Energy Management Strategies for Industrial Facilities in the U.S.

A. Halbe and D. Yeaman

M+W U.S., Inc, 201 Fuller rd., Suite 401, Albany, NY, 12203, USA, ankush.halbe@mwgroup.net

ABSTRACT

Solar installations in the U.S. have grown from 2 GW in 2010 to 25 GW in 2015, fueled primarily by falling system costs and the extension of federal tax incentives. The economics of distributed solar are at risk as the industry continues its unprecedented growth. Distributed solar is unable to provide power during peak hours, which typically occurs in the evening time. Furthermore, utility companies are considering net-metering and electricity rate reforms to meet peak hour demand and to better incorporate distributed solar into the electricity mix. There are market opportunities in energy storage, particularly in the commercial and industrial building sectors that typically have demand charges constituting over 50% of the electricity bill. M+W Group (M+W) surveyed the energy storage market for demand charge reduction and for grid-services. Furthermore, M+W characterized electricity demand from an industrial facility and determined that the economics for solar and energy storage are attractive. M+W also made a case for energy efficiency, which has a direct impact in reducing power consumption from the grid.

Keywords: commercial & industrial, energy storage, distributed solar, demand charge reduction, energy efficiency, demand side management

1 INTRODUCTION

Solar PV has seen unprecedented growth in the last 5-years. In 2010, the annual installed PV capacity was at 2 GW. In 2015, the annual installed capacity rose to 7.7 GW [1]. Solar PV is a $15B industry, although it is only 1% of the overall electricity mix today. Almost all of the growth in solar has come from 5 key states: California, Arizona, Massachusetts, Nevada, and North Carolina. There are numerous catalysts for the continued pace of growth in solar over the next five years. Electricity prices continue to rise 2.6% every year, which augments value proposition of solar as a hedge against rising prices. The cost of PV systems continues to decline every year. To put that into perspective, the average system cost for utility scale PV installations in 2010 was $3.48/W. That cost has fallen to $1.45/W in 2015, and is projected to reach $1.04/W in 2020 [1]. These reductions have been primarily driven by reduction in module and the balance of system costs. The biggest catalyst for growth in PV in the near term is the extension of the 30% investment tax credit through 2019, then with a gradual step down until 2023. Besides national level targets, states have their own solar growth targets. In California and New York, utility companies are required to procure 50% of their energy portfolio with renewable energy sources by 2030. As of 2015, renewable friendly states in the U.S. have a maximum solar penetration of 6-12%. Increasing solar penetration also necessitates building of substation infrastructure and additional transmission lines for the incoming power from customers via net-metering. As many as 18 states have proposals in place to eliminate net-metering, or to introduce higher demand charges for clients. The solar growth catalysts, coupled with the above risks have opened up market opportunities for energy storage. This study is aimed at determining the value proposition of solar and storage for industrial facilities. Demand-side energy efficiency, PV, and energy storage are assets industrial facilities can provide to the grid in a mutually beneficial way. Operational cost efficiency and sustainability are the key drivers of innovation in energy supply and management for industrial facilities.

M+W is a global leader in the design, engineering, and construction of high-tech facilities, utility-scale solar plants, and other major complex projects.

2 VALUE OF ENERGY STORAGE

Fig. 1 shows how the majority of the electricity markets function in the U.S. The wholesale markets are regulated by ISOs (Independent System Operators), which are primarily responsible for grid resiliency and demand forecasting. Electricity is funneled into the distribution utilities via ISOs (orange arrows). Solar is on the retail side of the equation and is available to the electricity system through PPAs (Power Purchase Agreements) with utilities, or through net-metering with consumers (green arrows). The over generation risk with solar assets is illustrated by a characteristic 'duck' curve, which is typical in places like Hawaii and California. Solar accounts for >10% of the electricity mix in these states. Steep ramp-up from conventional plants are required during peak demand hours (evening time) to cover for the solar assets that wind down. The result is a demand charge, particularly for highest energy usage customers: C&I buildings. California has seen a rise in average demand charges by as much as 31% in the past 3-years alone. These demand charges account for >50% of the electricity bill for consumers. Energy Storage offers value to the C&I consumer by offsetting these demand charges.

