones but by seeing the important delivery points it travels through and adding the congestion costs of each to the power costs (Boyle, 2010). An example of this taken at 4:42 eastern time 3/28/17 can be seen here (ERCOT Real Time Market, 2017). These prices are calculated every 5 minutes and the prices of electricity to the customer are set every 15 minutes (Yoon, Baldick, and Novoselac, 2014). This form of pricing offers much higher efficiencies as not only are the costs of meeting the higher demand being reflected but also the costs from congestion are reflected as well. This incentivizes those in the real time market to reduce demand when prices are high acting as a natural brake on



peaks as large consumers may work to avoid them and so reduce the peak in the first place. This also allows the utility to dispatch resources, both demand and supply side, efficiently as the location of the resource is already being taken into account (ERCOT Real-Time Market, nd). While these programs are run by the electricity suppliers the real time prices are decided by ERCOT's formulas.

Block & Index

Block and Index offers a compromise between traditional flat rates of electricity and the variability of real-time pricing systems. These contracts are typically run by the REP's but operate within ERCOT's markets (PUCT Report to Texas Legislature, 2017). Customers buy a fixed rate for a certain amount of electricity usage. Any usage above that set block is paid at the wholesale market real time price (ERCOT, Price Responsive Load, 2016). If the block is not filled and the real-time price is below the block price then the customer has to pay the difference between the block price and the real time price



(Thomas quoted in Hunt, 2014). This payment system approach offers certainty for companies who are worried about variable prices. It also encourages a flatter demand as the blocks are equal throughout the time period and so the customer doubtless will try to avoid paying the real time price to stay within their demand. An example of this approach can be seen in the graph above, from NRG Energy Inc, the pink is the electricity at the block price while the blue would be paid for at whatever the market price during that time period was (2016).

Critical Peak Pricing

Critical peak pricing is an adjustment to the typical flat rate paid by many of ERCOT's consumers. It is also a rare example of a dispatchable ERCOT supported program. While the program is run by the REP's much of the analytical work is done by ERCOT (TexasElectricityRatings, 2014). This has allowed several different variation to flourish however they all share one thing, when the grid needs stabilizing, the programs can be called upon and users gain credits for reducing their usage. Despite these incentives the programs have lacked significant customer participation with only 30-40 MW deployed (Annual Report on ERCOT DR, 2016).

Time-of-Use

ERCOT's time-of-use plans vary depending upon the supplier of electricity. The generally base of them however is functionally identical to SCE's, prices vary according to preset time periods (ERCOT Acronyms and Glossary, 2007). They have been very popular across Texan energy companies and have helped Texas balance out the nightly output from wind farms (Krauss & Cardwell, 2015). Unfortunately ERCOT has not yet finished its analysis of the time-of-use plans in its territory and so its full effects upon the grid have yet to be determined (Annual Report on ERCOT DR, 2016).

Policy Paradigms and Reasoning for DR in ERCOT

Texas and ERCOT make their reasoning for promoting so much demand response quite plain. It encourages competition and increases efficiency. In fact in ERCOT's Load Participation in the ERCOT Nodal Market publication they state,

> “Demand response in the ERCOT Nodal market is viewed as a means of enhancing competition, mitigating price spikes, encouraging the demand side of the market to respond better to wholesale price signals, providing for resource adequacy, and preserving system reliability.” (2015).

This explanation reflects ERCOT’s reliance upon the free market and see’s demand response as purely an economic to help increase its efficiency. As mentioned earlier one of the assumed reasons for ERCOT’s lack of adoption of a capacity market is due to its inherent non free market aspects (Zarnikau, 2013).

This free market attitude is reflected in their demand response programs with most of their programs being non-dispatchable automatic ones with little or no direct control of them by ERCOT. Even their Emergency Response programs involve preset bids with the participants being paid according to the particular emergency and only if the event lies within their bid parameters. The few programs it has that are dispatchable, critical peak pricing programs, do not actually require the customers to reduce their electricity, merely giving them energy credits if they do.

Methodology

This paper will use the six demand-side management levers designed by Davito, Tai, and Uhlaner to examine and compare the demand response policies of both Southern California Edison and the Electric Reliability Council of Texas. In the analysis section their emergency response programs and their overall price responsive programs will be examined and compared along the six levers explained below. Not every program will have every lever however every program will have some combination of the levers. The emphasis will be on where the programs differ as opposed to restating the aspects the programs share.

Demand-Side Management Levers

In their paper on demand-side management and the role of the smart grid Davito, Tai, and Uhlaner write about the six major levers that are needed for successful DSM programs (Davito, Tai, Uhlaner, 2010). The six levers are rates, incentives, access to information, controls, education and marketing, and finally, customer insight and verification (Davito, Tai, Uhlaner, 2010). As many policymakers have little experience with DSM programs, the levers help them to understand the options available to them. Each lever covers a different aspect of demand-side management programs, ensuring policymakers examine the full range of policy options and consider the effects of their policy. Each lever provides multiple choices that allow the customization of the policy to the specific needs of the policy maker.

The rate lever is not about how much consumers are charged but about the specifics of when the rates change. Currently, most utilities charge a flat rate meaning that they charge the same price for the same amount of electricity no matter when it is used. Some areas, however, are moving towards variable pricing where the price of electricity changes depending upon the time of day or demand. Different types of variable rates have been proposed; critical peak pricing which has higher prices only during peak times, prescheduled changes in costs where they set prices at different levels in advance, or real time variable electricity where the price changes constantly depending on demand. Some authors have even suggested inverted block pricing where the price increases with consumer demand (Badouard, 2013). Policymakers should closely examine each option as it is estimated that 60% of the energy gains that could be achieved by 2019 through DSM come from getting rid of the current flat rates (Davito, Tai, Uhlaner, 2010).

Incentives encourage energy efficiency and conservation by convincing consumers to participate in load shifting programs. This is one of the best known policy levers and is already widely used. For example, consumers who change their energy habits to reduce peak use for San Diego’s utility receive reductions and reimbursements on their energy bill to offset the upfront costs of load shifting technology (SDGE, nd). The policy maker must determine what level of incentives they can afford and to whom they will offer the incentives.

Access to energy information, like with the rates lever, has more to do with timely access to information than the mere ability to get it. In order for real time pricing to be effective, customers must be able to get real time info on the price of electricity and how much they are using. Increasing information has other benefits; a study showed that participants who saw their energy use in real time decreased their consumption by 6.5% (Davito, Tai, Uhlaner, 2010).

As opposed to simply encouraging consumers to reduce consumption, the control lever strategies provide consumers greater levels of control over their energy use. Although most people currently have no automation on devices to reduce energy consumption, the technology exists for homeowners to centrally control almost all of the home’s energy consumption. Control options even include the utility having the ability to cut customers energy use through turning off their air conditioners or other appliances (Galbraith, 2010). Control options have increased with the growth of information technology and are typically most effective when combined with real time rates. For instance, one could program a dryer or other such appliance to only use electricity when the price is below a certain level.

