Better Plants®
U.S. DEPARTMENT OF ENERGY

Demand Response in Industrial Facilities:

Peak Electric Demand

2022

ORNL/SPR-2021/2299

Authors and Acknowledgements

Demand Response in Industrial Facilities: Peak Electric Demand was developed for the US Department of Energy's Office of Energy Efficiency and Renewable Energy as part of the Better Buildings, Better Plants program. The report was developed by staff at Oak Ridge National Laboratory in collaboration with the US Department of Energy. This report was funded by the Office of Energy Efficiency and Renewable Energy under Oak Ridge National Laboratory Contract No. DE-AC05-00OR22725.

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Report Number: ORNL/SPR-2021/2299

Preface

The US Department of Energy's (DOE's) Better Buildings, Better Plants Program (Better Plants) is a voluntary energy efficiency leadership initiative for US manufacturers and water/wastewater entities. The program encourages organizations to commit to reducing the energy intensity of their US operations over a 10-year period, typically by 25%. Companies joining Better Plants are recognized by DOE for their leadership in implementing energy efficiency practices and for reducing their energy intensity. Better Plants Partners are assigned to a Technical Account Manager, who can help companies establish energy intensity baselines, develop energy management plans, and identify key resources and incentives from DOE, other federal agencies, states, utilities, and other organizations that can enable them to reach their goals.

Better Plants Partners are expected to report their progress to DOE once a year. This involves establishing an energy intensity baseline upon joining the program and then tracking their progress over time. *Demand Response in Industrial Facilities: Peak Electrical Demand* is intended to help companies understand peak demand response programs offering by their local utility. Manufacturing industries can learn about time-varying rates and smart technologies they can use to help them reduce their energy bills.

This guidance document is applicable to companies participating at either the program or challenge level. Although this guide is intended primarily to assist companies participating in Better Plants, the methodologies and guidance within the document are applicable to any organization interested in understanding peak demand response programs.

For more information on the Better Plants Program, please visit:
betterbuildingssolutioncenter.energy.gov/better-plants

For more information on the Better Plants Challenge Program, please visit:
https://betterbuildingssolutioncenter.energy.gov/better-plants/better-plants-challenge

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Introduction

The electric grid is a complex network in which electricity is produced by a centralized power plant and then distributed through substations, transformers, and power lines to customers. The US grid includes more than 7,300 power plants, nearly 160,000 miles of high-voltage power lines, and millions of miles of low-voltage power lines and distribution transformers.[1] To maintain the stability of the grid, any electricity that is being produced must be used immediately. Utility companies leverage power plants to generate energy to meet consumer demand. To help combat dispatching additional power plants, utility companies can instruct both commercial and industrial customers to reduce their load on an ad-hoc basis, while others offer “interruptible” electric rates. An interruptible rate plan requires large commercial and industrial consumers to curtail their electric demand during peak events when the load on the grid is critically high. Despite these efforts, the rise in demand eventually raises energy prices and decreases grid reliability.

Demand response (DR) is a consumer’s ability to reduce their energy consumption when the wholesale cost of electricity in their area is high, or the reliability of the grid is at risk. In the United States, the electric grid often experiences overload during the summer months when the outdoor temperature is high, forcing customers to lower their thermostat temperature setting and thereby increase the electric load on the grid. Since a reliable energy source is crucial for industrial customers to maintain continuous operation, a DR program in a facility can help to control peak demand load and lower energy cost.

DR programs provide an opportunity for consumers to play a significant role in the operation of the electric grid. These programs help lower the cost of electricity in the wholesale markets, which leads to lower retail rates. Utility companies engage in DR with customers by offering time-based rates. DR can also include direct load control programs in exchange for a financial incentive and lower electric bills. The electric power industry considers DR programs an increasingly valuable resource. New technology, such as sensors and advanced metering infrastructure, expands the range of time-based rate programs that can be offered to consumers.

Although electricity demand management has been around for a long time, natural gas demand management is in the early stages of development. Demand for natural gas in the United States is predominantly driven by weather. The highest demand occurs during winter when natural gas is commonly used for space heating in buildings. While this rise in natural gas demand mostly affects residential and commercial customers; the industrial sector relies heavily on natural gas for space heating and manufacturing processes. Learning from the success of electrical demand programs some utilities are launching gas demand response programs to help customers reduce their natural gas demand. Since natural gas DR programs are more focused on residential and commercial customers and are still in a nascent stage, they are not discussed in this document.

Participating in a DR program sometimes requires some amount of commitment and effort for commercial and industrial customers. Manufacturing facilities can tailor their internal DR programs to their needs and business cases. The biggest benefits of participating in a DR program are the financial incentives and rebates. Reducing energy demand as part of DR helps earn revenue incentives to offset energy costs. Some programs can be voluntary, others require a firm commitment, and some can have different levels of incentives for the customers. These programs increase grid reliability and help customers have a better understanding of their power usage. The ability

[1] S. Hoff, “U.S. electric system is made up of interconnections and balancing authorities,” Today in Energy, US Energy Information Administration, 2016.

of a facility to know if and when they can reduce their electric load while not jeopardizing the operation of the facility can help them to reduce cost and increase operational resiliency.

This document summarizes the different types of time-varying rates utility companies offer their customers, how a DR management program can be set up in a typical manufacturing facility and examples of how some Better Plant Partners are taking part in utility DR program to save money on their utility bills.

Energy Consumption vs. Demand

Utility companies charge all customers for the amount of energy they use (consumption). Industrial and some commercial partners are also charged for the rate of energy that is consumed over a certain period of time (demand). Electricity consumption is measured in kilowatt-hours (kWh). Electricity demand is the rate at which electricity is consumed, measured in kilowatts (kW). To understand the difference between electricity consumption (energy) and electricity demand (power), consider the conditions shown in **Error! Reference source not found.**. There are 5 bulbs of 100 W each. Depending on the need the lights are turned on and off throughout the day. In this example at 10 am the facility has one bulb on at 10 am while in the next hour has 2 bulbs on. The total electricity consumption from 10 am till 5 pm is 1.8 kWh. At 11 am all 5 lights are turned on at the same time and the demand is 500 W.