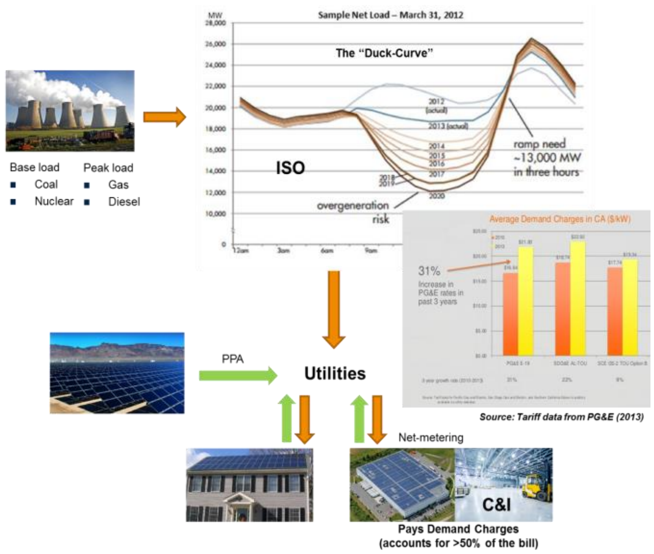

Figure 1: Demand charge mechanism: C&I building

The utilization of energy storage assets solely for the purpose of demand charge reduction may not be economically feasible, especially in the case of advanced energy storage technologies like Lithium-ion (Li-ion). The utilization of batteries is in the range of 5-50% when dispatched only for demand charge reduction. A storage asset can provide as many as 13 services to the ISOs, utilities, or end-use commercial customers [3]. The energy storage asset can provide most services to the electricity system only if located at the end-use customer site, such as a C&I building. This allows the asset owner to also monetize 'grid-services' such as frequency regulation, voltage support, transmission and distribution deferral, etc. that are more up-stream in the electricity system. Regulatory barriers prevent customer-sited storage assets that are primarily deployed for demand charge reduction from monetizing such grid-services today.

3 DEMAND PROFILE: INDUSTRIAL

M+W identified an advanced manufacturing facility with 24/7 operation located in the U.S. to use as a test case to evaluate the potential ROI of using energy storage for demand charge reduction and for participation in grid-services. Electricity consumption data was collected and analyzed for a calendar year from this energy intensive facility. Average load data (MW) over a 24-hour period was collected for each of the days in the calendar year. The average daily demand from the facility was anywhere between 55 MW and 90 MW. The facility was under ramp-up in the first half of the year, which is reflected by the increasing slope in Fig. 2. The facility operated at full capacity towards the end of the year. A sizeable proportion of the load from the facility is contributed by the facility systems, typically consisting of chillers, cooling towers and the HVAC systems. The average daily demand at the facility gradually decreased in the last quarter of the year, due to reduced loading on the chillers during the onset of winter.

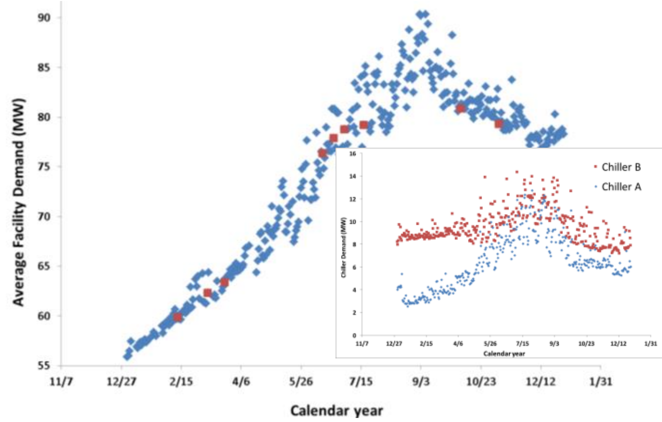

Figure 2: Average daily electricity demand from the industrial facility for 1 year correlated to chiller load profile

M+W analyzed randomized days from summer, fall, and, winter to characterize the demand profile from the facility within a 24-hour period (indicated in red – see Fig. 2). The manufacturing facility essentially remains under heavy demand through the 24-hour period. This is unlike commercial office buildings, where one would expect the facility load to bottom out during non-business hours. The effect of lights and climate control during off-shift hours is expected to have little effect on the overall load of an industrial building. The warmer months tend to see larger swings in demand data than the colder months. This is reflected in the standard deviations of the data set: 0.76 MW in June-July as compared to 0.47 MW in Oct-Nov, and 0.40 MW in Feb-Mar periods. This may potentially be related to the higher magnitude of temperature variation during 24-hour periods in summers as compared to winters, and the effect of that variation on power usage from the facility systems. The data also shows a cyclic nature of the facility demand curve (see Fig. 3), with little peaks and troughs in the profile every few hours.

