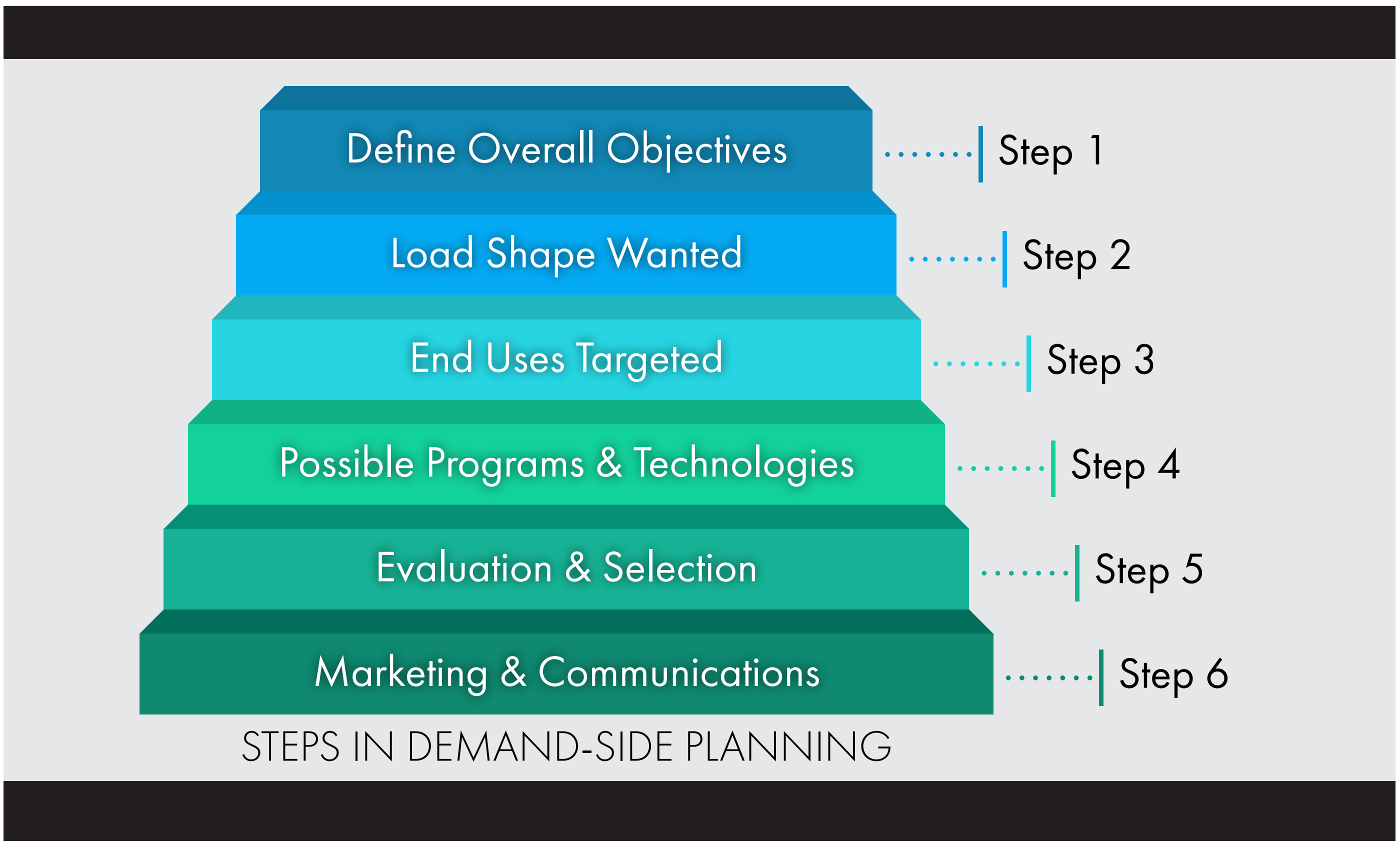
DEMAND-SIDE PLANNING FOR ELECTRIC SERVICE PROVIDERS



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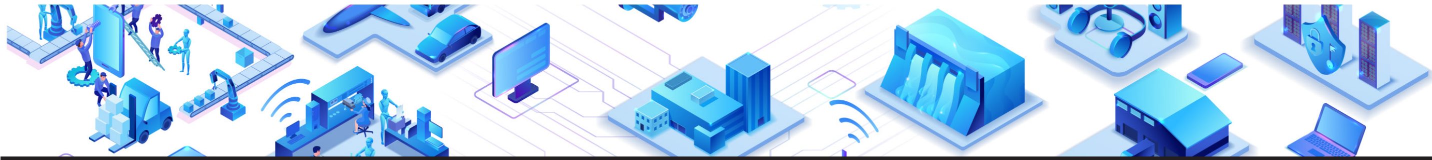

Introduction

Consumer preferences and behavior regarding electricity service purchases are changing rapidly at the same time as service options and associated technologies are expanding. Utilities are no longer the sole providers for retail electric energy and related energy services. Meeting customer needs is an increasingly difficult challenge facing all retail energy companies and service providers. In addition, environmental concerns regarding global warming attributed to carbon emissions, including the production of electricity from fossil fuels, has become of heightened concern. In 2022 and beyond, consumers will meet their energy needs by a combination of providers using an array of new technologies and services. Demand-Side Planning is essential to understanding which technologies consumers will embrace, who may provide them and what the resulting characteristics of the service offerings will be.

The power delivery system is becoming more than wires and hardware needed to deliver electricity from distribution substations to consumers. It is evolving into an interactive, dynamic system of distributed resources, due to demand responsive loads and distributed energy resources (DER) enabling two-way power flow. The power system is evolving with enhanced functionality, including real-time grid security assessment and recovery. As a result, the methods and considerations involved in planning consumer services and to meet the needs of tomorrow's consumers must change as well.

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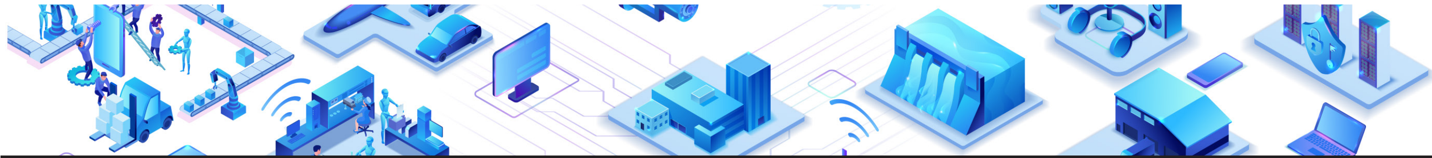
Advancing Demand-Side Planning

Until recently, future demand for electricity has been treated as a predetermined quantity by planners. Their job was to determine that quantity, then plan accordingly.[1] That process has been challenged. Predictable demand and reliable supply are hard to determine. Today, increasing numbers of consumers are generating some or all of their own electricity a majority of the time. Some are also using batteries to store electricity. Consumers can now buy