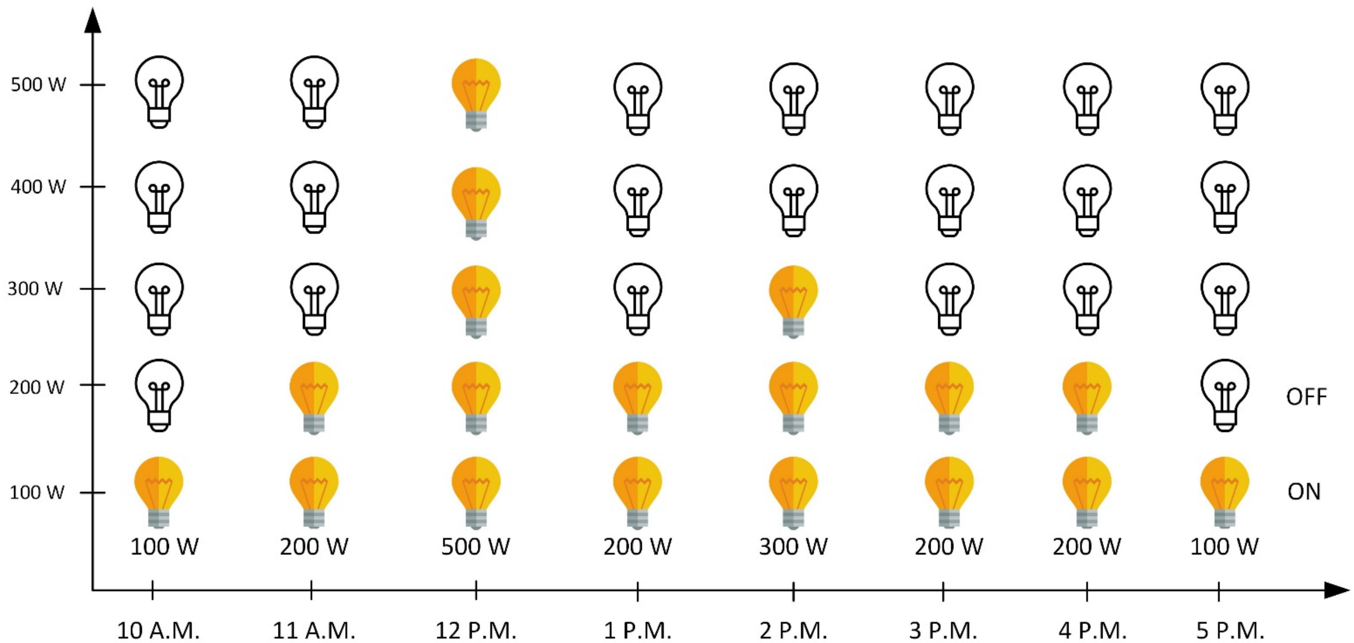


Figure 1: Electric consumption and Electric Demand Comparison

Demand charges are designed in a way for utility companies to recover some of the costs associated with meeting instantaneous energy demand. The utility companies attempt to disperse the cost of building and maintaining the capacity of their power systems to customers who use the most energy. Almost all medium and large commercial customers pay demand charges.

Industrial Sectors that are Good Candidates for DR Programs

While all industries and sectors can participate in DR in one form or another, some sectors may be better suited than others. Facilities will find that more flexibility in product scheduling and process timing means participating in the DR methods described in this guide will be easier. Facilities that find themselves with consistent, continuous, and steady power draw from the grid will find that DR can be much more difficult than those with reoccurring, explainable peaks. Similarly, facilities that operate continuously near their processing capacity will have difficulties in implementing DR methods. Figure 2 provides a classification of industrial processes displaying simplified facility categories using processing volume and variety of processes or job flows.

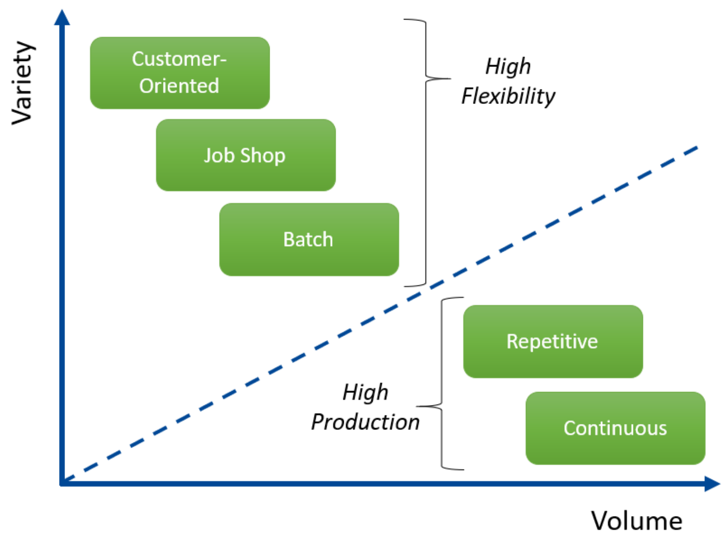


Figure 2: Classification of industrial processes.[2]

Ideal facilities for demand management can alter or adjust their processes day to day while still meeting production demand. These facilities build custom pieces, work in batches, or are classified as job shops. The categories in the upper left of Figure 2 have the most variety and lower throughput and are the ideal candidates for flexible DR programs. If your facility is classified as repetitive or continuous, meaning low variety but high volume, DR solutions can still be implemented but may be more difficult and may need a more thorough analysis to implement a DR program. The most notable method for DR for the high-production categories is energy efficiency. Energy efficiency will lower the overall power draw and thus reduce demand. To discover if the other methods of DR are appropriate at your facility, a systematic process assessment can help uncover possible demand-saving solutions.

Types of Demand

Electric utility companies typically measure demand as the average electricity consumed over a 15-minute period. Depending on the rate structure, demand charges can be anywhere from 30% to 70% of a monthly electric bill. Demand charges are usually based on the monthly peak demand, although several other kinds of demand can be measured. This section details the different types of demand and how they can affect DR programs.

[2] Adapted from: P. Lombardi, P. Komarnicki, R. Zhu and M. Liserre, "Flexibility options identification within Net Zero Energy Factories," *2019 IEEE Milan PowerTech*, 2019, pp. 1-6, doi: 10.1109/PTC.2019.8810494.

Daily Demand

Energy demand for a facility can vary throughout the day depending on production and hours of operation. Figure 3 shows a typical daily electricity load profile of a facility during a summer workday. The highest 15-minute period of demand over a billing cycle is known as the *Peak Demand*. Peak demand typically occurs during the hours when the facility is operational, and production is in full swing. The energy consumption when only essential systems are operating is defined as the *baseload*, which is steady irrespective of operation, time of the day/year, or the weather. The energy consumption over a period of time is called average load.