Currently demand-side management remains relatively unknown in the business world (Dena, 2013). While this is slowly changing, any DSM policy must ensure that its benefits are targeted to the areas where they will have the most effect. Different aspects of DSM may be best targeted to different groups; a businessman may care most about the cost saving aspects while the environmentalist homeowner may care more about the carbon footprint reduction. Deciding what media to use and what segments of the market to educate about the benefits of a DSM program are crucial to ensuring success.

Lastly, customer insight and verification are important in ensuring constant improvement and customer satisfaction. Yet they are all too often ignored. Customer insight involves getting feedback from previous customers and finding out what parts of the DSM program were most effective and which parts need work. Verification of energy savings is equally important in order to ensure the public that DSM policies are working. Unfortunately, researchers struggle to quantify the benefits of most DSM programs (EPA, 2015).

Analysis

Emergency Response Programs Compared

Emergency response programs are those that can be called upon during or just prior to emergencies on the electrical grid. SCE has three programs that are considered emergency response programs while ERCOT has only one. The two organizations have taken quite different approaches to their emergency demand response programs and that is reflected in the six levers. SCE triggers its two interruptible programs when grid reserves hit less than 5% (SCE Time-of-Use Base Interruptible Program, 2010), while ERCOT can call its emergency program whenever there is an emergency energy alert (Technical Requirements, 2017), the lowest of which is when reserves fall below 2,300 megawatts (ERCOT Power Watch, nd). These programs will be analysed according to the six aforementioned policy levers.

Rates

As discussed previously ERCOT essentially pays a rate for disuse of electricity. That rate is determined by how bad the incident is, and thus how much funding is provided, and by what other bids there are in the emergency response program at that time. All whose bids fall beneath the minimum are paid according to the highest bid for their reductions (ERCOT's ERS Procurement Methodology Report 2016). SCE does nothing with rates for its emergency response programs.

Incentives

SCE has relied upon incentives to encourage consumers to sign up for demand response programs. For its two interruptible programs SCE offers, depending upon the season, peak time, and size of the customer, between $1.05 and $21.11per kW reduced, as well as a small credit for being a part of the program (SCE Time-of-Use Base Interruptible Program, 2010). While SCE"s Optional Binding Mandatory Curtailment Program provides the incentive of not having one's power shut off during rotating outages (SCE OBMCP, 2010).

Access to Information

Access to information, while crucial to both SCE and ERCOT’s demand response programs in general, is less critical to their emergency response programs. ERCOT offers either 10 or 30 minute periods after which the promised demand reductions must be manifested. It also offers lists online of the previous offers and events from the last contract period (ERCOT ERS, 2017). SCE does not offer any warning for agricultural interruptible program but its time of use base interruptible program offers 15 or 30 minutes for demand to be reduced (SCE Time-of-Use Base Interruptible Program, 2010). All SCE’s programs allow different ways for notifying customers of an event.

Utility Controls

SCE and ERCOT, arguably, differ most widely on utility controls in their demand response policies. This is perhaps best illustrated in their divergent policies for emergency demand response.

SCE’s two interruptible emergency programs are called into action by the utility. For the agricultural program there is nothing the customer can do SCE automatically shuts off the pumps, all of the control is given to the utility (SCE Agricultural and Pumping Interruptible Program, 2010). For the other two programs while customers are responsible for reducing their demand they face penalties if they do not reduce demand in time (SCE.com DR section, 2017). Everyone in the program either makes the cuts or gets fined. The utility holds the control with the ability to call these events and thus require the reductions or not to depending upon its needs. This makes sense considering these are emergencies programs and are designed to only be used during system events.

ERCOT however, while still having a dispatchable, leaves much more up to market participants. Those who sign up for the program get to bid for demand response prices for various time periods. When there’s an event ERCOT calculates the amount it is willing to spend on emergency response to deal with that event and the demand responders are picked from cheapest up, with everyone paid at the price of the highest accepted bid (ERCOT Load Participation, 2015). While this seems similar to SCE’s program it gives far more control to participants in the program. First of all they can put the price where they want it and be guaranteed to only get called on if they get it or higher. Secondly they can tailor their bids to fit their schedule and simply not bid during times that are troublesome for them. So while ERCOT can still call the events they cannot force any customers to participate nor control the prices they will pay to the customers involved.

Education and Marketing

SCE and ERCOT also vary widely in their education and marketing efforts. For all of its emergency demand response programs SCE has two to five page pamphlets explaining how they work and the general benefits of these programs as well as. These seem geared towards the users of the specific programs being relatively simple to understand while also emphasizing the benefits to businesses that sign up. However to get more complete data about each of the plans customers are asked to call the demand response help desk (SCE.com DR section, 2017). SCE’s 2015 report also suggested increasing marketing of dual enrollment programs to current emergency response users (Churchwell, 2015). ERCOT on the other hand has no simple explanatory pamphlets for their emergency response program. Instead its Emergency

Response Service web page contains links to data about the program and their methodology and schedules for this year as well as for previous contract periods (Ercot.com, 2017). This data seems, in this author's opinion, to be much more geared towards the qualified servicing entities, the groups that act as intermediaries between the customers and the program for ERCOT.

Customer Insight and Verification

In their reports on demand response programs both SCE and ERCOT quantify the demand savings from their emergency response programs (Churchwell, 2015)(Annual Report on ERCOT DR, 2016). This verifies to the utility that the demand response programs are working while customers receive payments and so get their verification relatively easily as well. Neither program emphasis its attempts to collect customer feedback. Though SCE does conduct research into customer preferences as well as into the best available technologies (SCE DR projects, 2013).

Final Comparisons

Emergency demand response programs are one of the areas were SCE and ERCOT vary most widely. Its Emergency Response Service is the closest thing ERCOT has to a dispatchable program but it still gives a lot of latitude to demanders. This reflects well with ERCOT’s more laissez faire free market approach to governing in its markets. SCE on the other hand has more dispatchable emergency response programs that forces everyone involved to comply or face penalties, this helps ensure a guaranteed amount of response but does give consumers significantly less flexibility.

Price-Responsive Programs Compared

Both SCE and ERCOT have several significant price responsive options for consumers. Price responsive programs are non dispatchable and involve changing the price of electricity to the consumer to incentivise them to shift their demand away from peak periods. It is important to note that ERCOT and SCE define price responsive programs very differently. ERCOT uses it for programs with customers responding to prices and shifting their demand. SCE however, uses it as the SCE responding to prices and activating programs. This analysis will focus on ERCOT's use of the term rather than SCE's. SCE runs three prices responsive programs, a Real-Time Pricing Program, a Time of Use Program, and a Critical Peak Pricing Program. ERCOT is involved in Real-Time Pricing, Time of Using Pricing, Critical Peak Pricing, and Block & Index Pricing.

Rates

Rates are the core aspect of price-responsive programs as they are what's changed in order to encourage consumers to shift their demand. The programs run by SCE and ERCOT are similar in many ways but do have several distinctive features and differences worth examining.