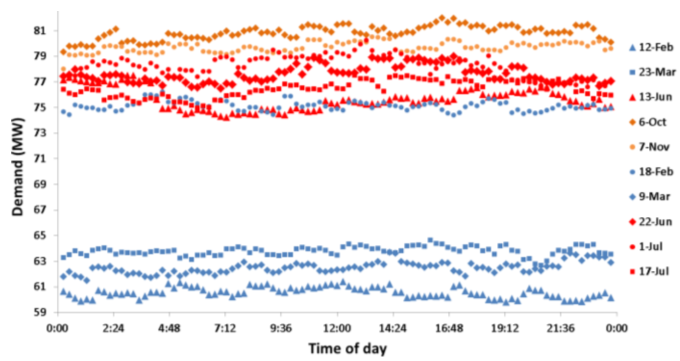

Figure 3: Demand profile from the industrial facility across winter (blue), summer (red), and fall (orange)

The load profile may seem flat from a macroscopic view, but the magnitude of shifts within in a 24-hour period is large enough to deserve an investigation into electricity bill management. To put into perspective, a day in the summer (1st July) exhibited 4 MW in demand range over a 1 pm to 9 pm time period (see Fig. 4). The characterization of electricity tariff structure for the jurisdiction where the manufacturing facility is located is crucial to determine the electricity bill savings opportunity. A time-of-use tariff or a demand charge structure from the utility for industrial facilities in the jurisdiction will determine the value proposition for peak shaving or shifting.

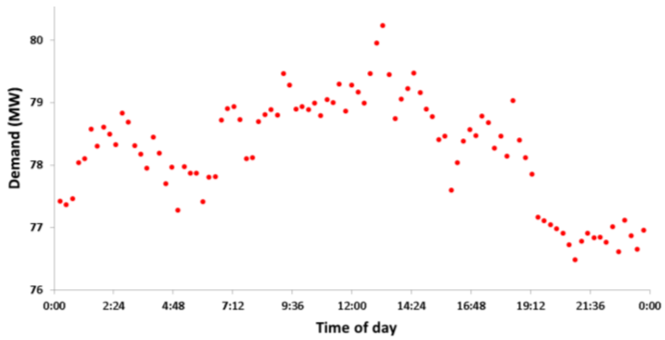

Figure 4: Electricity demand profile from the industrial facility over a 24-hour period on a random day in the summer time (1st July)

4 ECONOMICS OF SOLAR & STORAGE

M+W analyzed 60-min interval demand data shown in the section above over a 1-year period, and ran an economic model to determine the payback for solar and storage assets. The reduction of demand charges was the primary use case under consideration for the study. M+W evaluated a hypothetical scenario, which assumed that such an industrial facility is located in southern California. Southern California Edison was chosen as the utility along with a rate tariff that would best represent the above industrial facility. The baseline case shows significant demand charges (37% of overall power bill) for the facility (see Fig. 5). A 25 MW solar farm was assumed to support the power production within the facility. The introduction of solar offsets the power consumption from the grid at a time when the sun is shining by almost 6%. It also offsets some of the demand charges, most likely towards the end of the day. However, it is the introduction of storage (15 MW/30 MWh) that offsets significant demand charges from the utility and improves the yearly energy savings from $2.8M (solar only) to $5.7M (solar and storage) for the facility. The combination of solar and storage should provide a faster payback on the investment than just installing solar. This analysis estimates an internal rate of return of >20% for the investments. The analysis makes the appropriate assumptions on the installed cost of solar and storage systems, investment tax credits, and the annual escalators. The cost of solar and storage are dropping rapidly every year. This should make the above economic case even more attractive to facility owners.

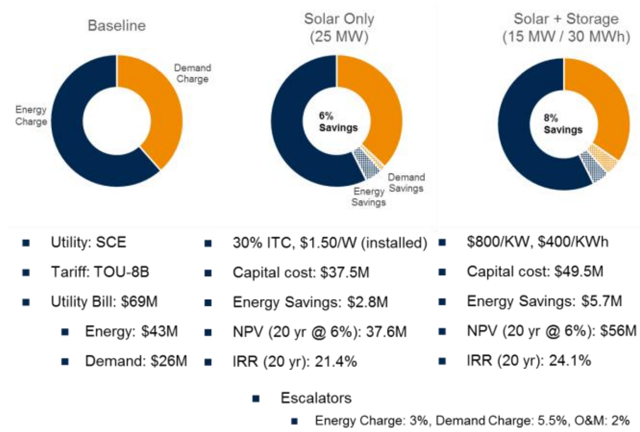

Figure 5: Return on Investment analysis on solar and solar assets for the industrial facility

The above economic analysis will need to address several key questions related to feasibility of installing solar and storage assets at such magnitude. These include challenges such as: a) evaluation of the location of these assets either in the vicinity of the facility or remote from the facility (but still net-metered) to reduce costs and provide smooth grid-integration, b) technical feasibility related to a large capacity storage installation, c) costs related to reliability of power to ensure that there are no interruptions in production, and d) financing of renewable energy assets that will be worth many millions. The above study is limited to a single scenario in terms of the geography and the size of the solar and storage systems proposed for the facility. A sensitivity analysis of +-25% around the sizing of these systems and a deeper understanding of different utilities and rate structures will provide several scenarios under which the installation of solar and storage assets may be even more favorable.