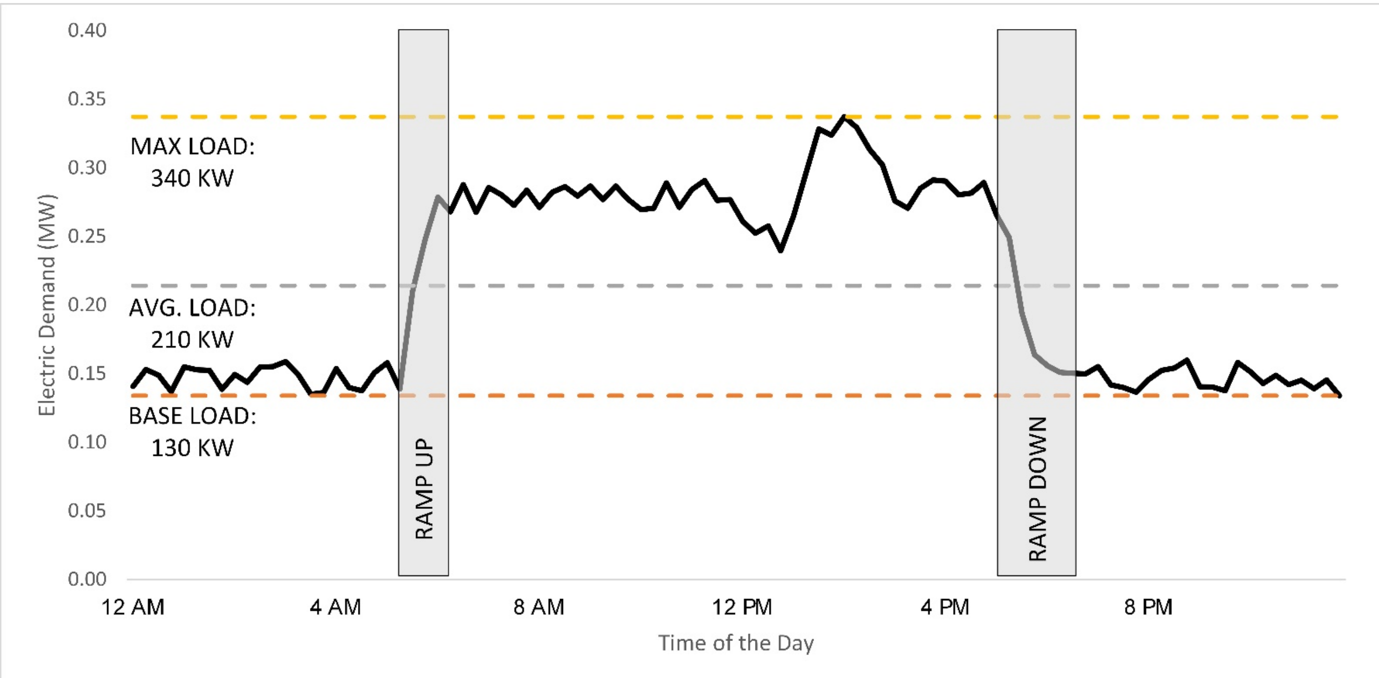


Figure 3: Typical energy use profile for a facility.

A typical load profile for a facility is shown in Figure 3. The facility starts operation around 7:00 a.m. or earlier by turning on process equipment, HVAC units, lights, and plug loads such as computers and printers. Demand slowly ramps up between 5:00 a.m. and 7:00 a.m. as more systems are turned on in the facility. Responding to such a load change on the grid often requires utility companies to deploy additional generating units that can start up quickly to meet demand. These dynamic units can be more expensive to operate than units that stay on for long periods to supply constant energy to the grid. Power prices can increase, sometimes considerably, during ramping periods. As the day progresses, production increases, and more equipment is brought online. Depending on the weather, the temperature outside can increase the load on the HVAC system. Energy consumption steadily decreases after 4 p.m., when the employees are beginning to shut down their equipment, and the workday is about to end. After 8 p.m., only essential equipment is kept running, which may include HVAC units and other equipment that cannot be shut down but can be put on standby mode.

For the example facility in Figure 3, the energy consumption reaches a peak load of 340 kW. The facility will be charged for peak demand of 340 kW unless the facility has 15 min average demand higher than 340 kW any other time/day of the billing cycle. In this example, the baseload is about 130 kW while the average load is 210 kW for this particular day. Understanding baseload, peak demand, and how the electric demand changes depending on operation and weather is crucial when trying to deploy a DR program in your facility.

Seasonal Demand

The diverse seasonal weather patterns of the United States affect electricity demand. While the western and the southern part of the country has a higher temperature in summer, the east and the midwest has colder winters. Areas with low temperatures in the winter have a higher natural gas demand during winter. Regions with warmer summers have higher electricity demand during summer. In industrial facilities, cooling is mainly provided by chillers, cooling towers, and refrigerant-driven HVAC systems. As these cooling systems mainly operate on electricity, the demand for electricity increases during the summer months. Conversely, heating systems for an industrial facility mainly use natural gas, although some facilities might have electric radiant heaters as their source of heat. **Error! Reference source not found.** shows the average electricity load during the summer and winter.[3]

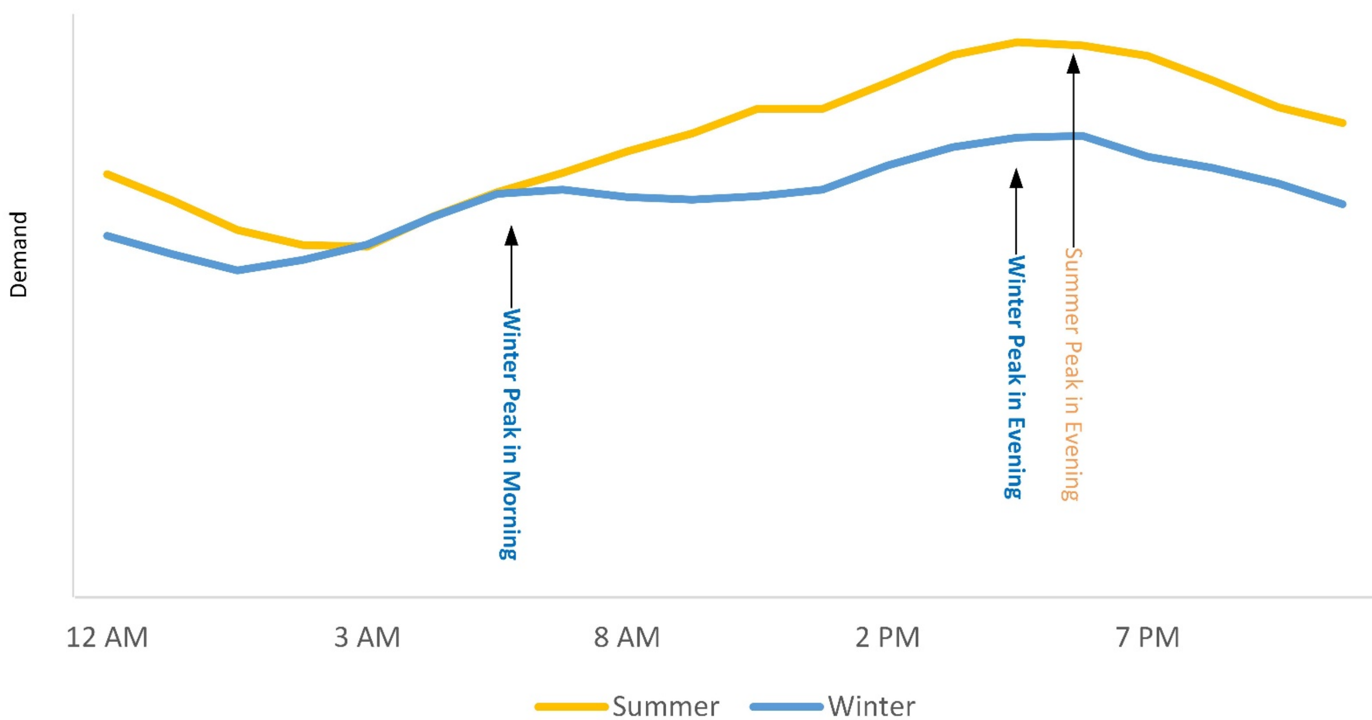


Figure 4: Typical Seasonal Peak Demand.

In the summer, the electricity consumption slowly ramps up all through the day and reaches its maximum peak during the evening. Summer electric peak demand is much higher than in winter. During the winter the electricity demand increases during the early hours of the morning and again in the evening. Based on when the peak demand occurs, utility companies apply time-based rate structures to help reduce the demand. In the following section, we will discuss some main types of time-based rates.