SCE's Real-Time Pricing Program is interesting as despite its name the rates are not determined in real time, instead they are set to change every hour on the hour and the prices are set according to time of day, season, weekday vs weekend, voltage, and temperature. Also the prices are set a day in advance so those in the program can prepare for them (SCE RTP hourly savings yearly benefits, 2013). The program is only open to non-residential customers (SCE DRE, nd).

SCE's Time-of-Use program splits the days prices into three sections of off-peak mid-peak and on-peak. SCE's Critical Peak Pricing Program lets SCE call certain days during which all involved must pay higher prices (George, Bode, & Holmberg, 2011). Otherwise rates remain unchanged.

ERCOT's Real time Pricing Market changes prices every 15 minutes with the prices being calculated every 5 minutes (Yoon, Baldick, and Novoselac, 2014). The programs are run by the Retail Electric Providers (ERCOT DR and PR Survey, 2014). Most large consumers in ERCOT pay the wholesale price of electricity and so they have a strong incentive to reduce demand during price spikes in the grid near them (Searcy, 2012). ERCOT's real time pricing may provide less benefits for consumers but also provides a stronger incentive to reduce demand during peaks as the time period of price changes is faster and is in close to real time as opposed to SCE's planning the prices the day before.

ERCOT's Critical Peak Programs does not change the rates offered to consumers. Block and Index partially changes rates by allowing consumers to choose for themselves whether they want a constant rate for a large amount of electricity or to buy a lower amount and risk more of their purchase going into the real time market. This gives consumers more freedom to reduce their risk of higher prices than any of the SCE's plans. Time of use plans change the rates depending upon preset time periods similar to SCE's but with more variety in the time periods depending upon the REP the customer chooses (Krauss & Cardwell, 2015).

Incentives

Judging the incentives of the programs is difficult as there are a wide variety depending upon type of consumer and size of demand. However, both the SCE's Critical Peak Pricing and residential Time-of-Use plans as well as ERCOT's Critical Peak rebate program offer credits to consumers who join them. SCE's residential Time-of-Use plans offers incentives depending upon their baseline allocations and can vary depending upon which of SCE's Time-of-Use plans the customer signs up for (SCE TOU rate plans, nd). SCE offers bill protection for consumers in its Critical Peak Pricing plan. In the first year their bills are guaranteed to not be any higher than they would have been outside of the plan. This of course offers consumers a strong incentive to sign up for the plan as they lose nothing for the first year (SCE SAI, 2013). ERCOT's Critical Peak Rebate Program also offers credits although the amount is not listed and varies by REP (TexasElectricityRatings, 2014).

Information

SCE and ERCOT both provide information however the type is different. While both states have pushed for smart meters, which provide a constant flow of information (Tweed, 2016), most of SCE's plans tend to involve providing information to consumers a day ahead while ERCOT's real time market means the price can change every 5 minutes. ERCOT maintains the current price on its website and publishes warnings on days when events are probable. This reflects the balancing act all grid operators must achieve. To afford consumers sufficient time to plan, and to more accurately charge consumers according to the real price in the market at that time. SCE's price responsive programs have leaned more towards trusting in its ability to predict events and to provide information to consumers earlier, while ERCOT's Real-Time Pricing has preferred to trust the markets to efficiently correct with the changing prices. Time of Use and Critical Peak Pricing however do provide their rate information ahead of time, although Time-of-Use rates are preset (Acronyms and Glossary, 2007) and so do not need constant information flows.

Controls

Controls for these programs lie entirely with the consumers. While both ERCOT and SCE have set up structures they believe will encourage consumers to reduce demand during peak hours, or use it during off peak hours, consumers are not subject to any fines or additional costs beyond the increased price of electricity. Both California and Texas have pushed for smart meters within their grids (Tweed, 2016), these meters give consumers more control over their electricity use by making them aware of how much they use at any time. Control to call upon the programs is shared in both states by the ISO, CAISO and ERCOT respectively, as well as the utilities within the states, SCE and a whole host of competitive sellers in Texas. Still consumer control is the key point of price-responsive programs and neither state has significantly affected it.

Education

Both ERCOT and SCE attempt to educate different segments of the market about their price-responsive programs. SCE, as mentioned before, has pamphlets that explain the programs in relatively simple terms (SCE.com DR section, 2017). These are geared towards business owners and other consumers who, while not large enough to be forced into one of ERCOT's price responsive programs, might be interested in joining. ERCOT on the other hand publishes little educational information on price responsive programs at all. While it has a large section of the website devoted to the real-time market (ERCOT RTM, nd) it devotes little attention to price responsive programs, even in many of its demand response reports (Frontier Asspcoates DR and PR, 2014). Doubtless this is because, while ERCOT does much of the heavy lifting with analytics for these programs and can call on them when needed, the programs are run by the REP’s (Annual Report on ERCOT DR, 2016).

Customer Insight and Verification

Price-responsive programs need little in the way of customer verification as customers can see right away the changes in their bill as well as the credits they receive for select programs. Customer insight is something both SCE and ERCOT need to work on moving forward if they are to remain ahead of the pack and create innovative and top notch demand response policies.

Final Comparisons

When compared to their respective emergency response programs ERCOT and SCE have rather similar price responsive programs. While their real-time pricing plans are different overall the two are remarkably similar along the levers. The sheer number of programs mean there was much to write about when comparing the differences in their approach to the specific policy lever but many of the programs shared more similarities than differences. The programs relied upon the consumers to decide how much to cut, or if they even wanted to at all, in response to the programs; showing a reliance on the market to find the most effective way of reducing demand. Overall both have strong price responsive programs that have allow demand response to do well in their respective areas (Tweed, 2016).

Conclusion

As noted previously demand response programs in both SCE in California and ERCOT in Texas share many aspects with each other but differ on a few key points. These points of differentiation come less from quantitative differences in the needs of their consumers, in fact Texas and California have surprisingly comparable electricity markets (Mormann Reicher & Hanna, 2016) than they do from the differing policy paradigms and political roles the actors play in each state.

ERCOT’s regulatory philosophy puts an emphasis on consumer choice and the free market have pushed its policies into being very consumer oriented. They give those involved large amounts of choice over demand reductions and prices involved. The few programs it has that are dispatchable are voluntary for those involved. Only its Emergency Response Service mandates certain demand reductions at certain times. This makes sense given the importance of having a program of last resort. Yet the program remains as consumer friendly as possible by allowing those involved to have bid on their reductions and when they are available for them, they are only called upon if the situation has reached a level where they will be paid at least their bid. The one negative effect of this form of program is, while it is very demand responder friendly, it does increase uncertainty for them some as they do not necessarily know right away how much money and single event will give them. The program also provides ERCOT with the ability to budget certain amounts for how bad the grid emergency is and then to maximize its reductions with that budget. This theme of programs designed to give consumers maximum choice and free market forces is a recurring aspect of ERCOT's programs.