Table 1. Three Major Areas Driving Changes in Demand-Side Planning

Major Areas	Issues	Related Demand-Side Program Activities
The Environment	Reduce CO_2 emissions from use of fossil fuel in electricity production, transportation as well as in residential, commercial, and industrial sectors.	Energy Efficiency, increased use of solar, wind and electric energy storage. DER based on renewables; electrification; and demand response focused on reducing the operation of fossil fuels in electricity production.
Electrification	Conversion of existing fossil fueled end uses to electricity and the application of electrotechnologies in places where fossil fuels would otherwise have been used.	Programs and activities aimed at conversion of fossil fueled end uses (e.g., with electric vehicles and heat pumps). Includes the promotion of renewables in electric systems with fuel switching to reduce the CO_2 content of electricity production.
Consumerism	Respond to consumer demands for cost control and enhanced choices in electric service and the retail electricity marketplace.	Alternative energy service offerings, including innovative utility tariffs, DER bundles like photovoltaics with batteries, and energy efficiency.



hyper-efficient appliances and devices networked on the Internet, installed, and maintained by a variety of different players who are not traditional electric utilities.

As a result, demand-side planners can no longer treat demand as fixed. Rather they must predict these changes in a way to enable the industry to serve changing consumers and to enhance services to those who are part of various consumer segments. Trends in three major areas point to a need to revisit Demand-Side Planning for the electricity industry. These areas include: the Environment; Electrification; and Consumerism, as summarized in Table 1.

The Environment

Concerns over CO_2 emissions can be addressed in Demand-Side Planning. The production of electricity from carbon-based fossil fuels releases greenhouse gas emissions, especially CO_2. The consumption of energy from fossil fuels also releases greenhouse gas emissions. In recent years, the issues of CO_2 emissions have become one of the principal issues in Demand-Side Planning.

Accelerated energy efficiency is facilitated, in part by the rapid growth in the use of sensors, electronic communication and computational ability. This trend will continue to change electric technologies and will also impact demand planning.

Referred to as Information and Communications Technology (ICT), ICT offers nearly ubiquitous electronic communication which supports the Internet along with the world's electricity infrastructure. As end-use energy consuming devices and appliances continue to evolve, the ICT fabric is increasingly woven into those devices as well. As the demand for electricity grows along with the increased functionality it offers, the world is more connected than ever. ICT fundamentally provides connectivity between technologies, which is necessary to enable coordinated response from technologies leading to load shape changes. CISCO has provided the highest estimate of growth in IoT devices, ranging up to 50 billion by 2020.[1]

Electrification

In a predominant number of applications, electric end-use technologies are far superior to fossil fueled technologies, in terms of net CO_2 emissions, overall reliability, maintenance, and longevity. Examples include the use of electric motors instead of gasoline or diesel engines used in cars, trucks, and trains. The producers of gasoline and diesel fuels by the oil industry have enjoyed dominance over energy demands in transportation markets ever since internal combustion engine-driven cars arrived. Electric vehicles are an increasingly effective technology as vehicle and battery developments continue to mature. EV adoption is accelerating and to further advance EV adoption, States have set targets limiting the future sales of internal combustion engine cars.

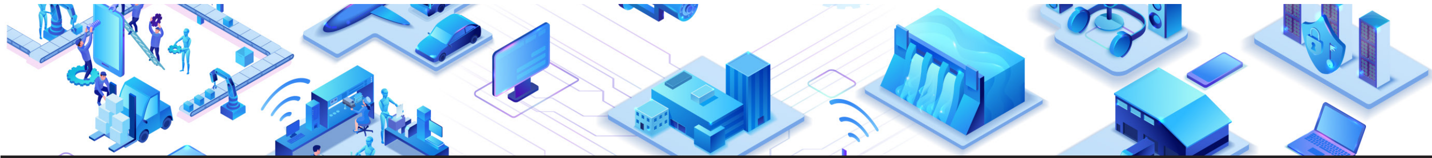
Nearly all electric uses are superior to fossil uses.[2] For example, heat pump water heaters can heat five times more hot water as a gas fired water heater. Electric freeze drying of food can be done with one third of the energy as fossil fueled alternatives. Electricity enables several unique phenomena which are at the heart of its advantages. This includes 1) creation of electromagnetic energy which enables motors, magnets, transformers and electro-forming and 2) microwave, infrared and radio-frequency heating. Even at the point of end use, electricity is already superior to a fossil fueled device since it uses less overall energy. When the electricity is produced with wind or solar energy, the result is a low carbon or carbon-free energy system. Distributed resources are an essential part of an electrification strategy. Effective electrification includes electric end uses in combination with the generation of electricity by carbon-free electricity.

Consumerism

Consumers are increasingly demanding value for all goods and services which they buy. While electricity is no exception, the electricity purchase is constrained by the ability of the industry to undertake rapid changes to an aging system which was never intended to provide highly reliable, digital grade power while responding to climate change, cyber security, and two-way power flow.

In his 1980 book, Third Wave, Alvin Toffler coined the term prosumer when he predicted that the role of consumers and producers would begin to blur and merge.[3] Since then various industry practitioners have begun to use the term to describe electricity consumers who both generate and consume electricity. Electricity prosumers can export some power to the grid while simultaneously displacing some or all of what would have been grid-purchased power. Demand-Side Management programs using consumer sited photovoltaics (PV) and labeled as Vehicle-to-Grid (VtoG) or involving feed-in-tariffs are among the options demand-side planners have to meet consumer needs.

1 http://blogs.cisco.com/news/cisco-connections-counter



Distributed Resources

Both Distributed Energy Resources (DER) and demand responsive loads can provide valuable services through adjustments in output and/or consumption coordinated with system or market needs. Examples of distributed resources include batteries and distributed generation (DG) like photovoltaics and wind turbine generators. See Figure 1. Major groupings of distributed resources include: 1) intermittent renewables, 2) non-intermittent DG, 3) distributed storage, and 4) demand responsive loads. The figure distinguishes DER as capable of producing electricity (for potential export to the grid), whereas demand responsive loads only consume power.[4]

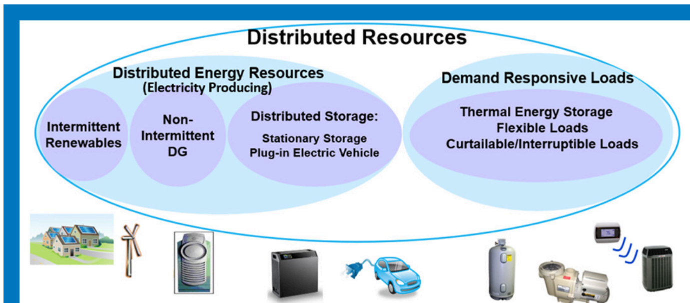


Figure 1. Distributed Resources include Electricity Producing DER and Demand Responsive Loads [4]

Demand Response (DR) is an adjustment in net consumption or production of electricity from customer-sited distributed resources (e.g., DG, energy storage, demand responsive loads, electric vehicle) coordinated to support system or market needs. The desired adjustment or demand response is a function of Demand-Side Management program provisions, market opportunities, and grid operating requirements. Demand response can be actuated through a variety of mechanisms (e.g., manual actions, direct control, demand limiting control), and incented through a variety of program approaches (e.g., discounted rates, financial incentives, or penalties for deviating from firm commitments).