Types of Time-Varying Rates

One way that utility companies try to reduce peak electricity demand is by using variable rates. By increasing prices during peak times, customers have an incentive to reduce their electricity use. More commonly, large commercial

[3] Hourly load profiles below are displayed for each region's local time zone. The data shows average aggregates of US hourly loads from 2017 to 2019. https://www.eia.gov/opendata/qb.php?category=2122628.

and industrial customers already use time-varying rates. With enabling technologies (e.g., advanced metering) and advanced energy companies developing energy management products and services that give customers the information and tools to respond to price signals, more states are beginning to implement time-varying rates. The four types of time-varying rates are listed as follows:

- Real-time pricing (RTP)
- Variable peak pricing
- Critical peak pricing (CPP)/critical peak rebate
- Peak time rebate (PTR)
- Time of use (TOU)
- Coincident Peak (CP)

The following section shows the increasing risk and financial reward of the various rate structures commonly available in the United States. Although RTP appears to have the greatest potential to align customer and system incentives, at a minimum, its implementation requires advanced metering infrastructure, and it has the potential to expose customers to a high degree of price risk. At the other extreme, TOU tariffs are much simpler to implement and are less risky to customers, but they only provide a very blunt (season and time-of-day) and static (determined a year or more ahead of time) price signal that may not be sufficient to alleviate the worst peak load conditions. Interruptible tariffs and programs aimed directly at peak load conditions (i.e., CPP/critical peak rebate and variable peak pricing) represent a middle ground.

Real-Time Pricing

Real-time pricing (RTP) is the most sophisticated and most variable structure; hourly prices are determined by day-ahead market prices or real-time spot market prices for electricity. RTP also has the highest incentives if it is correctly implemented. For this pricing scheme, electricity rates vary by hour and are meant to represent the marginal cost to serve electricity to the consumer. For buildings with smart technology such as meters, sensors, and controllers that can help provide flexibility, can benefit from the RTP rate approach. Customers often undergo training and have dedicated employees or third-party service providers to gain the full benefits of this rate structure. The notification of the rate structure can be from a day to an hour ahead. In some RTP designs, only a portion of the customer load in any hour is subject to the real-time prices. In such cases, an agreed upon or defined amount of energy in every hour is subject to a rate, and energy used above that defined baseline is charged at the real-time rate. Conversely, the building could earn a rebate at the real-time price if the energy consumed in an hour is below the baseline amount.

Variable Peak Pricing

Variable peak pricing (VPP) rate structure mirrors the standard rate structure during off-peak hours, but the price varies during on-peak hours. These prices can be based on a predetermined rate structure or be tied directly to the wholesale market. This structure is less complex than RTP rates, but customers only have to respond to VPP rates for a fixed period.

Coincidental Peak Demand

Coincidental Peak (CP) demand occurs when your actual demand and the grid demand reach their highest level at the same time. CP demand is different from peak demand in that it may not occur during the same time interval as the facility peak demand, however, the electricity grid that your local distribution company is part of is peaking and you are billed for your contribution to the system peak. Typically, the time interval is an hour. CP demand is usually set based on the prior year's energy consumption. CP uses external information like weather, state of distribution and transmission lines, and other factors to predict when it might occur. In the PJM regional transmission organization (RTO) market, CP demand is also called Peak Load Contribution (PLC) where they look at the previous year’s 5 highest peak during the summer. Similarly in Texas (ERCOT) market, the CP demand charges are set based on Four Coincident Peaks, or 4CP where RTO checks every hour each month from June to September to determine the highest demand. Customers can subscribe to alerts from their energy suppliers to let them know when CP demand would occur and can avoid additional demand charges by reducing their peak demand.

Critical Peak Pricing

Critical peak pricing (CPP) has higher rates during an announced event for a limited amount of time. For CPP rate structures, fixed rates are punctuated by higher rates charged during peak demand events (announced in advance). The event is limited to a certain number of days or hours per year. When utility companies observe or anticipate high wholesale market prices or emergency conditions, the rates are substantially raised in the CPP pricing structure. Two variations of this rate design exist: one in which the time and duration of the price increase are predetermined when events are announced, and another in which the time and duration of the price increase may vary based on the electric grid’s need to have loads reduced. Utility companies can also set a specific time (e.g., 3 p.m. to 6 p.m. of a peak summer weekday) in which the rates are substantially higher than usual.

Peak Time Rebate

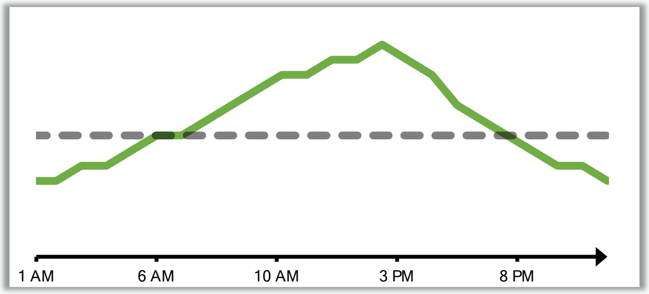
Peak time rebate (PTR) is essentially the reverse of CPP—where customers receive a financial rebate when they reduce their usage during a peak demand event. The customers are notified in advance to reduce usage in exchange for a bill credit. PTR is low risk because customers have no financial risks. The price for electricity during these periods remains the same, but the customer is refunded at a single, predetermined value for any reduction in consumption relative to what the utility deemed the customer was expected to consume. Industrial facility’s energy consumption is driven by production and shutting down critical pieces of equipment or putting them in standby mode to meet the load reduction level set by the utility provider is not an attractive option for many manufacturing facilities.

Time-of-Use Rate

Time-of-use (TOU) is the most basic pricing scheme; it consists of predefined peak and off-peak periods with a tiered pricing structure for each, which can be found easily from your local utility provider. TOU rates are set on a fixed schedule depending on the customer’s utility provider. The day is broken into off-peak and on-peak hours that have different rates that remain constant from day to day over a season. This simple method of pricing encourages customers to reduce their electricity use during peak demand times by charging a higher price and shifting use to times of lower demand with a lower price. TOU rates can include lower costs during weekends and higher costs during weekdays.

TOU programs are usually voluntary or opt-in programs. Enrollment in these programs is low because of the risk involved. If the customer fails to reduce their load, they can be penalized by paying higher rates. Therefore, many customers opt for a PTR structure, which involves no financial risk. TOU also varies with the season in different parts of the country. Regions with higher summer and winter peaks have higher TOU rates during those seasons.

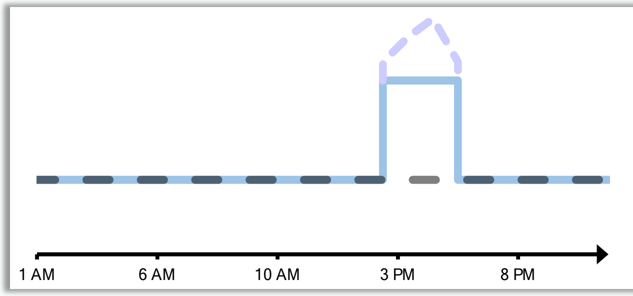
Figure 5 shows the comparison of different time varying rates that are commonly available from utility provider. The rates structures are listed in order of highest to lowest bill volatility. Bill volatility is the amount of risk or uncertainty in the monthly electricity bill. From the figure below you can see the higher the risk or uncertainty, higher is the savings on their electricity bills.