Southern California Edison also works hard to incorporate market forces into its programs. However there is more of an emphasis of utility control in SCE's programs and less of one on consumer choice and more on utility control and certainty. SCE relies heavily on dispatchable demand response programs. Moreover the vast majority of its demand response programs block the hours they will be called and penalize those who do not carry out the promised reduction. For example SCE's emergency response programs do not allow bids, either you are in or out. Rather than picking an amount of money and seeing how much reduction that will get them as ERCOT does SCE knows the amount of reduction and the amount they will have to pay to get it if they activate their programs. This makes accounting easier for SCE as it knows what to expect. It also allows SCE to promise the max number of hours and uses of each program giving consumers some certainty in the amount of reduction that will be required of them. However it does not attract consumers who may be on the margin and would prefer to only be called on if the price was above a certain level. Overall this emphasis on utility control and certainty seem to underlie many of the differences from ERCOT's demand response programs.

SCE and ERCOT demand response programs have different objectives with the markets. SCE attempts to find small niches where demand response will be effective and run multiple programs each targeting different niches of consumers. ERCOT however focuses on a few larger scale programs that any decently sized consumer can opt in or out of. This makes sense given their respective positions as a utility and an ISO. ERCOT has to create policies that cover almost the entire state while SCE can create ones focused to meet its needs in a much smaller area.

Neither way of using demand response is inherently better or worse than the other nor does either ERCOT or SCE entirely devote itself to one or the other, both have programs with aspects of both. In fact CAISO in California is taking a leaf from Texas and aggregating much of its demand response programs into itself instead of leaving them independent with the utilities (Combs & Morales, 2016) Texas and California both face issues of meeting electricity demands with low electricity prices driving older coal and natural gas power plants out of business and an increasing amount of variable renewable energy generation in both states (O'Donnel, 2016). Both states are using demand response programs as tools to help them deal with these growing problems (Trabish, 2016).

In conclusion, the electrical grid faces challenges. California and Texas provide excellent examples of states that are relying on demand response programs to help meet these rising problems. Though Texas and California have significant policy and regulatory philosophy differences, they are far from opposites. They are different sides of the same coin, not opposite ends of the spectrum. Moving forward, both Southern California Edison and the Electric Reliability Council of Texas will continue to need their demand response programs as they adapt, doubtless along their regulatory philosophy's, to increased numbers of intermittent energy sources and the growing ability of technology to shift demand. Whether demand response will be enough to meet the challenges of the changing electrical grid remains to be seen, but Texas and

California offer proof that even with very different policy paradigms behind the programs, demand response can be an effective tool for grid stabilization.

So what will the future hold for demand response? It is this author's opinion that the main driver behind the expansion of demand response programs will be from the increasing use of intermittent energy sources on the electrical grid. A certain level of smart grid is a necessity for most demand response programs and the development of microgrids will doubtless help facilitate an increase in demand response programs use. However, I do not think it is a coincidence that two of the states with the most advanced demand response programs, Texas and California, also have significant amounts of variable resources integrated into the grid. Demand response can allow for greater increases and decreases in electricity usage than microgrids, or other alternatives, can. Storage is still rather inefficient, as it loses its capacity over time, and so it is not yet ideal for meeting the needs of a more variable grid. Demand response programs on the other hand, when setup correctly, do not lose their effectiveness over time and, in some cases, can work constantly and passively to reduce peaks and increase valleys in demand. As the U.S. starts using more variable resources demand response programs will doubtless spread from the more niche position it holds now to become one ocrf the main pillars of our electric system.

Citations

ABACCUS. (2015, July). *Annual Baseline Assessment of Choice in Canada and the United States 2015* [PDF]. Distributed Energy Financial Group LLC.

AEP. (n.d.). AEP Texas North Company. Retrieved April 01, 2017, from http://www.aepefficiency.com/TNC.html

Andersen, G. (2016, June 20). INTEGRATING RENEWABLE ENERGY. Retrieved April 1, 2017, from http://www.ncsl.org/research/energy/integrating-renewable-energy.aspx

Baddour , D. (2016, June 08). Texas' deregulated electricity market, explained. Retrieved April 01, 2017, from http://www.houstonchronicle.com/local/explainer/article/texas-electric-deregulation-ERCOT-TCAP-7971360.php

Bade, G. (2016, June 15). CPUC approves extra demand response in wake of Aliso Canyon gas leak. Retrieved April 01, 2017, from http://www.utilitydive.com/news/cpuc-approves-extra-demand-response-in-wake-of-aliso-canyon-gas-leak/420968/

Badouard, T. (2013, March 31). The residential increasing block pricing structure: an efficient solution to control energy demand and tackle inequalities. Retrieved April 01, 2017, from https://www.energypolicyblog.com/2013/03/31/the-residential-increasing-block-pricing-structure-an-efficient-solution-to-control-energy-demand-and-tackle-inequalities/

Borenstein, S. (January 01, 2005). The long-run efficiency of real-time electricity pricing. *The Energy Journal, 26,* 3.)

Boyle, B. (2010, March 15). What a Nodal Market Means for Texas and ERCOT. Retrieved April 01, 2017, from https://webberenergyblog.wordpress.com/2010/03/14/what-a-nodal-market-means-for-texas-and-ercot/

Centerpoint Energy. (n.d.). Commercial Load Management Program. Retrieved April 01, 2017, from http://www.centerpointenergy.com/en-us/SaveEnergyandMoney/Pages/commercial-load-management-program.aspx?sa=ho&au=bus

Churchwell, C. A. (2015, April 1). *Executive Summary: 2015–2025 Demand Response Portfolio of Southern California Edison Company* [PDF]. Nexant Inc.

COMBS, J. S., & Morales, A. M. (2016, February 1). *SOUTHERN CALIFORNIA EDISON COMPANY'S (U 338-E) PROPOSAL FOR APPROVAL OF ITS 2017 DEMAND RESPONSE PROGRAM AND BRIDGE FUNDING AUTHORIZATION* [PDF]. Rosemead, California: Southern California Edison.

Daniels, J. (2017, February 09). Less than 1 percent of California now in 'extreme' drought. Retrieved April 01, 2017, from http://www.cnbc.com/2017/02/09/less-than-1-percent-of-california-now-in-extreme-drought.html

Davito, B., Tai, H., & Uhlaner, R. (2010). The Smart Grid and the Promise of Demand-Side Management. Retrieved April 1, 2017, from http://assets.fiercemarkets.net/public/smartgridnews/mckinsey_demand_side_mgtm.pdf

DENA. (2013, June 25). Demand side management remains unknown in industry and commerce. Retrieved April 01, 2017, from http://dena.goprelive.de/en/press-releases/pressemitteilungen/demand-side-management-remains-unknown-in-industry-and-commerce.html

Denholm, P., & Hand, M. (March 01, 2011). Grid flexibility and storage required to achieve very high penetration of variable renewable electricity. *Energy Policy, 39,* 3, 1817-1830.

DePaolo, A., & Brown, J. (2016, June 21). Gexa Energy Teams Up with AutoGrid to offer New Demand Response Programs in ERCOT. Retrieved April 01, 2017, from http://www.businesswire.com/news/home/20160621006077/en/Gexa-Energy-Teams-AutoGrid-offer-Demand-Response

DOE. (2014, August). *2014 Smart Grid System Report* [PDF]. Washington DC: Department of Energy.