Participants in the Energy Industry

There continue to be fundamental changes in the electricity sector's legacy providers. The industry will increasingly rely on flexibility and on a largely interconnected delivery system to react to massive changes in climate and to manage the impact of significant weather events. Power producers will need to: cycle generation assets including fossil, nuclear, and renewables. Power delivery providers will increasingly seek methods to employ electric energy storage in central and distributed applications. Demand response will be deployed wherever it makes sense often facilitating communications with technologies located on consumer premises.[5]

Tomorrow's energy industry is considerably more complicated than it was during the industry's formation. The economy depends heavily on a safe, reliable, and economical energy supply. Consumers enjoy the fruits of a phenomenal system of energy production, distribution, and utilization. Energy is used for comfort and convenience, for production and distribution of goods and services and for creation, processing, and distribution of information. Because of electric power industry restructuring, dynamic market forces, new technologies, increasing concerns regarding the environment and rising consumerism, existing industry participants are changing, and many new ones are emerging or evolving.

Demand-Side Participants

For Demand-Side Planning, the participants of interest include both consumers and providers, in addition to energy regulators and policymakers at the federal, state and local level. Providers include two groups: 1) the providers of energy itself and 2) providers of the related technology and services needed to adjust demand with customer-sited distributed resources (e.g., through producing, delivering, storing, and/or utilizing energy). Major categories of providers are described below.[6][7]

- Providers of electricity, natural gas, and other energies to residential, commercial, industrial and transportation consumers. This includes traditional regulated utilities and unregulated electric and natural gas providers as well as regulators, system owners, and operators and demand response aggregators.
- Providers of equipment, products, services, and systems needed to deliver energy and to convert energy into energy services for utilization (e.g., lighting, heating, cooling, process heating and electric vehicles).
- Engineering, design, construction, operation and maintenance firms for energy production, delivery, and utilization assets. This includes several groups often referred to as "trade allies" to utilities, including architects, engineers, plumbers, electricians, builders, and contractors.
- Knowledge, information, and data services companies related to all aspects of energy extraction, delivery metering, management, and utilization.

Table 2. Steps in Demand-Side Planning: 1984 vs. 2022

Year/Step	1984	2022	Key Differences in 2022 vs. 1984
Step One	Define Utility's Broad Objectives	**Define Overall Objectives** – Define Society's Energy Objectives	Society's objectives are broader than the narrower objectives of an individual utility. For example: society is concerned with global warming while an individual utility focuses on CO_2 emissions from one specific power plant.
Step Two	Determine Load Shape Objectives	**Load Shape Desired** – Outline Energy Specific Load Shape and Operational Objectives for Suppliers of energy and energy-related services.	Load Shape Objectives in 2022 now include both changes in utilization technologies as well as those impacted by Distributed Energy Resources (DER) for both consumers and prosumers.
Step Three	Select End Uses	**End Uses Targeted** – Select electric end-use devices with significant current and forecasted electric energy demand which can produce the desired load shape changes.	Include end use devices now currently served or forecasted to be served by fossil fuels which can be converted to electricity.
Step Four	Identify Alternatives	**Possible Programs & Technologies** – Identify viable electric energy service approaches with variable time horizon, price, and reliability parameters.	Include DER (e.g., distributed generation and energy storage) as well as electric service alternatives.
Step Five	Evaluate and Select Alternatives	**Evaluation & Selection** – Alternative programs and technology options designed to enable the desired load shape modification.	Include actions which can impact electrification.
Step Six	Develop Marketing and Communication Plan	**Implementation** – Identify the desired marketing and communications activities.	Focus broadened to include DER in synergy with utilization.

Steps in Demand-Side Planning

Demand-Side Planning is best viewed as a six-step process as shown in Table 2, adapted from [8]. It begins by defining society's energy objectives and translating those into objectives for the electricity industry. That translation is most conveniently accomplished by identifying which load shape objectives would allow industry participants to meet those needs for energy and energy services. The steps which follow allow planners to select the methods by which those load shape objectives would be met, including which end uses would be targeted, and what alternative methods of promotion as well as programs would be used. The table highlights the evolution of the steps in Demand-Side Planning since 1984. Overall, Demand-Side Planning takes a much broader societal view in 2022 than it did in 1984 and includes more focus on the environment.

Table 3. Examples of Possible Broad Objectives and Resultant Focus

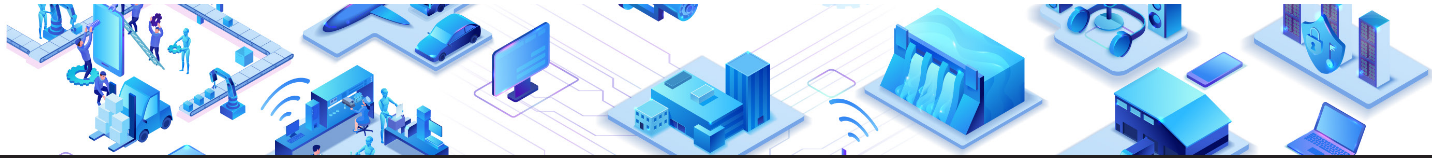
Broad Objective	Examples of Focus Areas
Improving earnings	Better matching consumer demand to utility system operation, delaying the need for a new substation, improved rate design
Reducing risk	Targeted reduction of local demand, implementing demand response programs, canceling unneeded power plants, hardening against storm impact
Improving the environment	Electrification
Increasing cash flow	Building off-peak load, reducing cost to serve
Lowering consumer cost and/or increasing consumer value	Offering service alternatives, improving customer service

Define Overall Objectives

Utilities may have several reasons to turn their attention to demand-side measures. At first the primary incentives were to change the demand for electricity to reduce capital requirements and reduce operating costs. In more recent years, concerns over the impacts of severe weather, system reliability, the environment and customer satisfaction have been added to the list of issues which demand-side programs can impact. Flexible and dynamic programs can reduce the magnitude and demand for energy while coincidentally reducing the need for electricity and its associated environmental impacts. In step one, utilities generally focus their objectives as shown in Table 3.