Real-Time Pricing: Dynamic pricing rates reflect the variation of wholesale electricity prices

Bill Volatility: ★★★★★

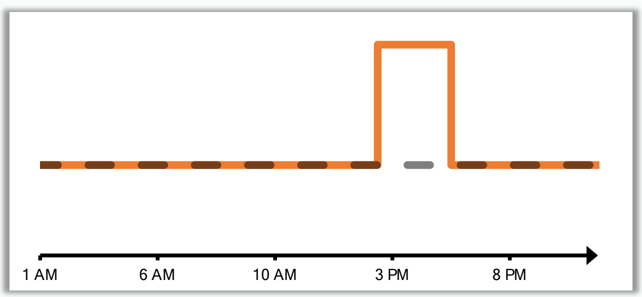
Bill Savings: ★★★★★



Variable Peak Pricing: On-peak and off-peak periods are defined in advance based on anticipated peak demand period. The prices in the other periods do not change from day to day

Bill Volatility: ★★★★

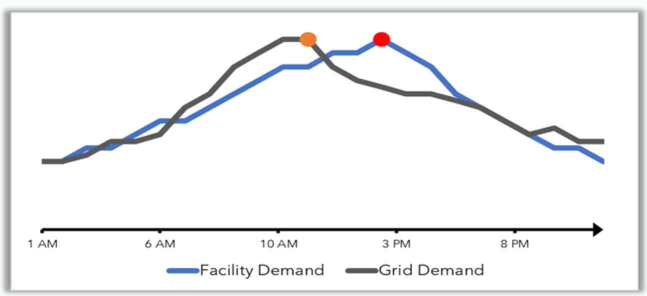
Bill Savings: ★★★★



Critical Peak Pricing: A period of time in the day when the grid load is critical, price may increase dramatically

Bill Volatility: ★★★

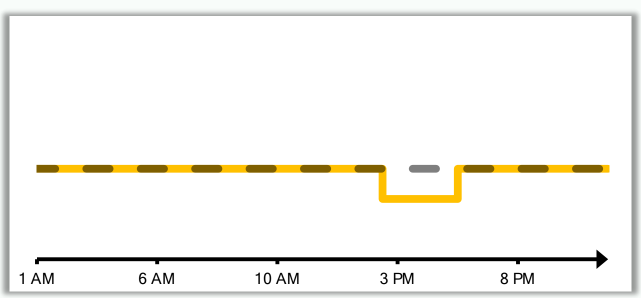
Bill Savings: ★★★

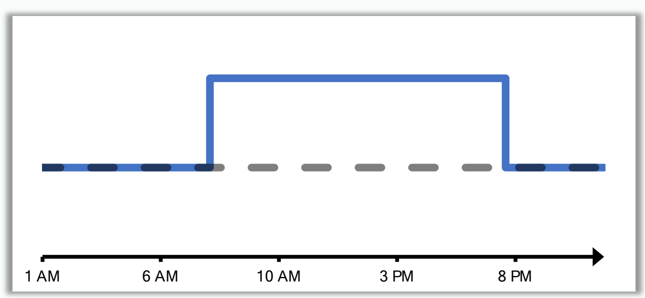


Coincidental Peak Demand: The time period when facility peak coincides with the grid demand.

Bill Volatility: ★★★

Bill Savings: ★★★★





Peak Time Rebate: A rebate for members who reduce electricity consumption when the grid load is critical. **Bill Volatility:** None **Bill Savings:** ★ ★ ½	**Time of Use Pricing:** A rate structure that has a stepped rate structure for on-peak and off-peak hours for predetermined block of time **Bill Volatility:** ★ ★ **Bill Savings:** ★ ★

Figure 5 Comparison of different types of Time-Varying Rates

What Type of Demand Response Program is Suitable for You?

The operations in an industrial facility are more complicated than in commercial and residential buildings, leading to a more complicated DR utility structure. Understanding what the customer is signing up for as part of the DR program is key for success. Enrolling in a program that rewards the participant based on the level of consumption reduction during a peak event and that does not penalize for failing to do so is lower risk for the customer (e.g., a PTR). The more demand the customer reduces during peak hours, and the longer they can curtail their load, the higher the incentive. Large companies have multiple facilities all over the country and have different utility providers and energy sources for their facilities. Knowing how many times during the season the facility may typically be notified for a DR event and the amount of time they are required to reduce their load can help facility managers understand the feasibility of enrolling in these programs.

DR programs can be generalized into two categories: continuous and event-driven. Continuous DR programs are driven by varying power prices, which can change based on the tariff, time of day, or market prices (e.g., RTP, variable peak pricing). Continuous DR programs do not wait for a seasonal event to trigger the program protocol, but rather, demand reduction can be a daily occurrence depending on a facility's utility tariff. Customers that have time-varying demand charges (e.g., on-/off-peak rate, CPP) on their utility tariff can choose to self-regulate their demand when energy prices are high. Manufacturing facilities might include a mix of different spaces (e.g., office, machining, assembly, production, warehouse, laboratory, and testing areas), and reducing load in all the areas of the facility might not be a viable option. If a plant manager understands which operations can be reduced or shut down based on the time of the day, they could set realistic peak reduction targets. This understanding also helps them develop a plan on how to successfully respond if there is a DR event. By self-regulating, facilities can reduce their overall energy bill. This method also fosters industry best practices (e.g., turning off unnecessary plug loads, turning off noncritical equipment when not in use, reducing HVAC set points).

Event-driven programs are triggered by utility providers; if customers respond to an event, they receive incentives or avoid penalties for reducing their load over a specific period (e.g., CPP, PTR). The participants in the event-driven response program reduce their load when the utility notifies them in advance, usually a few hours or a day ahead. Depending on state and utility regulations, these programs may be mandatory or voluntary. If customers reduce their energy demand, they can receive credits for their utility bills, receive direct financial compensations, or avoid penalties. Large facilities sometimes use a third party or energy account management firm to help keep track of alerts, notifications, and monetary incentives. Typically, customers with large peak demand will take part in these programs. This helps the utility to better control load on the grid and increase grid resiliency. Similar DR strategies and technology can be used for either DR program type. For an example of an event driven DR program, read about Better Plants partner Agropur Dairy Cooperative.

④ Agropur Dairy Cooperative

Agropur has participated in an electric DR program with their local utility for almost 14 years. Agropur signed up to reduce roughly 1,000 kW during a DR event. For this particular program, there is no penalty if the facility cannot make the complete reduction; the benefit received is based on the amount that is reduced. Typically, before an event happens, Agropur will get a day-ahead warning. However, the program can call an event anytime during summer months. Some of the strategies Agropur uses to reduce demand during an event include cooler and freezer temperature setbacks, reducing lighting loads, turning off battery-charging forklifts, and turning off their wastewater treatment plant for as long as possible. Similar to a rebate, a check is given to Agropur based on the amount of demand reduced during an event. During their time with the program, Agropur has received an average of $12,000 annually.

Agropur also participates in a natural gas DR program. Agropur locations in Minnesota are subject to harsh winters, which led to an opportunity to participate in the natural gas program. During a natural gas event, Agropur switches its entire fuel load to propane. Depending on the severity of winter, the plants experience an average of five events during the season. The utility company gives Agropur a 1-hour notice before the natural gas event occurs. The three plants that participate in the program consume roughly 14,000 gal/day of propane during the event period. During the winter of 2020, Agropur saved more than $121,000 in natural gas expenses.

Demand Response Strategies in a Facility

Technology in DR is used to deploy the management methods mentioned in the DR hierarchy section. Technology on the market ranges from simple timers and occupancy sensors to sophisticated smart devices that can predict and react to real-time events, such as the Fine Factories example in Figure 6. The goal of using technology in DR is to lower and manage the peak demand at a facility. The newest and most advanced technology in DR relies heavily on leveraging smart manufacturing methods to react, predict, or prepare for the dispatch of a DR program. Cross-cutting smart technology such as smart metering, IoT, and energy generation and storage are at the forefront of smart management methods.