DOE. *QUADRENNIAL TECHNOLOGY REVIEW AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES Chapter 3: Enabling Modernization of the Electric Power System*. N.p.: Department of Energy, Sept. 2015. PDF.

EDISON. (n.d.). About Us | Edison International. Retrieved April 01, 2017, from http://www.edison.com/home/about-us.html
EEX.GOV. (2011). Load shifting | Energy EXchange. Retrieved April 01, 2017, from https://www.eex.gov.au/opportunity/load-shifting
Energy.gov. (2015, September). Energy Incentive Programs, Texas. Retrieved April 01, 2017, from https://energy.gov/eere/femp/energy-incentive-programs-texas
EPA. (2015, August 3). *Evaluation Measurement and Verification (EM&V) Guidance for Demand-Side Energy Efficiency (EE)* [PDF]. U.S. Environmental Protection Agency.
EPRI. (2011, March). *Estimating the Costs and Benefits of the Smart Grid : A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid* [PDF]. Palo Alto, CA: Electric Power Research Institute .
ERCOT. (n.d.). About ERCOT. Retrieved April 01, 2017, from http://www.ercot.com/about
ERCOT. (n.d.). Load Serving Entities. Retrieved April 01, 2017, from http://www.ercot.com/services/rq/lse
ERCOT. (n.d.). Resource Entities. Retrieved April 01, 2017, from http://www.ercot.com/services/rq/re
ERCOT. (n.d.). Emergency Response Service. Retrieved April 01, 2017, from http://www.ercot.com/services/programs/load/eils
ERCOT. (n.d.). Load Resource Participation in the ERCOT Markets. Retrieved April 01, 2017, from http://www.ercot.com/services/programs/load/laar
ERCOT. (n.d.). Emergency Response Service. Retrieved April 01, 2017, from http://www.ercot.com/services/programs/load/eils/
ERCOT. (n.d.). Real-Time Market. Retrieved April 01, 2017, from http://www.ercot.com/mktinfo/rtm
ERCOT. (n.d.). POWER WATCH - CONSERVATION NEEDED ENERGY EMERGENCY ALERT 1. Retrieved April 1, 2017, from http://www.ercot.com/eea_info/show/26462
ERCOT. (14, October 14). *EMERGENCY RESPONSE SERVICE Procurement Methodology* [DOC]. Electric Reliability Council of Texas.
ERCOT. (2006). *ERCOT QSE and CRR AH Qualification Guide* [DOC]. Electric Reliability Council of Texas.
ERCOT. (2007, May 1). *ERCOT Load Profiling Guide Acronyms and Glossary* [Doc]. Electric Reliability Council of Texas.
ERCOT. (2010). *Texas Nodal Market Guide* [DOC]. Electric Reliability Council of Texas.
ERCOT. (2014, April 23). *Load Participation in SCED v1 Overview & Refresher* [PPT]. Electric Reliability Council of Texas.
ERCOT. (2015, April 23). *Load Participation in the ERCOT Nodal Market* [DOC]. Electric Reliability Council of Texas.
ERCOT. (2015). *ERCOT Demand Response* [PPT]. Electric Reliability Council of Texas.
ERCOT. (2016, August). *Price Responsive Load/ Demand Response Data Collection* [PDF]. Electric Reliability Council of Texas.
ERCOT. (2016, December 7). *Emergency Response Service Technical Requirements & Scope of Work February 1, 2017 through May 31, 2017* [DOC]. Electric Reliability Council of Texas.
ERCOT. (2017, January). *ERCOT Quick Facts* [PDF]. Electric Reliability Council of Texas.
ERCOT. (2017, March). *2016 Annual Report of Demand Response In the ERCOT Region* [DOC]. Electric Power Research Institute .
ERCOT. (2017). Emergency Response Service. Retrieved April 01, 2017, from http://www.ercot.com/services/programs/load/eils
ERCOT. (2017, March 28). LMP Contour Map: Real-Time Market - Locational Marginal Pricing. Retrieved April 01, 2017, from http://www.ercot.com/content/cdr/contours/rtmLmpHg.html

Felix Mormann, Dan Reicher, and Victor Hanna, *A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas, and Germany*, 35 *Stan. Envtl. L. J.* 55 (2016).

FERC. (2016, March 10). FERC: Electric Power Markets - Texas. Retrieved April 01, 2017, from https://www.ferc.gov/market-oversight/mkt-electric/texas.asp

FERC. *Assessment of Demand Response and Advance Metering*. N.p.: Federal Energy Regulatory Commission, Dec. 2016. PDF.

Follett, A. (2016, January 10). Lights Out: The Top 7 Threats To America's Power Grid. Retrieved April 01, 2017, from http://dailycaller.com/2016/01/10/top-7-threats-to-americas-power-grid/

Frontier. (2014, June 23). *2013-2014 Retail Demand Response and Dynamic Pricing Project* [PDF]. Austin TX: Frontier Associates LLC.

Galbraith, K. (2010, January 23). Why Is a Utility Paying Customers? Retrieved April 01, 2017, from http://www.nytimes.com/2010/01/24/business/energy-environment/24idaho.html

Galligan, K. F. (2016, March 30). *Overview of Microgrids* [PPT].

Galvinpower. (n.d.). What are the benefits of the smart microgrid approach? Retrieved April 01, 2017, from http://www.galvinpower.org/resources/microgrid-hub/smart-microgrids-faq/benfits

George, S. S., Bode, J., & Holmberg, S. (2012, April 2). *2011 California Statewide Non-residential Critical Peak Pricing Evaluation* [PDF]. San Francisco, CA: Freeman, Sullivan & Co.

Gimon, E. (2016, June 10). Texas Regulators Saved Customers Billions by Avoiding a Traditional Capacity Market. Retrieved April 01, 2017, from https://www.greentechmedia.com/articles/read/texas-regulators-save-customers-billions

Gross, D. (2015, September 18). A Bizarre Thing Happened in Texas: Wind Power Made the Price of Electricity Go Negative. Retrieved April 01, 2017, from http://www.slate.com/articles/business/the_juice/2015/09/texas_electricity_goes_negative_wind_power_was_so_plentiful_one_night_that.html

Hunt, H. D. (2014, April). *Purchasing Power The Business of Buying Electricty* [PDF]. Tierra Grande Magazine.

Jarred, M. W. (2014, June). *DELIVERING ON THE PROMISE OF CALIFORNIA'S DEMAND RESPONSE PROGRAMS* [PDF]. Sacramento California: California Senate Office of Research.

KEMA. (2014, February 3). *Microgrids – Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts* [PDF]. Burlington, MA: DNV KEMA.

Kennedy, R. F., Jr. (2011, May). Green Transition Integrating distributed resources into the smart grid. Retrieved April 01, 2017, from https://www.fortnightly.com/fortnightly/2011/05/green-transition

Kohansal, M., & Mohsenian-Rad, H. (January 01, 2016). A closer look at demand bids in California ISO energy market.(independent system operators)(Technical report). *Ieee Transactions on Power Systems, 31,* 4.)