Shaping Load

Load shapes represent patterns of electrical demand from end-use electrical devices or appliances. The pattern and amount of demand



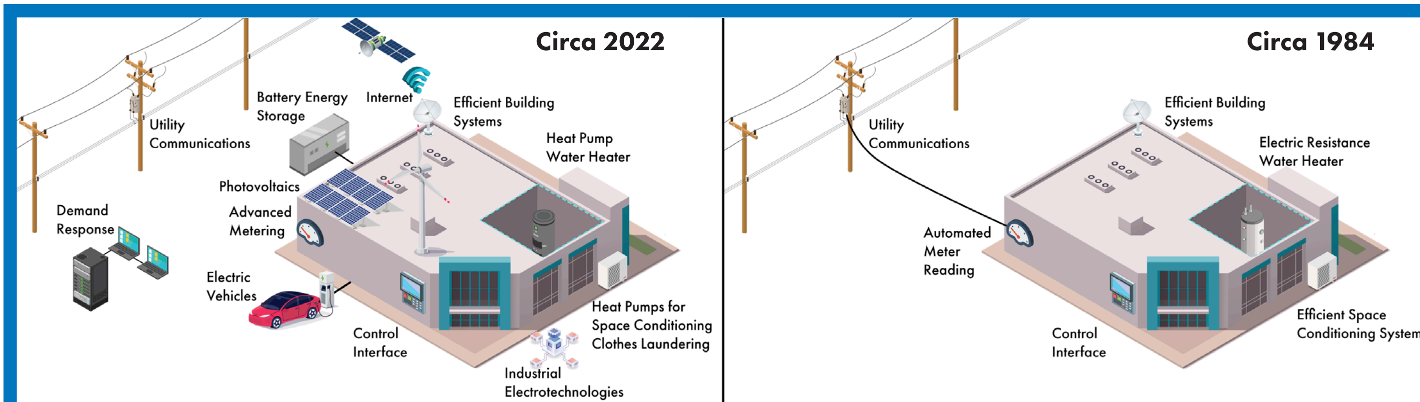


Figure 2. End-use Technology Alternatives in 2022 vs. 1984

is dependent on the characteristics of the device itself and how it is controlled and utilized. Examples of end uses include artificial illumination, space conditioning, water heating, and refrigeration. Many of these technology alternatives are illustrated in Figure 2. The figure indicates a change in types of end-use technologies available in 2022 beyond those available for consideration in Demand-Side Planning back in 1984.[9]

The extent to which load can be shaped is dependent on how flexible the end use is, and if it can be controlled. All end uses can be controlled to some extent with devices like thermostats, timers, on-off switches, etc. Flexible end uses are those which can be controlled and whose service can be stored. Storage devices may include

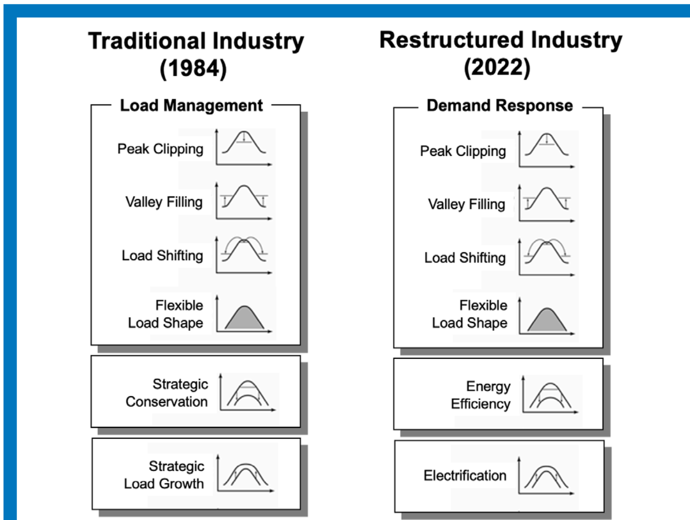
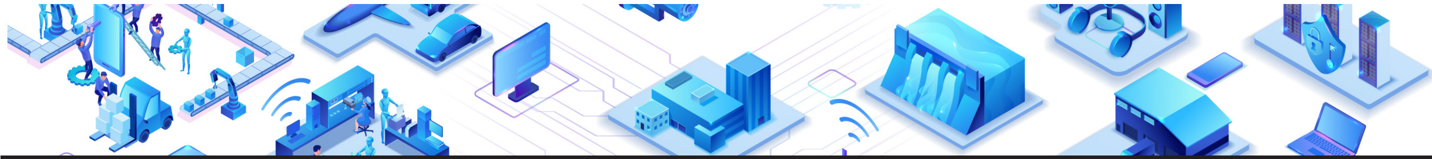


Figure 3. Illustrations on Load Shaping Objectives

batteries, ultra-capacitors, electric vehicles, municipal water systems, thermal storage units, and water heaters. Industrial activities such as manufacturing and chemical or petroleum processes each have inherent flexibility and can delay consumption as if they contained built-in energy storage as do other manufacturing systems. More elaborate storage systems could include the use of electricity off-peak to produce hydrogen by electrolysis which can be stored and used as a transportation fuel later.

Peak Clipping – Peak clipping is a reduction in demand during what would otherwise be peak periods. It is usually achieved by directly controlling appliances or end-use devices, it can be used to reduce capacity needs or power purchase requirements at time of peak. The most common examples are direct load control of air conditioners and water heaters, implementation of interruptible or curtailable electricity tariffs or load reduction programs. Businesses can also clip peaks by modifying their business activities or industrial production.

Valley Filling – Valley filling is building or adding load during off-peak periods. It is usually considered as applicable to adding off peak loads but can be applied seasonally as well. Valley filling can be an effective way to increase system utilization without necessarily adding system capacity. The most common examples are night-time uses like charging electric vehicles, heating, storing domestic water, and storing heat or cooling (ice or chilled water) with space conditioning systems. More recent applications include battery storage systems in buildings to store less expensive electricity in periods when it is available for use in other periods. Historically industries have filled valleys by shifting production schedules or by adding new production at night.



Load Shifting – Load Shifting accomplishes many of the goals of Peak-Clipping and Valley Filling. It shifts demand from on-peak periods to off-peak periods. The best example is to move an industrial production process from daytime to night-time. In residential applications it could involve encouraging shifting use of energy for end uses such as home laundry or cooking typically done in the daytime to less critical periods.

Energy Efficiency – is a reduction in energy use which can be accomplished by upgrading end-use appliances, devices and building energy efficiency which uses less energy, and which accomplish the same or grater work. Similar results can be obtained by outright conservation or a reduction in the demand. Building Energy Efficiency includes adding insulation, installing storm windows, using smart thermostats as well as enlightening consumers to lower heat settings or to use less hot water. Industrial Energy Efficiency can include the use of high efficiency motors and motor controls, piping insulation and the use of electro-technologies in processing such as microwave heating, ultraviolet curing, heat recovery heat pumps and electroforming

Electrification – is the use of electricity for an energy service heretofore provided by a fossil fuel. Electric energy services are increasingly lower in overall CO_2 emissions. In electrification these are often linked with low or zero carbon electricity production. The most common electrification technologies include electric vehicles, electric heat pumps, electric heat pump water heaters and electric process heating. Less well-known new uses of electricity may also be considered in an electrification strategy. These could include such as the use of electrolysis to produce hydrogen which may be used as a transportation fuel. Other exotic new uses may include Bitcoin mining. Bitcoin mining is an electricity intensive process used to convert computer hardware infrastructure, software skills and electricity into electronic currency. Bitcoin mining during demand surplus hours would consume lower cost electricity.[10]

The most promising low carbon or zero carbon generation is from renewable energy resources, particularly solar and wind. These sources of energy are typically distributed and intermittent. Unless properly installed, they can cause instability and inefficiencies in the grid. As the number of distributed renewable energy resources increases, the significance of demand response as a balancing technology also increases. Without increasing demand response to a critical level the amount of distributed renewable resources is limited. A Union of Concerned Scientists has identified flexible end uses as a key enabling feature of tomorrow's power system, and have in particular highlighted: space heating and cooling; water heating; electric vehicle charging; behind the meter batteries; industrial/commercial applications; and other devices and appliances.