DR strategies take many different shapes and forms. There is no guaranteed way to design and implement a successful program. A DR program must be designed to accommodate facility needs and the amount of consumption that can be realistically and effectively reduced during a DR event. To help better understand possible loads that can be affected by a DR event, Figure 6 depicts an example facility, Fine Factories Inc.

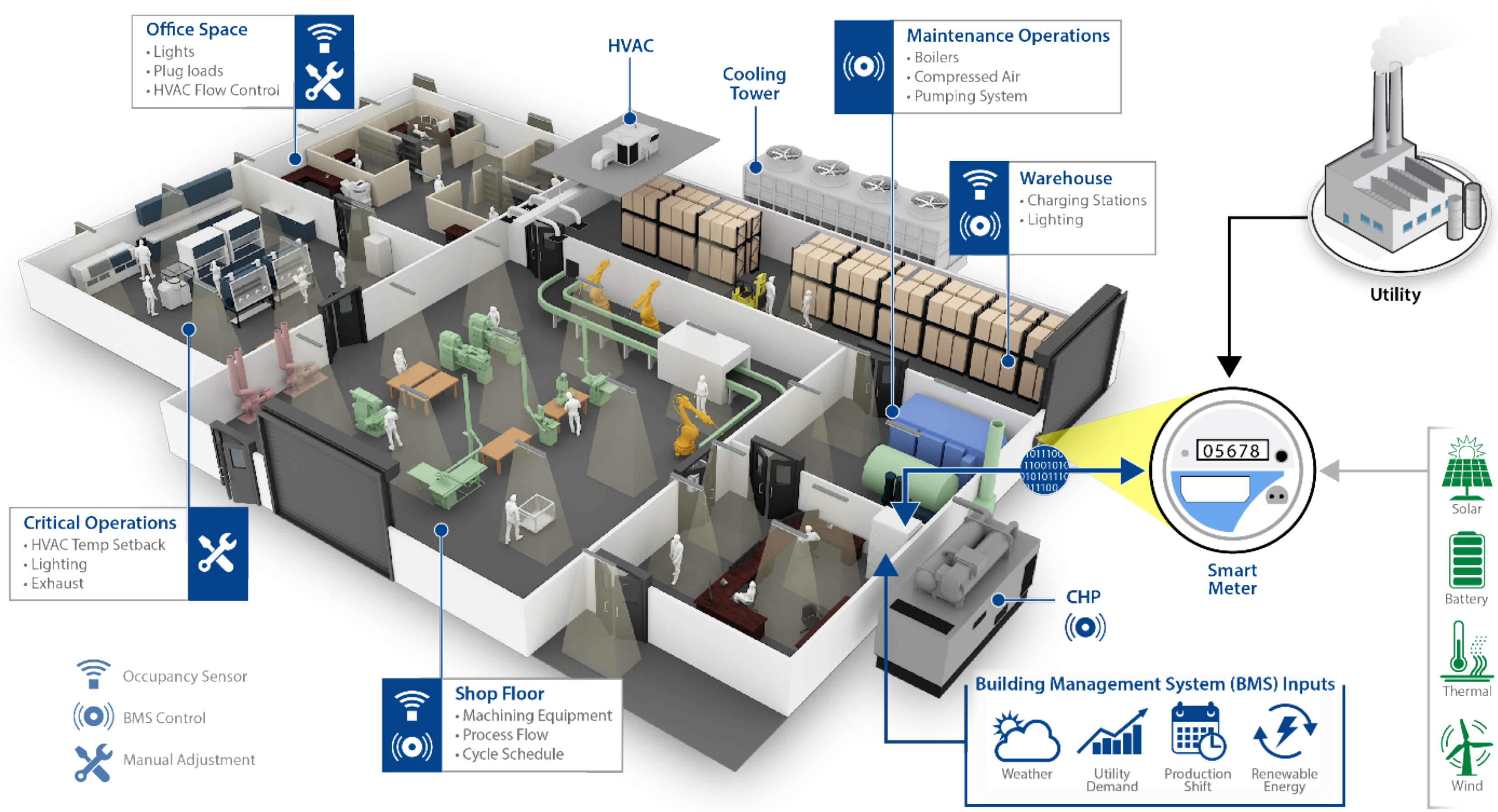


Figure 6: Fine Factories DR system.

The Fine Factories facility is an example of a systematic facility-wide DR strategy. For this facility, the system is managed using a building management system (BMS) and internet of things (IOT) technology. The system acts as an optimization center that takes in external and internal information and uses it to dispatch load management tactics during a DR event. The system uses information from the on-site smart meter, which communicates with the local utility grid, along with on-site generation and energy storage at the facility. Other key data includes the local weather, predicted utility demand trends, and scheduled production shifts.

The Fine Factories facility consists of the standard areas and departments seen in manufacturing facilities (e.g., offices, maintenance areas, warehousing, the shop floor, and critical operations areas). Each of these areas poses a unique opportunity to aid load reduction during a DR event. Each area can have set points or load adjustments in three ways: manual, occupancy sensor, or through the BMS controls. BMS controls are dispatched and controlled via automatic system optimization sequencing. Occupancy sensors detect the volume of personnel in an area and reduce load appropriately, which could include turning off or dimming lights, reducing HVAC flow in common areas when no or low carbon dioxide is detected, and other actions. Fine Factories can also control load during an event by manual adjustment. These adjustments are made by personnel physically changing a set point or reducing power consumption around them without sensors. This method is commonly seen in office spaces with reducible plug load (e.g., computers, printers, vending machines, and TVs) or critical operation areas. Critical operations in a manufacturing facility, such as a lab or research space, can be temperamental and may require manual adjustment to ensure the safety and quality of the work.

Each system input plays a key role in dispatching the DR protocol. Historically, there is a direct correlation between extreme weather conditions and the call for a DR event. The system can examine the forecasted weather and forecasted market demand prices and anticipate a DR event. Once an event is determined, the system will begin its DR protocol by notifying the necessary personnel to reduce the load. The system will start an optimization sequence to reduce consumption while still supporting production needs. Then, the system will prioritize and optimize the production schedule where possible, moving the lower energy intensity processes to begin before the anticipated event and rescheduling the higher–energy intensity processes to low-demand periods or after the event. Simultaneously, the BMS will consider on-site power options for the facility. This may mean preparation for dispatching the stored thermal or battery energy at the facility or increasing generation through combined heat and power systems. The controls system will signal smart sensors throughout the facility to reduce load through the various departments, turning off forklift charging stations, changing HVAC setpoints, dimming lights, slowing or turning off non-critical pumping processes, and so on. Finally, the BMS notifies administrative and shop supervisor personnel of the upcoming event to manage their local load manually.

The system that Fine Factories has implemented is an advanced system that can read and react to the ebb and flow of power needs. This system shows an example of a company that has prioritized and entwined DR into its standard operating practices. A system of this magnitude is created over years of research and technology implementation customized for specific needs and the manufacturing sector. Read about Better Plants partner, Cleveland-Cliffs Inc., for an example of a partner using a multilevel approach to DR.

④ Cleveland-Cliffs Inc.

CLIFFS
CLEVELAND-CLIFFS INC.