Kolo, E. (2016, July). U.S. Wholesale DER Aggregation: Q2 2016. Retrieved April 01, 2017, from https://www.greentechmedia.com/research/report/us-wholesale-der-aggregation-q2-2016

Kotin, A. (2015, August 13). Energy Use in a Time of Drought. Retrieved April 01, 2017, from http://calclimateag.org/energy-use-in-a-time-of-drought/

Krauss , C., & Cardwell, D. (2015, November 08). A Texas Utility Offers a Nighttime Special: Free Electricity. Retrieved April 01, 2017, from https://www.nytimes.com/2015/11/09/business/energy-environment/a-texas-utility-offers-a-nighttime-special-free-electricity.html

Litos Strategic Communication. *The Smart Grid : An Introduction*. N.p.: Department of Energy, n.d. PDF.

Liu, M., Lee, W.-J., & Lee, L. K. (January 01, 2014). Financial opportunities by implementing renewable sources and storage devices for households under ERCOT demand response programs design. *Ieee Transactions on Industry Applications, 50,* 4, 2780-2787.

López, M. A., de, . T. S., Martín, S., & Aguado, J. A. (January 01, 2015). Demand-side management in smart grid operation considering electric vehicles load shifting and vehicle-to-grid support. *International Journal of Electrical Power and Energy Systems, 64,* 689-698.

MacCracken, M. M. (2013, July 23). Permanent load shifting and the future of energy storage. Retrieved April 01, 2017, from http://www.energycentral.com/c/iu/permanent-load-shifting-and-future-energy-storage

Mohsenian-Rad, A.-H., Wong, V. W. S., Jatskevich, J., Schober, R., & Leon-Garcia, A. (December 01, 2010). Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid. *Ieee Transactions on Smart Grid, 1,* 3, 320-331.

Nadel, S. (2017, February 9). Demand response programs can reduce utilities' peak demand an average of 10%, complementing savings from energy efficiency programs. Retrieved April 01, 2017, from http://aceee.org/blog/2017/02/demand-response-programs-can-reduce

NERC. (2013, March). *2011 Demand Response Availability Report* [PDF]. North American Electric Reliability Corporation.

NRG. (2016). *Block & Index Product Overview* [PDF]. NRG Energy Inc.

O'Donnell, P. (2016, April 05). What do Texas and California have in common? 'Negative power' caused by renewables glut . Retrieved April 01, 2017, from http://www.dallasnews.com/business/energy/2016/04/05/what-do-texas-and-california-have-in-common-negative-power-caused-by-renewables-glut

O'Donnell, P. (2016, April 05). What do Texas and California have in common? 'Negative power' caused by renewables glut. Retrieved April 01, 2017, from http://www.dallasnews.com/business/energy/2016/04/05/what-do-texas-and-california-have-in-common-negative-power-caused-by-renewables-glut

PCEA. (2013, August). *ECONOMIC BENEFITS OF INCREASING ELECTRIC GRID RESILIENCE TO WEATHER OUTAGES* [PDF]. President's Council of Economic Advisers.

Penn, I. (2017, January 24). Southern California Gas taps Aliso Canyon amid conservation warnings. Retrieved April 01, 2017, from http://www.latimes.com/business/la-fi-southern-california-gas-20170124-story.html

PERI. (n.d.). Smart Grids. Retrieved April 01, 2017, from http://www.perisoftware.com/peri_case_studies_smartgrid.php

Pittman, Evan. "The Rise of Targeted Demand Management: How Dr Can Reduce the Need for New T&d Investment.(demand Response in Transmission and Distribution)(energy Efficiency & Demand Response)." *Electric Light & Power*. 94.1 (2016).

PUTC. (2017, January 15). *Report to the 85th Texas Legislature Scope of Competition in Electric Markets in Texas* [PDF]. Austin TX: Pubic Utility Commission of Texas.

Rose, E. (December 01, 2014). Smart Meters and Federal Law: What Is the Role of Federal Law in the United States in the Deployment of Smart Electricity Metering?. *The Electricity Journal, 27,* 10, 49-56.

SCE. (n.d.). *SCE Fact Sheet* [PDF]. Rosemead Calif: Southern California Edison.

SCE. (n.d.). Smart Meters FAQ. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/customer-service/my-account/smart-meters/FAQ/!ut/p/b1/tVLBdoIwEPwVLh4xi0GgvdHqQxS1FovCxQcYkBYIQqi1X99o7YH3qtZDc9rdzO5mJoM8tERe7r8nsc8SmvvpIfeUlaQZ-sC0wYSRA2A-

9BTLnMxhPJc5wOUAOHN0aPZrIyzzfrk_nz52QFUwWiAPeWHOCrZBbhWSVUhzRnK2Ink LTjEP6orRjJRCVRcFLXkl2wt-GNL6cFtlfsmEjDBSVs1MiPztYUERJmvk4oCApshrkQSRJsrQCUVNirpiVw78dbBWgEQ_hC68-IogR0KNCZajcohhz5wnBwaWegUwxifAnQH9wXAKpjGfYTDxDCa2rmMA5QS4oPoQeXFKg-MPunoeYC1GXkkiUpKyXZe8vGGsqO5b0ILdbteOKY1T0g5p1oLfWja0YmjZRCKXS6We1QJ3kH2j9t8Dh2ZPlwy5Y8LYUEDvA9iYk7dm0s0Dh3-wb_K63Xo6N-HBbB-c5f-4sMheMg3vxbfnwadFFqIfaIC7afwFHdJSQw!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/#sce_HashableContentPane_0-hash/sce_HashableContentPane_1-hash

SCE. (n.d.). Home and Business Area Network FAQ. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/residential/my-account/hanlogin/faq/!ut/p/b1/rVRNc5swEP0rzoEj1gpRCXrDDsVQf9TguDEXjxDCpjHgYBLX_fWVM57pmNZJnKkOjBa9fVo97ROK0T2KS_6cr3iTVyXfHOOYLrHlOQM_At8yv2DwQ3pnw4BCNP2kAAsFgAvDgVb-V2KC3zPd2aRvAKMEfUcxikXZbJs1WuyEXIqqbGTZLGWpwWmuQS13eapmOd9oUBx0LkT1dFxYcwVbV4Xs8FryTimbfVU_dDL-eOTdijxFC04ptVOCdY6NTDcNS-jcxuqTUpYyiq1EiNM5Xin07Bwe6feVDpHhmMwE26Pt_L8Bb-j4osMZZDhnqgIvms6_zWEwZG8ARuQEsD1wB8FE1TCbEvDJFMaR4xAAegK8dlmtLXrEVVvAZOyEDkRzsw3wQmaAH8zd4aSHDbAMFKB4tamSl9ZZOGVCrBWKa5nJWtbdp1r9XjfNdvdZAw32-313VVWrjeyKqtDgXynrateg-3MkWiix2UWxLYaiP7dvcC4Zs7HOEkvqJs6Enhgy0aXghplyIyMJOREG_q2DPdNQhOEt-OPeKPQjn2CbfpDwYoX4asLgHQ2Y_3h8jB1Ip6NtfirZPuSndu2tXlVWiK70VktdGHkUHBcgIqo5hz6-mjB4x6v0f8S49Lhsi7vCIodcfwjd0DqQzXNRLMdjnScq-DXLVDTaOTc3vwGJeYsT/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