5 ENERGY EFFICIENCY

The management of industrial building and facility system loads is an effective way to reduce the overall energy consumption from the grid. An inside-out approach to facility energy management takes into account the effectiveness of the manufacturing tools along with the personnel and material movements within the facility at its core. The facility systems (air handlers, exhaust, chemical and gas delivery, abatement, etc) are designed accordingly to meet the demand and the environmental specifications of manufacturing. Facility systems are designed to recover heat from processes and repurpose for use back into the facility. This reduces the energy consumption associated with energy intensive pieces of facility systems such as boilers, chillers, HVAC, etc. The effective management of energy demand within the facility has a significant contribution towards reducing the overall facility loads. This can dramatically reduce the energy required from the grid or by renewable sources such as solar and storage. To illustrate the demand-side management, M+W conducted an energy use audit of an advanced manufacturing facility operating 24/7 to determine potential for energy savings.

#	System	Changes	Power Saving MWh/a	Power Saving KW (Peak)	Natural Gas Saving MWh/a	Energy Cost Saving	Payback Years
		Set-point changes					
1	Cleanroom	Cleanroom Specification Change	965	150	1159	$ 61,118	NA
2	Make-up Air	Make-up Air Supply Temperature Reduction	589	67	654	$ 44,954	NA
3	Chilled Water	Chilled Water Supply Temperature Increase	687	TBD		$ 40,602	NA
4	Vacuum	Temporary Shut-off	146	33		$ 8,608	NA
5	Cleanroom	Cleanroom Air Velocity Reduction	676	77		$ 39,936	NA
6	Ultra Pure Water	Replace Electric with Hot Water Heating	10186	1170	-11647	$ 421,486	1.6
7	Exhaust	Heat/Particle Exhaust Recycling	464	53	436	$ 34,217	2.1
8	Hot Water	Installation of VSD at Pumps	864	215		$ 51,062	2.4
9	Chilled Water	Installation of VSD at Pumps	1405	TBD		$ 83,036	2.9
10	Make-up air	Final Filter Replacements	387	44	-430	$ 16,195	3.0
		Hardware changes					
Total			16369	1809	-9828	$ 801,214	
Total without risk			15504	1660	-10986	$ 740,096	

Figure 6: Opportunity for energy savings from an advanced manufacturing facility

The objective for auditing the facility for energy management was to reduce wasteful, excess power and natural gas usage without compromising manufacturing or facility operations. The energy use analysis for the facility was conducted inside the cleanroom. Mechanical and process systems such as make-up air units, exhausts, chillers, boilers, ultra-pure water, and process vacuum units were also analyzed. The potential for power savings were broadly classified as those needing set-point adjustments or the installation of new pieces of hardware (see Fig. 6). Merely tuning set-points on temperature (make-up air, chilled water), valve timings, and air velocity (cleanroom) will achieve power savings of as much as 3,063 MWh/year. These changes are related to the over-specification of facility system operation. Hardware changes associated with installation of new heater-types, variable drives, and filters can achieve up to 13,306 MWh/year in power savings. Certain heating systems were recommended to switch from electric to natural gas to achieve a net energy cost savings resulting from the elimination of expensive power for the purpose of heating. The total cost savings for the facility was estimated between $740,000 (without risk) and $800,000 (manufacturing environment contamination risks to be evaluated). They payback for hardware changes was estimated at <3-years, which is much lower than what would typically be observed by solar or storage. The facility can save more money by addressing all energy efficiency related savings with low payback prior to determining any alternative sources of energy supply. A solid understanding of specifications for manufacturing environments such as temperature, humidity, cleanliness, etc. is critical for a manufacturer. It allows the reduction of both CAPEX and OPEX related to energy supply and management by engineering the facility systems only to the required specification.

6 SUMMARY

Industrial facilities have ample opportunities to reduce their energy usage and make costs more predictable. Certain industries also set sustainability goals in addition to economical reasons. The energy supply and management landscape is complex with levers such as solar, storage, and energy efficiency each playing their role to reduce reliance on the grid. Demand charge reduction is a key motivation behind energy storage for industrial facilities. Energy storage is known to enhance the economic case for solar. To that end, a high volume manufacturing facility was analyzed for energy use and shown to have significant demand swings over 24-hour periods. An economic model using 25 MW solar and 15 MW/30 MWh storage showed energy and demand savings with a healthy rate of return for the industrial facility. Opportunities for demand-side management through energy efficiency measured were also analyzed. There is a potential to impact direct energy usage by tuning facility systems to relax the specifications such as temperature, humidity, and cleanliness. A strategy that first reduces the use of power within the facility, and then offsets the remainder using solar and storage will likely provide the best value to the owners of the industrial facilities.

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