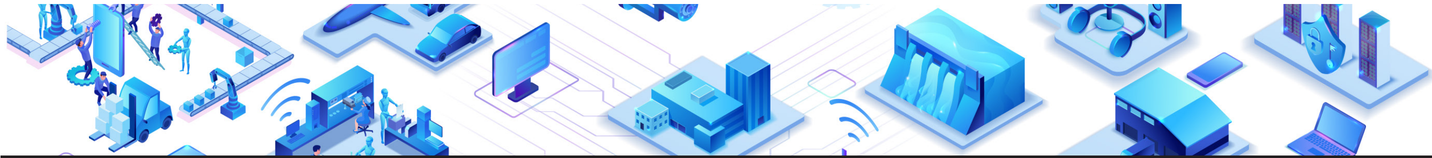
Flexible Load Shape – Flexible load shape captures a range of technology and service options. These include options like demand subscription, load control, aggregation of controlled loads, energy storage and DR programs organized primarily by DR aggregators, independent system operators (ISOs) and other aggregators or prosumers. Flexible load shape is often pursued by more than one supplier or consumer in an energy system. DR programs and technologies typically include those involving either passive incentives; dynamic pricing incentives; voluntary load control or involuntary load control.

Flexible Load Shape objectives are enabled by dynamic electricity systems. A dynamic system is more capable and more flexible in handling different power flow scenarios. One example is the opportunity to manage demand on peak days. By providing price signals to consumer devices which reflect system constraints, the electric demand from appliances and devices can be automatically adjusted without consumers being inconvenienced. Another example of adding power system flexibility is its capability to accommodate two-way power flow. A customer with roof-top solar panels and battery storage can be a consumer or a prosumer, or supplier depending on the time of day or usage.

The amount of DER in each energy system will change the degree by which renewable energy resources will impact the actual load shape. As a result, the potential load shape objective which would be used for planning purposes may need to be modified. The capacity value of a flexible load shape option is highly dependent on precisely when the option is exercised. For example, a strategy to increase power is particularly valuable when demand is low and when renewable generation is in excess.

Power Up and Power Down

The U.S. Federal Energy Regulatory Commission (FERC) estimates demand response peak reduction potential from retail DR programs in 2019 was over 31,000 MW, making those programs an essential part of the U.S. energy portfolio.[11] Flexible demand response can also target an increase in load at times of high production and low demand. Some systems may arbitrage between periods of low and high demand, or low and high prices.



Within the application of Demand Response to shaping loads, two strategies have evolved: Power Down and Power Up. These strategies add granularity to the operational dimension of load shaping, shifting, or reducing load by peak clipping, valley filling or load shifting. Demand can be reduced or **Power Down** to assure continuity of supply at minimal costs. The Power Down approach is well-known and widely used. What is new and somewhat unique, is the **Power Up** strategy.

For example, during a Power Down event, a reduction of day-ahead wholesale market prices indicate a peak price period the next day, so reducing the power consumption during the peak price period helps reduce energy cost. During a Power Up event, low or negative day-ahead prices indicate an opportunity the next day, such that shifting the power consumption to coincide with this period helps take advantage of the lower costs.

The increased presence of variable generation such as wind and solar drives the need for Power Up and Power Down resources to balance the operation of the power system. Consequently, independent system operators are structuring ancillary service rules to accommodate the companion need for frequency regulation. Moreover, energy retailers, power producers, and independent system operators are employing flexible load shape strategies to offer a variety of electricity service options. Examples of innovative retail electric service offerings include:

1. Local Power which includes locally produced electricity from distributed generation
2. Premium Power which may include redundant distribution capacity and/or DER
3. Priority Power which may include assurance of increased electric service reliability
4. Community Power which would contain shared DER
5. Green Power which assures electricity is provided by renewable power generation
6. Curtailable Power which offers a lower price for demand reduction flexibility

Identifying End Uses and Technology Alternatives

Although customers and suppliers act independently to alter the pattern of demand, the concept of Demand-Side Management implies a supplier/customer relationship that produces mutually beneficial results. To achieve that mutual benefit, suppliers must carefully consider such factors as: the way the activity will affect the patterns and amount of demand (load shape); the methods available for obtaining customer participation; and the likely magnitudes of costs and benefits to both supplier and customer prior to attempting implementation.

Because there are so many demand-side alternatives, the process of identifying potential candidates can be carried out more effectively by considering several aspects of the alternatives once a load shape objective has been determined. This involves identifying the appropriate end uses whose peak load and energy consumption characteristics generally match the requirements of the load shape objectives. In general, each end use (e.g., residential space heating, industrial freeze concentration, commercial lighting) exhibits typical and predictable demand patterns. The extent to which load pattern modification can be accommodated by a given end use is one factor to select an end use for Demand-Side Management.

Buildings, Transportation, and Industrial End Uses

It is useful to consider utilization technologies in three major categories: 1) buildings; 2) transportation; and 3) industrial. The industrial category can be further divided into process industries, materials fabrication, and materials production. In the buildings sector, the first consideration is improving the thermal integrity of the structures themselves including insulation, fenestration, thermal mass, and ventilation. In electric end uses within buildings the major electric end uses which have the most potential for electric Demand-Side Management include space heating, space cooling, water heating, lighting, refrigeration, food services, laundry, swimming pools, and miscellaneous uses. Each of these end uses provides a different set of opportunities to meet some or all the electric load shape modification objectives. Some of the end uses can successfully serve as the focus of programs to meet any of the load shape objectives, while others can realistically be useful for meeting only one or two of these objectives. In general, space heating, space cooling, and water heating are the end uses with the greatest potential applicability for achieving load shape objectives in buildings. These end uses tend to be among the most energy intensive and among the most adaptable buildings-related end uses for Demand-Side Management.

In addition to building envelope technologies, the sector may also benefit from the installation of thermal energy storage devices, energy, and demand control options, distributed generation, and electric energy storage.

Industrial end uses include those that align with the business aspects of materials fabrication, materials processing, and process industries. There are many technologies that serve these industry groups. The most popular include motors, compressed air, process heating, process cooling, lighting and miscellaneous technologies.