SCE. (n.d.). Demand Response Programs. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response/!ut/p/b1/hc9Lj4IwFAXg3-KCpfRYfKC7-giU6CBiELsxYLCSIDWIQ_z3UydunDh6d-fmO8m9RJCYiDL5zmVS56pMinsW_V3HdpjLQ3CsphPw8dBlC39KJ5xqsNUA_wzDp_6GiGdiz6OBJk4YRMsIrIe_wFkNKLgXzeb-uEPRpQ8wdDBzPV-DdWCBWwG-QsYsoP8Ab470iJCFSn8f3rIytWxJRJUdsiqrzGuI18e6Pl9GBgw0TWNKpWSRmXt1MvCqclSXmsTPkpxPMXLeFumtaf0AcKY94w!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/?from=drp#

SCE. (n.d.). Save Power Days Program Update. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/residential/rebates-savings/save-power-day/!ut/p/b1/rVVdc6IwFP0rffEx5ZKkAfYNW5eP9WOF1lZenBCCslWwQOvqr9_QcWYrbqvtLA-ZBM49uffknqBF2oMW5fwlm_M6K3K-bNYRm-mmY7teCB64bg-8rtMN7tgEHEYVYKoA8M5jw2G8-YNQFU97t6NrDAYj2r0WaZHI63W90KaVkDNR5LXM65nMO7Cfd6CUVZaoWcaXzSLmtaxQpRLN51UH1ESidbGRJUr4tiFciyzRpjIWNGWMIc4SjmhMKTIJTpFlUCFZTDFJ4n0BH2R4UIBDrq_BC0JsU4OC5bB2_DHgUAD6XVef2Z0FLoNwfHW0_xHgxAG8CnjA0J8YDSQcT35OwO0bJwADsgdYDvRcf6RquB0T8MgYhqFtEwC2B3x0yq0tuqRJE0ZDO7AhnNA2wAkMDJ4_6fVHXR2DiY8ARzr6WjRfFvFrU07tPCbmXItKmcpSlpfPpXq9qOt19a0DHdhsNpfzopgv5aUoVh34V8iiqGrt4RCpTdVpGO9mYRpa-Le9MOfSMCwdGbEpEdVTgWIsYyQFxzThOCUx2RP63o2tOxQrwuAGvGF3EHihR3SLfZHw3Qz1TxP6Z3R49uvpKbKVURtD_laynefU1RZxIYrn5sOC5-3cW72uvPYmd66MayVER1xXlqXYFIhbuhoSZiQG081YiLa6MHAY2D2AkKju7Xv6pwn9M-z6f8RQQ7GSF7yU_CKX9aYoHy9S_tTWqGX4wdXbks664E4Q4k8T-mf8E76o0amrfb26W5lkm2XoMegF7q4v7xGPTSBX65ddPx0Om9WW7G7T1Wo2qOw_4RIj9Q!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/#accordionGrp1-1-hash

SCE. (n.d.). Summer Discount Plan. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/residential/rebates-savings/summer-discount-plan/!ut/p/b1/hc9BC4JAEAXg39LBY-7TRbNuG4muRGFF2V5Cw1bB3DBL-vdZdInK5vaG78EMESQiooyvuYzrXJVx8cjC3hmOx3y-BPdci4GPMVxZU5tOYLVg2wL8GIZ__Q0RXSQ06AdYDEzwYO1O52PDhGO-wNCD6wfzFqxCCk5DzJaMUcB-gY4jAyJkoZLnw1tWJtSRRFTpIa3SSr9U7Tqr69N5pEFD0zS6VEoWqb5XRw3fKpk61yR6l-R0jJDzvkhuTe8O1BznKg!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/#accordionGrp1-3-hash/accordionGrp1-5-hash/accordionGrp1-4-hash/accordionGrp1-6-hash/accordionGrp1-8-hash/accordionGrp1-7-hash

SCE. (n.d.). DR AMP Program. Retrieved April 1, 2017, from https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response/!ut/p/b1/hc9Lj4IwFAXg3-KCpfRYfKC7-giU6CBiELsxYLCSIDWIQ_z3UydunDh6d-fmO8m9RJCYiDL5zmVS56pMinsW_V3HdpjLQ3CsphPw8dBlC39KJ5xqsNUA_wzDp_6GiGdiz6OBJk4YRMsIrIe_wFkNKLgXzeb-uEPRpQ8wdDBzPV-DdWCBWwG-QsYsoP8Ab470iJCFSn8f3rIytWxJRJUdsiqrzGuI18e6Pl9GBgw0TWNKpWSRmXt1MvCqclSXmsTPkpxPMXLeFumtaf0AcKY94w!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/?from=drp#accordionGrp1-6-hash/accordionGrp1-5-hash/accordionGrp1-7-hash

SCE. (n.d.). Time-Of-Use. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/business/tools/time-of-use/!ut/p/b1/nZLLcoIwFIZfxQ1LzAkghu7QKgZtGe_CxhEMSCsEJWrbpy9aNnYqrc0mOZnv_HMuP_LQAnnp6hhHKxHzdLU9x56-tOmjiS1NoUSzukC7w9mw3-0DYFwAbgHAjWPCdT4McKfI1zGhjSlAT0Nz5CEvSEUmNsjNA7YMeCpYKpYslaB8S-Af8jhleS6B4Hx7vuKE1XhYO-TsLJAF8Rq5Yaj4oIMh64ZKZI0ogUyIRmS8amCNhX6wxs2y4IqKfmn4UnA18gVgYpk9OgbqtKgOtNU2245jA7G174A1aipA7Vln4LSwAppSAoYFnZ7tFMBkqAJVh_A8Nk0VQC-BirHbyIu23L-s0DVTXyUR8vYsZHu2rx_2xfdGiCx_kECC0-lUjziPtqwe8ESCn1I2PBdocU0it5hl8-Ykejoa37mcakED7ha0_-Df-GW388zChWe3vRVd_s-GWTJNiPouv4464ZNo-I3s-DEJk_knFcif-w!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

SCE. (n.d.). Permanent Load Shifting. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response/permanent-load-shifting/!ut/p/b1/hc_LDoIwFATQT2LaIo9leVguQStgKnZjWJkmii6M3281uiFR726SM5PcwAZDYKfx7o7jzV2m8fTMNjrUVEimQk5KVwCZZZYKEzOECw_2HuDLSfzr7wL7IixRsqIehK7IQVlayZUueE58DpLGxB6ovjUbA7nAHKgu5qDalI3OGEf4WUgVyqrWHmxbARIt1r2UAoje4McX1_MAR04-ABNOW_Q!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