Cleveland-Cliffs participates in a DR program managed by their local utility. The program allows participating companies to set the amount of power they can reduce during a DR event. If a participant cannot reduce the power required during a given event, there is a financial penalty. To alleviate this risk, Cleveland-Cliffs partnered with a third-party company to help manage their position in the program. If the plant is unable to lower their demand to their contracted value, the third-party company absorbs the penalty. In return, at the end of the year, the third-party company receives a portion of the revenue from the DR program.

Cleveland-Cliffs tracks the PJM day-ahead forecast concurrently with the weather forecasts for the area. The facility found a direct correlation between weather and the call for an event. This finding allows the facility to plan for an event and schedule production accordingly before receiving the actual warning from the utility.

Cleveland-Cliffs takes a two-method approach to DR. The first method is to reduce or eliminate the use of the facility's significant energy users. The shop floor will get a call from management and react accordingly, reducing or turning off noncritical equipment. The second method is to ramp up generation. During their process, the steel mill produces blast furnace gas. These gasses are normally captured, injected into the steam system, and then used to generate energy. During a DR event, blast furnace gas generation is pushed even higher to help generate more energy to use inside the facility.

In a typical year, Cleveland-Cliffs sets their demand target at about half of their normal peak. This results in an annual revenue of half a million to one million dollars. During their five years in the program, Cleveland-Cliffs has had great success with DR.

Demand Response Hierarchy

To better understand your options as a manufacturer interested in DR, a DR hierarchy is shown in Figure 7 outlining the four main methods of controlling demand: eliminating load, lowering load (energy efficiency), moving load (demand management), and substituting load (on-site generation). The hierarchy is organized by methods that will have the greatest impact on a facility's demand requirements, eliminating load being the most drastic to load reduction from the grid and generation being the least drastic. The hierarchy also arranges the methods that will allow for the greatest future load growth at a facility, eliminating load having the least impact on future growth and on-site generation giving the greatest potential for load growth and energy flexibility at a facility. All four methods can be used to respond to a demand event. Each method has the same objective, but each possesses its own unique benefits and barriers. Many facilities will find themselves deploying a combination of two or more of these methods to manipulate their demand.

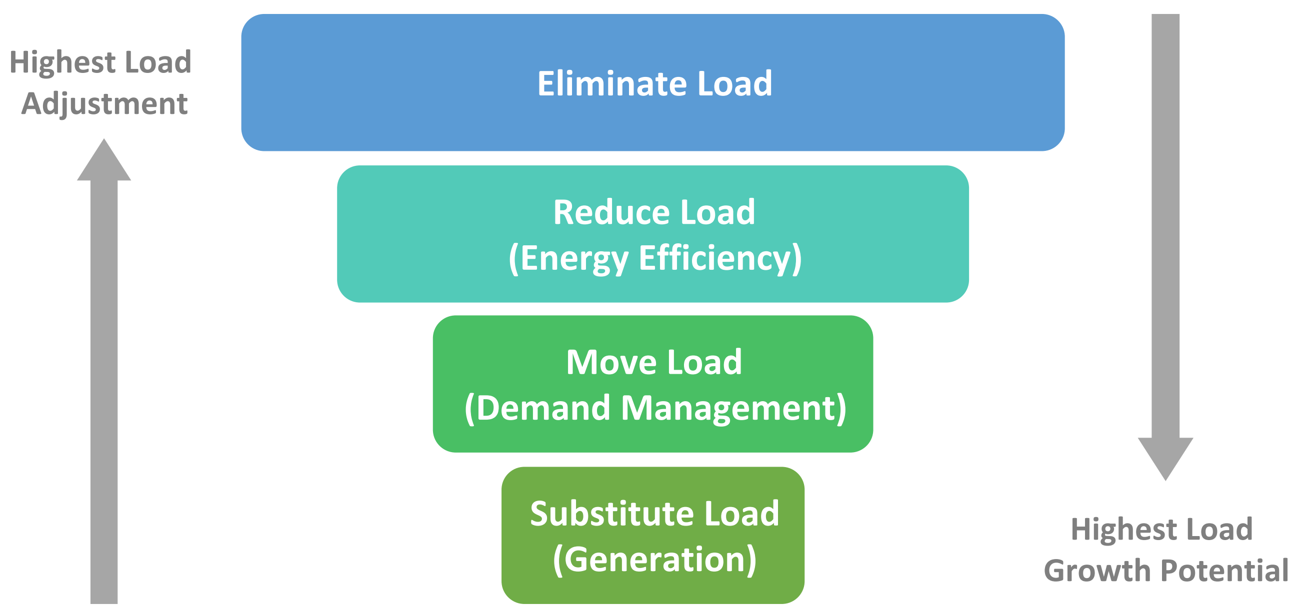


Figure 7: Demand response hierarchy.

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Eliminating Load

Of the methods mentioned in the DR hierarchy, load elimination is the easiest to understand but can be the hardest to implement. Eliminating load removes part of the process or removes unnecessary power that a facility draws. This means that the load that was removed will never return. Examples of load elimination could be shutting down an old processing line that no longer runs, cutting power to old buildings on site that are out of commission, or removing idling back-up equipment that is no longer needed. If load is able to be eliminated, there will be a direct impact on electricity and peak demand costs.

Energy Efficiency and Demand Response

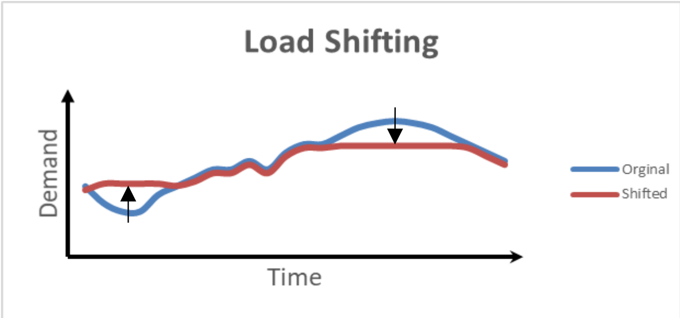
Energy efficiency refers to reducing energy consumption by using less overall energy to accomplish the same task and can be considered a partial load elimination. Energy efficiency reduces costs through consuming less energy no matter the time of day, season, on peak, or off peak. Energy efficiency opportunities are the first step facilities should consider when trying to reduce their energy use. Identifying inefficient energy use in the facility can help permanently reduce energy use and reduce the overall demand at a facility. Shutting down equipment or putting it in standby mode when not in use is often the simplest way to reduce energy demand.

Approaches to Demand Management

When load cannot be reduced or eliminated further, the next step to consider is demand management. For production-flexible manufacturing facilities, demand can also be flexible, leading to opportunities to lower peak demand. Demand management can be categorized into two main methods: load shift and load shed. Some DR opportunities can be classified under multiple methods.

④ Load Shifting

Load shifting refers to the ability to move or time when peak load occurs to realize demand cost savings. This could refer to moving a particular operation to off-peak times or temporary load relief during peak times through energy storage. With a shift, actual energy used during a non-peak period may increase, but the peak demand cost savings will compensate for the additional energy cost during that period.



Common methods used to shift demand include rescheduling manufacturing processes to a different time when facility demand is lower, or during an off-peak hour. This can be done by analyzing the intermittent power drawn by multiple processes and finding the optimal combination that will lower overall demand while meeting product output.

For less flexible facilities, a non-process–dependent activity could be rescheduled to shift the demand. For example, HVAC systems can deploy thermal energy storage to shift HVAC loads to off-peak hours. Other examples include charging equipment (such as electric forklifts) at night during off-peak hours.