Selecting Alternatives

Demand-side alternatives are analyzed through a hierarchy of evaluation levels, starting with an intuitive selection, continuing with an aggregate analysis, and ending with a detailed and comprehensive evaluation. To a large extent, the appropriate level of analysis depends upon the importance of the decision that will be influenced by the analysis. In the hierarchy, quick and less demanding analysis is used to identify the most attractive candidates for more extensive analysis. However, the analyst must ensure that the potential value of additional, more detailed analysis is not outweighed by the costs of completing the detailed analysis.

The next level in identifying alternatives is a quantitative analysis that examines costs and benefits to all parties affected by implementation of a specific program. Interested parties include the government, utilities and energy providers, the participants in the program, other customers, and often society-at-large.

The final step in the selection of the most appropriate Demand-Side Management alternative is a detailed analysis of the most cost-effective alternatives. In a typical detailed analysis, the performance of the entire energy system from both an operational and a financial viewpoint is simulated over the planning horizon, with and without the selected Demand-Side Management alternative. This analysis estimates changes in the supply system and its operation that will result from the altered load shape produced by the selected demand-side alternatives. It builds heavily on capacity expansion analysis tools and the use of corporate modeling.

Marketing Plans to Influence Customer Adoption

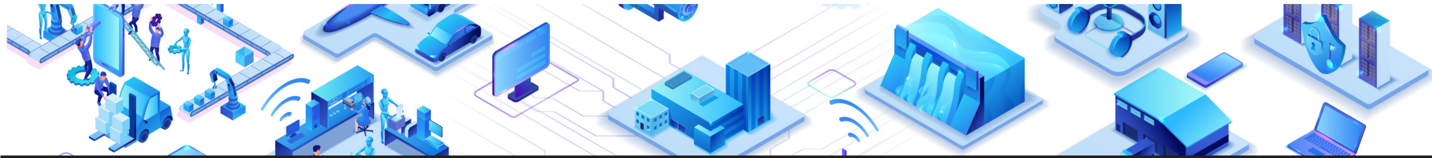
Once a prospective demand-side program has been designed and vetted, the remaining planning step is to establish a marketing plan which includes communications. Table 4 highlights the possible elements of a marketing and communication plan.

Adoption Alternatives

There are five consumer adoption alternatives which encompass the marketing and communications of technologies, programs and activities which may impact the demand, pattern, and amount of end-use energy usage. See Table 4. In general, they are intended to: 1) raise awareness about energy and energy-related issues primar-

Table 4. Summary of Marketing and Communication Alternatives

Technique	Purveyors	Objective	Alternatives
Customer Education	Utilities, demand-side service providers, technology vendors	Increase awareness of service offerings, technologies, and programs including concepts like solar power and energy efficiency	Online marketplace and information exchange platforms, video/tutorials, bill inserts, brochures, technical briefs, displays, direct mail, podcasts
Direct Customer Contact	Utilities and other demand-side service providers	Encourage consumer response to programs and sale of technologies and services	Email campaigns, social media and door-to-door contact, energy audits, workshops, trade fairs, energy clinics
Advertising and Promotion	Utilities, demand-side service providers, technology vendors	Increase awareness of service offerings, technologies, programs, and services	Targeted ads, search engine, social media, Radio, TV, Internet, print media
Alternative Electric Service Offerings and Rate Designs	Utilities, demand-side service providers, demand response aggregators, technology vendors	Provide consumers with enhanced choice over attributes of electric service	Variety of electric service plans and non-utility service offerings as well as alternative rate designs
Direct Incentives	Utilities, demand-side service providers, demand response aggregators, technology vendors	Increase participation in utility programs, alternative tariffs, and innovative service offerings	Low and no interest loans, cash grants and various subsidies



ily regarding the demand for electricity; 2) inform consumers as to technologies and programs related to electricity use; and 3) facilitate the purchase of technologies and the adoption and operation of technologies, programs, and activities.

Programs and Initiatives

Rate Design

Demand-side programs use a rate design framework to set prices for electricity and electricity-related energy services. This framework sets prices which reflect the actual costs of providing energy services. In Demand-Side Planning the framework includes recognizing and encouraging technology innovations, using demand response, accommodating consumer-sited generation and storage and possibly opening new markets. Pricing methods include time-of-day, time-of-use and off-peak rates to offer consumers some price differentiation across time periods. Typically, these time periods are fixed and vary only by time-of-day and possibly by weekends vs. weekdays. In theory, when reinforced by utility communications, consumers would modify their demand for electricity during various time periods in response to their understanding of the potential impacts on their electric bill.

Dynamic price incentives usually involve the use of technology to directly communicate and control loads. Voluntary load control involves engaging consumers with or without incentives to modify their demand. Involuntary load control involves the use of hard-wired communications and control.

Once the utility has targeted its load shape objectives, planners have a diverse group of options for meeting those objectives. Quite often a utility will choose flexible load shape in combination with another load shape objective. For example, a Time Of Use rate may be employed for load shifting in conjunction with a flexible DR program designed to achieve a flexible load shape.

Preparing for Power Up

The elements of traditional demand response that targets a load reduction (i.e., Power Down type response) are well known and are the most popular approach for DR programs. Power Up type response is more recently also desired. When excess generation capacity is anticipated in the time ahead, technologies, programs or initiatives can be launched to meet the excess generation capacity opportunity. The presence of excess capacity available from renewable resources presents an excellent opportunity for electrification to accelerate the opportunity to reduce CO_2 emissions.

Taking the Initiative

Demand-Side Planning is not a panacea. It is highly utility specific to an individual utility service area or region. The outcome is highly dependent on the generating mix, the portion of carbon-free electric generation, the customer load mix, end-use application saturation levels, and demographics as well as expected load growth. Detailed information is needed on load factor, load shapes for average and extreme days, the regulatory climate and reserve margins. All this influences whether and how the demand-side approach can work for a specific energy system. Demand-Side Planning offers a special opportunity for many utilities and energy service companies to sustain a leadership role in shaping the future.[12]

An Innovative Option Highlighted: Water Pumping

According to the Union of Concerned Scientists, a key enabling feature underpins flexible demand: a subset of electricity consuming technologies and processes can be flexible in when they consume energy without significantly affecting the eventual level of service.[13] There are several new innovative Demand Management techniques which have been identified. These new techniques use the flexible load shape objective and will become more popular as the proliferation of DER increases. The most popular among these is the control of electric motors in municipal water and wastewater applications in combination with the adjoining reservoirs and water systems.

Water pumping is an ideal end use which can be used to facilitate the flexible load shape concept since it has the following characteristics:

- Water pumping electrical demand is variable and can be controlled dynamically
- The water pumping system typically has several dimensions of storage options including reservoirs and pressure vessels as well as the water distribution system itself. There is a great deal of energy efficiency potential.
- It has the potential to increase electric demand as well as the potential to generate electricity

A few other applications of electricity which may follow these characteristics include liquid fuels distribution pipelines such as oil distribution and natural gas pipelines.