SCE. (n.d.). Demand Response Eligibility. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response/eligibility/!ut/p/b1/vZLLVsIwEIZfxU2XJUNvFHdROKU9KEIVbTecph1LtKS1iSI-vUFZeEXdmFUy-TKZ_58hKbkiqcgeeJkpXous2p5Tb9H1AzoKYwhhNjiG8Kg_oieTgXV85mgg0QB8syjsfR9a5JKkJM2FatSSJDLHRV4LhUItUBiw2xvA7iUXKKUBUlcnSmlykesb_oA6VuAqE8VBi7KphcRPgQOseMkZr7jabL9rcl6QJANEcKEwuzaA6RTMNRljjtm3Cw_dzMn6DtvJ21P_D_a8yHuL-ON5TyNBPJ2fzYG68BEIZj0Lwmg-HE-OuhY41g7oBzAcRRMNnE9tCO0pnMaU6tK9HbCnBxFJy6pmL_1MqGC2X5K0xWtsse3ctzq8VKqRhwYYsF6vO2VdlxV28nplwFdPlrVU5Oo9SRJtVe9bL1yLxH_0_jVhFA5oN3CsEE4CD-gQILa1-LHr_Tlh9Ith5jd3dynVI7kdvUet8j9msIldrHx7Y97ORk9jvDQz5oPtVuUzv7ipaw!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

SCE. (n.d.). Time-Of-Use Residential Rate Plans. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/residential/rates/Time-Of-Use-Residential-Rate-Plans/!ut/p/b1/hc9Bb4IwFAfwz7IDx9FXipR56yLWEpVhjcNeDBisJEANspF9-3XGi3Gb7_Z_-f2T95BCGVJt_lnpvK9Mm9c_WQW7WEwY5r4nErmkwLCMFjydk4j5FmwtgD-GwaP-

O1IXgkPOZkKC4G8jH0RM10CpxOGU3oEV9SzYRPPkFXsQelfwwiGaxYkF65SAICksJWMEILiCf46MkdK1KS4Pb1lbkFAj1ZWHsis796Oz62Pfn85jBxwYhsHVxui6dPemceC3ytGce5TdSnRqMqjEsyq-hqdvTtaZJw!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/#accordionGrp1-2-hash/accordionGrp1-4-hash

SCE. (n.d.). Time-Of-Use Residential Rate Plans. Retrieved April 01, 2017, from https://www.sce.com/wps/portal/home/residential/rates/Time-Of-Use-Residential-Rate-Plans/!ut/p/b1/hc9Bb4IwFAfwz7IDx9FXipR56yLWEpVhjcNeDBisJEANspF9-3XGi3Gb7_Z_-f2T95BCGVJt_lnpvK9Mm9c_WQW7WEwY5r4nErmkwLCMFjydk4j5FmwtgD-GwaP-O1IXgkPOZkKC4G8jH0RM10CpxOGU3oEV9SzYRPPkFXsQelfwwiGaxYkF65SAICksJWMEILiCf46MkdK1KS4Pb1lbkFAj1ZWHsis796Oz62Pfn85jBxwYhsHVxui6dPemceC3ytGce5TdSnRqMqjEsyq-hqdvTtaZJw!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

SCE. (2010). *Optional Binding Mandatory Curtailment Program* [PDF]. Southern California Edison.

SCE. (2013). *Summer Advantage Incentive (SAI)* [PDF]. Southern California Edison.

SCE. (2013). *Real-Time Pricing Frequently Asked Questions* [PDF]. Southern California Edison.

SCE. (2013). *Real-Time Pricing (RTP): How Much You Save Is Up To You* [PDF]. Southern California Edison.

SCE. (2013, September). *Emerging Technology Demand Response (DR) Projects Semi-Annual Report: Q1–Q2 2013* [PDF]. Southern California Edison.

SCE. (2013). *Agricultural and Pumping Interruptible Program (AP-I)* [PDF]. Southern California Edison.

SCE. (2014). *Aggregator Demand Response Programs* [PDF]. Southern California Edison.

SCE. (2014). *Time-of-Use Base Interruptible Program* [PDF]. Southern California Edison.

SCE. (2015). *Demand Bidding Program (DBP)* [PDF]. Southern California Edison.

SCE. (2016, December 21). *Schedule TOU-BIP : TIME-OF-USE-GENERAL SERVICE BASE INTERRUPTIBLE PROGRAM* [PDF]. Rosemead, California: Southern California Edison.

SCE. (2016, April 17). *Schedule CPP CRITICAL PEAK PRICING* [PDF]. Southern California Edison.

SCE. (2017, April 1). Demand Response Event Status. Retrieved April 1, 2017, from https://www.sce.openadr.com/dr.website/scepr-event-status.jsf

SCE. (2017). *Capacity Bidding Program* [PDF]. Southern California Edison.

SDGE. (n.d.). *Permanent Load Shifting (PLS)* [PDF]. San Diego Gas & Electric.

Searcy, R. (2012, July 11). ERCOT launches wholesale pricing forecast tool. Retrieved April 01, 2017, from http://www.ercot.com/news/releases/show/26244

Spees, K., & Lave, L. (January 01, 2008). Impacts of responsive load in PJM: load shifting and real time pricing. *The Energy Journal, 29,* 2.)

Texaselectricityratings. (2014, July 29). Critical Peak Rebate Programs. What Are They? Retrieved April 01, 2017, from https://www.texaselectricityratings.com/blog/2014/07/29/critical-peak-rebate-programs-they/

Texaselectricityratings. (2014, July 29). Critical Peak Rebate Programs. What Are They? Retrieved April 01, 2017, from https://www.texaselectricityratings.com/blog/2014/07/29/critical-peak-rebate-programs-they/

Trabish, H. K. (2016, January 26). What to expect from California utilities' new aggregated demand response offerings. Retrieved April 01, 2017, from http://www.utilitydive.com/news/what-to-expect-from-california-utilities-new-aggregated-demand-response-of/412614/

Tweed, K. (2016, October 14). Texas Has Millions of Smart Meters. So Why Haven't Third-Party Energy Services Blossomed? Retrieved April 01, 2017, from https://www.greentechmedia.com/articles/read/texas-highlights-the-challenge-of-one-click-energy-services

Woolf, Tim, Erin Malone, Lisa Schwartz, and John Shenot. *A Framework for Evaluating the Cost-Effectiveness of Demand Response*. N.p.: Department of Energy, Feb. 2013. PDF.

Xu, Q., Liu, Y., Ding, M., Zeng, P., & Pan, W. (January 01, 2014). Research on the Performance of Electric Vehicles in Peak Load Shifting. *J. Appl. Math.*

Yoon, J. H., Baldick, Wattles, P. (2012, April 6). *ERCOT Demand Response* [DOC]. Whitacre College of Engineering.

R., & Novoselac, A. (January 01, 2014). Dynamic demand response controller based on real-time retail price for residential buildings. *Ieee Transactions on Smart Grid, 5,* 1, 121-129.

Zarnikau, Jay, Three Simple Steps to Clip the Peak in the Texas (ERCOT) Electricity Market (September 12, 2013). USAEE Working Paper No. 13-143. Available at SSRN: https://ssrn.com/abstract=2334001 or http://dx.doi.org/10.2139/ssrn.2334001