Example 1: Demand Shift Savings Calculation

A manufacturer uses five 10 kW battery-operated forklifts and recharges them at the end of the day. The manufacturer notices that their peak demand is recorded every month between 4:30 p.m. and 5:00 p.m. on any given weekday. This time frame is when the forklifts are being charged. The utility tariff uses the TOU rates shown in the following table to determine the cost of demand What are the savings if the forklifts are charged after 5:00 p.m.?

Known: Demand load due to forklifts, utility tariff:

TOU	Rate	Time frame
On-peak	$6/kW	9:00 a.m.–5:00 p.m.
Off-peak	$3/kW	5:00 p.m.–9:00 a.m.

Calculate: Demand savings from charging forklifts during off-peak hours.

The total load from the five forklifts is:

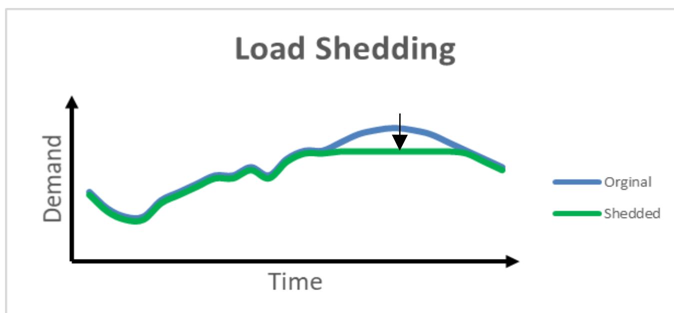
$$\text{Demand load being shifted} = 5\text{ forklifts} \times 10\text{ kW/forklift } = 50\text{ kW}$$

Demand savings are the difference in demand rates multiplied by the total shifted load:

$$\text{Demand savings} = 50\text{ kW} \times (\$6/\text{kW } - \$3/\text{kW}) = \$150/\text{month} = \mathbf{\$1{,}800/yr}$$

④ Load Shedding

Load shedding is similar to load shifting but occurs in real-time based on facility or production conditions. Shifting moves the load to a different time, whereas shed alleviates an unknown peak with DR technology. A load shed is typically not planned and is dispatched on short notice. Shedding load is temporary and is done using real-time controls.



Examples of load shed include setting up sensors to detect high-peak times and react to lower the demand using various controls, such as changing temperature set points for HVAC or dimming the lighting. A more advanced approach to load shedding is the use of power storage such as battery technology or fuel cells. Batteries can dispatch stored power to negate peak demand and lower the power being drawn from the utility grid.

Example 2: Demand Shedding Savings Calculation

A manufacturer is considering adding controls to allow half of the shop lights to be turned off in case of a DR event. The areas that can have lights shut off are automatically run with little interaction, and the lights being shut off will not affect employee safety. Events typically happen three times per year. During an event, the demand cost can be as high as $10/kW. The current lighting load would be 1,000 T8 fixtures with five 20 W lamps each and a 5% ballast loss. If 50% of the lights can be shut off, what are the savings?

Known: Demand load due to lighting, cost of demand during DR events, and number of DR events:

Calculate: Demand savings if 50% of the lights are turned off.

The current shop demand is calculated by multiplying the number of fixtures by the number of lamps, power per lamp, and by the ballast loss.

$$\text{Current shop lighting load} = 1{,}000 \text{ fixtures} \times 5 \text{ lamps/fixture} \times 32 \text{ W/lamp} \times 1.05 \ = 168 \text{ kW}$$

Demand savings from turning off 50% of the lights is half of the lighting demand multiplied by the peak demand cost:

$$\text{Demand load being shed} = 168 \text{ kW} \times 0.5 = 84 \text{ kW}$$

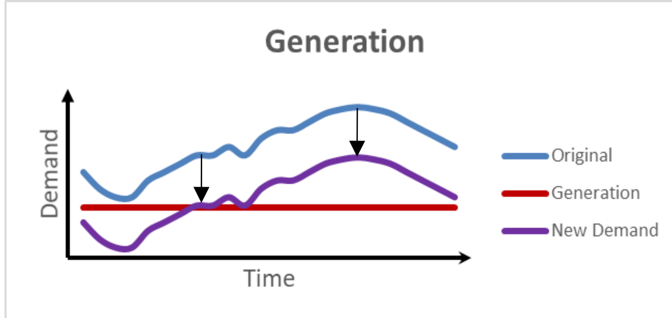
$$\text{Demand savings} = 84 \text{ kW} \times \$10/\text{kW} = \$840/\text{event} = \$\mathbf{2{,}520/yr}$$

④ Automated Demand Management

One sophisticated form of load-shedding is known as Automated Demand Response (Auto-DR). Auto-DR can automatically shed load based on a set of pre-programmed instructions and policies that are agreed upon by a utility and its customers. These measures depend on a set of standard, continuous, and bi-directional signals that allow facilities to shed load during peak demand periods. The customer and utility work together to identify places or processes where electrical usage can be reduced or eliminated during high price periods or grid emergencies. Then, instructions for demand reductions are programmed into a customer's building energy control system similar to the Fine Factories example in Figure 6. When the utility needs customers to shed load, it can send a signal via the internet to the energy control system which initiates the agreed upon series of pre-programmed load-shedding measures.

Industrial customers may be eligible for significant financial incentives for participating in Auto–DR programs. Some utilities will offer an installation incentive based on the amount of reduced electricity demand that the customer is willing to forego, and a performance incentive based on the electricity demand reduced.

Generation



As seen in Figure 7, generation is at the bottom of the DR hierarchy. While generation can be used to shift or shed load, it is not usually considered a demand management tool, rather, a way to substitute load. Generation is instead a flexible and additional energy source for a facility. Generation as a DR method refers to a facility being able to produce energy on-site to substitute the load from the grid. On-site generation can then be used to lower the grid demand, thus reducing the peak demand seen by utility companies. Generation can also be used with energy storage and be deployed during peak demand.

Generating energy can be accomplished through a variety of technologies. Common generation found in manufacturing can include renewables such as solar photovoltaics, combined heat and power, and general waste recovery such as biogas. The generated energy can then be utilized during a peak demand time, used steadily throughout the day, or stored until the optimal time for demand reduction.

Conclusion

With increasing future energy needs and pressure to improve grid resiliency and reliability, customers are looking at DR as dynamic load management tool to effectively conduct system and operation planning. Currently, facilities manually lower their loads after getting a peak demand notification or fail to reduce load completely. Although there is still value in reducing load manually, opportunities to further reduce load are available through automated systems. Advanced technologies can quicken the transition to reliable automated DR programs, building entire systems that can communicate with the electric grid and on-site energy generation to reduce peak load, optimize operations, and provide reliability to the grid.

With more organizations opting for renewable energy deployment, it is important to consider DR as a resource to reduce emissions and optimally deploy on-site generation and storage to achieve maximum financial benefits. Implementing an advanced DR management program can be costly and difficult to understand, thus increasing operational stress. However, huge benefits are available in adding a DR program as a mechanism to reduce utility bills. DR programs can help facility managers to determine which loads are flexible and are good candidates for DR as well as areas in operations where equipment is not turned off or put in standby mode when not in use. Facility managers should only include energy reduction measures that their operations can manage during an event without putting stress on production. Before enrolling in the DR program, understanding the economic trade-offs is crucial to making the right decision regarding DR participation.

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