The U.S. public water industry has large electricity requirements, making it a market segment of investigation for demand management. Water systems are comprised of electric motor driven pumps, reservoirs in the form of tanks and ponds or lakes and a massive network of pipes. Storage tanks vary by tank type, capacity and volumes of storage allocated to fire, emergency, and equalization storage. For distribution pumping systems, parameters vary by the volumetric flow rate, line pressure, system configuration and water demand patterns. Each water system has differing energy demand patterns associated with pumping. Systems also vary by the amount of excess energy which can be recovered. Reservoir levels can be controlled with motor-driven pumps and valves used to fill them or used in a piping network to discharge them. The pumps, pipes and enclosed reservoirs are often a sealed system whose capacity is a function of pressure and temperature whose capacity can be changed by varying the pressure of the fluid in the system. The degree to which pumping can increase the pressure and capacity of a water system can be substantial as can the actual water levels in reservoirs themselves.

Modulating the flow within the water system and storage in the systems' reservoirs and storage tanks is accomplished by modulating the electrical demand of pumps and control valves and therefore can be a demand management option. Figure 4 illustrates major components of water systems and types of pumping stations involved in water extraction, treatment, storage, and transportation over long distances, culminating in water distribution along with local storage and treatment to service water demands of end customers. The diagram in the figure extends from wholesale to retail water systems, illustrating major components.

With sufficient advance planning, water systems may adjust operations to shift load to lower cost periods. This can be done manually by water systems operations personnel using existing water management systems to interrupt or adjust the speed of water extraction and/or conveyance pumps. More sophisticated systems are more automated. The American Water Works Association has previously estimated that U.S. distribution pumping uses more than 20 billion kWh per year with electrical demand of 3,000 – 4,000 MW of demand.

There are three potential novel opportunities to take advantage of water systems as demand management opportunities. These include:

1. Using DER to pump water. This application uses solar PV or wind to pump water.
2. Using gravity water storage to shift electric demand.
3. Recovering excess line pressure to produce electricity. This option would deploy micro-turbine devices in the distribution system to generate electricity and change the net demand pattern from pumping.[14]

Figure 5 below illustrates the potential demand flexibility of water pumping operations. The average load profile to the right of the fig-

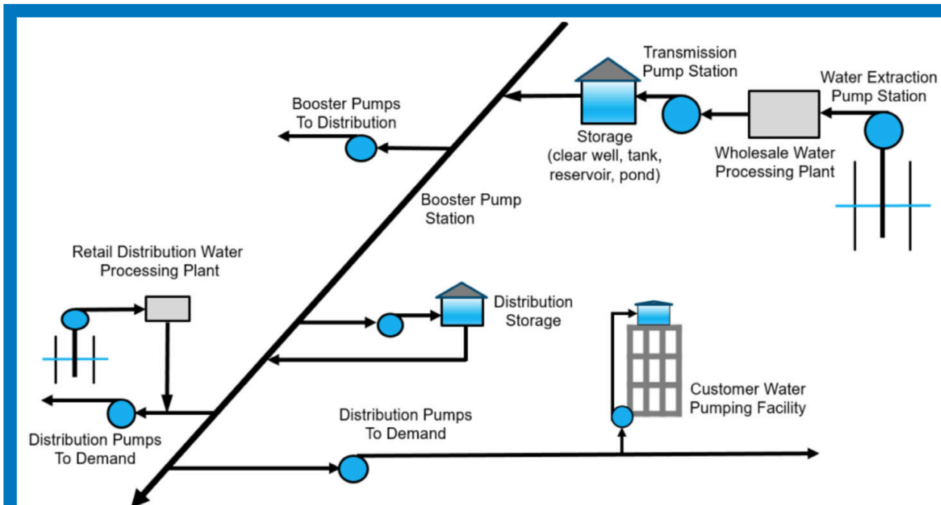


Figure 4. Diagram Illustrating Wholesale and Retail Water System Components

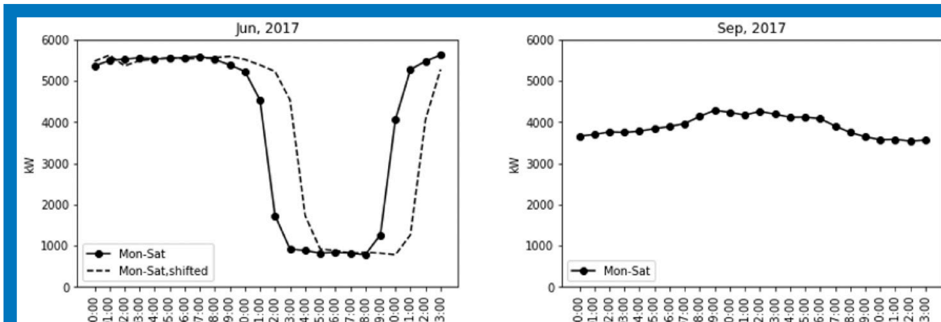


Figure 5. Sonoma Water Agency Average Load Profile with Demand Shifting (on left) and before Demand Shifting (on right) [15]

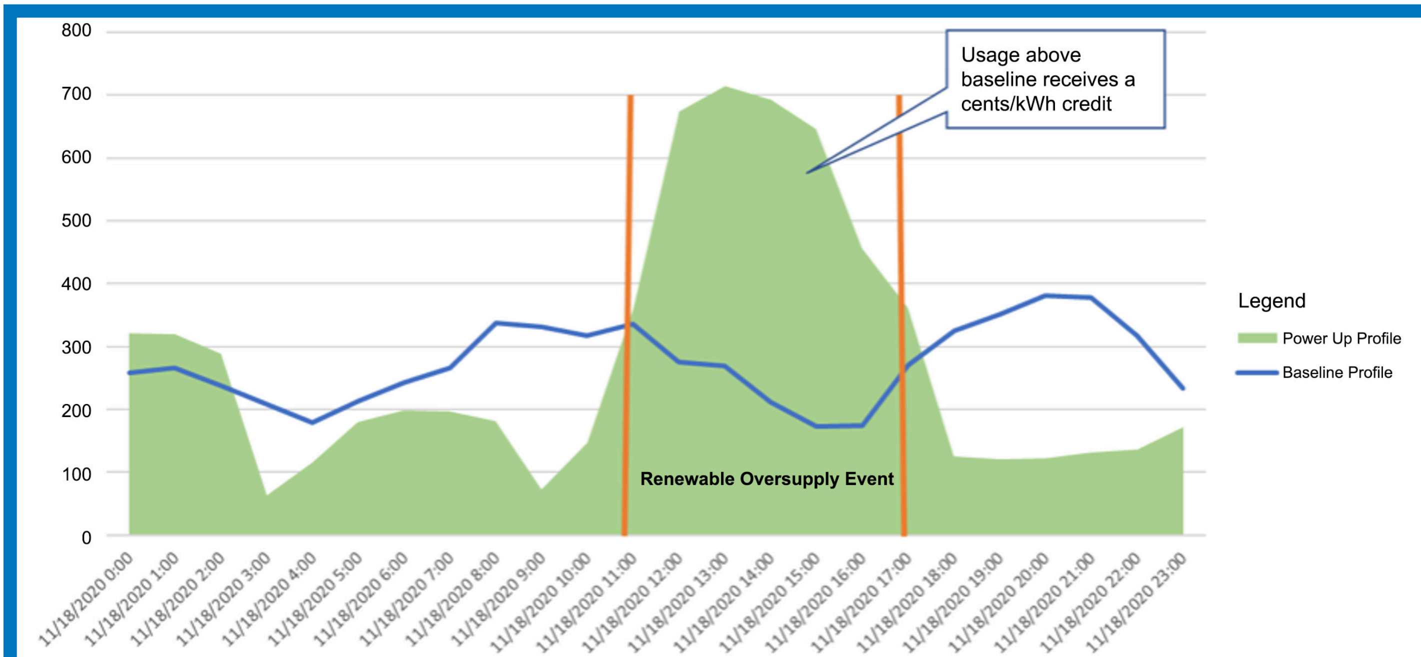


Figure 6. Holy Cross Green Up Program – Average Load Profile Before and After Power Up Event on November 18, 2020

ure reflects normal operations of a water agency during September 2017, whereas the load profile to the left of the figure reflects average power demand during one month of shifting operations (during June 2017). By further shifting the actual demand by two hours (as represented by the dashed curve), an optimal shift would have been achieved based on wholesale market prices.[15]

Figure 6 illustrates an example of the potential which programs and rate design could offer so as to create additional benefits for flexible water pumping. The average load profile used as the baseline is shown in blue and reflects normal operations of a water district served by Holy Cross Energy. The green profile in the figure depicts the adjusted energy consumption of the water district during a Power Up type event triggered by renewable oversupply conditions, as monitored and called by Holy Cross Energy. The water district's usage above its baseline during the Power Up event is credited at a pre-established rate, which incents the desired response.

Conclusion

Planning for Demand-side programs can achieve a variety of objectives for society as well as utilities. Demand-Side Planning has evolved to include emerging objectives such as Electrification for enhanced productivity and Power Up to absorb overgeneration with end-use equipment. Customer sited technologies have also expanded to include a wide variety of DER capable of producing electricity as well as hybrid (e.g., energy storage) resources, well beyond curtailable/interruptible loads that are demand responsive. One flexible demand-side alternative highlighted for consideration in the described six-step process for Demand-Side Planning is flexible water pumping. Such flexible end uses can be employed in a variety of different programs, for Power Down as well as Power Up type response.

The death spiral hypothesis advanced by some industry critics suggests that utilities and particularly distribution utilities are still caught in a spiral of rising production costs and sluggish demand. This view reflects the dual assumption that utilities are captive to uncontrollable costs on the one hand and to mature markets on the other. But, neither of these assumptions needs to be the case if a dynamic Demand-Side Planning effort is in place.

Demand-Side Planning offers ways to cut both capital and operating and maintenance (O&M) costs. It offers several avenues to develop new markets for electricity without encouraging excessive or wasteful energy uses. These new applications—electric vehicles, batteries, industrial lasers, and advanced heat pumps for the home—benefit the customer and the utility. They are highly energy efficient, so they help control customers energy bills at the same time as they build utility loads.

How then, will the demand-side approach affect the way that energy and energy service companies do business? The industry will become a more efficient industry, and it must be a more competitive industry. And the industry will need to become closer to its customers. The change will be fundamental. Customers will witness the evolution of the industry to one the is more responsive and has a better understanding of customers' needs and wants. The industry is to evolve to offer services at lower cost than would be possible without Demand-Side Planning.

The potential for influencing demand has been tried and proven in the industry for years. But never has it been done in an organized manner. Never has a planning structure allowed comparing a combination of energy efficiency, electrification, and the environment—until now. Demand-Side Planning by itself won't help utilities avoid a death spiral. However, it will highlight weaknesses in customer focused programs and activities, which assists utilities in targeting prudent actions.

Appendix A

Successful Demand Management Programs

There are literally thousands of Demand-Side Management programs in the world. Many of these programs utilize a combination of technology and market mechanisms to modify the pattern of and amount of consumption. The following are a sample of the varying types.

PJM's Demand Response Program – Arguably one of the first labeled as a "Demand Response" program in the U.S., PJM's program is a voluntary program that allows customers to reduce their electricity usage during periods of high processes. Retail customers are compensated through PJM members known as Curtailment Service Providers.

SMUD's Planning Process – SMUD Sacramento Municipal Utility District's planning process follows a five-step process which is unique in that it holistically integrates combined heat and power (CHP), distributed photovoltaic solar, energy efficiency, behind the meter energy storage and electric vehicles. The steps include 1) System Assessment; 2) Pattern of Demand; 3) DER Impact; 4) Financial; 5) DER Strategy.

Alameda Municipal Power – Alameda Municipal Power (AMP) **Energy Plus** Program helps commercial customers with energy efficiency by offering a turnkey, one stop shop for direct-install lighting, refrigeration, heating, ventilation, and air conditioning services.

Eugene Water & Electric Board Business Continuity Plan (BCP) designs and installs Distributed Energy Resources and microgrids to ensure business continuity. Key installations have included municipal pumping supplied by back-up batteries integrated with PV. The PV systems are roof-top mounted at schools.

California investor-owned utility Optional Binding Mandatory Curtailment (OBMC) program exempts customers from rotating outages provided they reduce the load on the entire circuit by 15%.

Holy Cross Energy (HCE) Power + Service Option – HCE pays for the installation of a battery system up front. Customers repay HCE with a monthly charge, free of interest and offset by bill credits received for periodic control of the battery. HCE controls the battery during times of high energy demand or renewable energy oversupply.

ENEL X Juicebox – ENEL's Juicebox is an EV charger controlled by the utility enabling cars to charge when the grid is producing the cleanest energy and managing demand during peak periods. ENEL is based in Italy and serves energy programs in 30 countries.

Great River Energy Load Management Program – Great River Energy has perhaps the most widespread load control Load Management Program involving over 100,000 customers including programs controlling the use of generation sets on C&I customers, air conditioning cycling, dual fuel: interrupting crop dryers, cycling irrigation and water heating.

Glasgow EPB Infotricity – Glasgow Electric Power Board had launched in 2016 a demand charge rate structure also applicable to residential and small commercial customers. In conjunction with the rate structure, select sites also installed solar PV with battery energy storage, leveraging a municipal broadband network for controls.[16]

Holy Cross Green Up Program – Customer optimizes cost savings by shifting pump load based on Demand Response incentives.

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