Building Intelligent Demand Response

Public Impact Report

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Overview

Flow Power's *Building Intelligent Demand Response Trial Project* (The Project), part of the South Australian Demand Management Trials Program, aimed to develop and implement an automatic rapid demand response (DR) process for participating customers, to minimise the risk of missing demand response events and to improve overall demand response performance.

At the beginning of The Project, many Flow Power customers were already participating in DR to avoid high wholesale electricity market prices. However, this participation was a manual process, where customers would be notified of events via email or text message, and be required to actively switch off equipment loads, or switch on alternative generation sources during DR events. Flow Power identified this manual intervention was often onerous, and as a result, customers were late to respond to DR events or did not respond at all. This diminished the potential benefit of responding to events. The Project was devised to assist these customers with automation, helping reduce the operational impacts of DR participation, and improving overall performance and customer benefit.

To achieve this goal, Flow Power contracted over 20MW of flexible demand capacity in South Australia, both for load-shed during peak electricity wholesale market price events, and for load ramp-up during negative price periods. This capacity was contracted from Flow Power's Commercial and Industrial (C&I) retail customer base, who are all exposed – directly or indirectly – to wholesale market price dynamics through one of our retail products.

VALUE OF FLEXIBLE DEMAND CAPACITY

The value of flexible demand capacity is twofold: improved customer bill outcomes and support for the local electrical grid. The reason for this intersection is that the highest electricity prices in the wholesale market typically occur when the supply vs. demand balance in the local grid is at its limit. Conversely, the lowest, negative wholesale market prices tend to occur when there is a large surplus of (predominantly) renewable energy.

Load-shed value is unlocked for customers by avoiding extreme electricity wholesale market prices, a mechanism that is enabled through Flow Power's suite of retail products. Peak wholesale market prices are significantly higher than average prices, making it essential for many Flow Power customers to avoid high prices. The average market price for a region is usually in the range of $50/MWh to $300/MWh (5c/kWh to 30c/kWh), however, as of July 2024 peak prices can reach as high as $17,500/MWh (or $17.50/kWh). This means that customers can incur large savings on their monthly bills by avoiding short periods of very high prices.

For example, a customer using an average of 100kW over a two-hour period of peak market pricing would save $1,750 for that two-hour period alone by curtailing their load or switching to alternative backup generation. Automation can improve this response and reduce the operational impact on businesses and individuals. The benefit to the local grid is the reduction of that load during high grid strain. This can avoid the need for more – potentially fossil-fuel fired – generation responding to meet the additional demand.

The load ramp-up value at the lower end of market pricing is unlocked via a different approach, which involves reducing behind-the-meter generation or increasing site load during periods of strongly negative prices. In contrast to high price avoidance, customers are paid for this additional energy use during negative price periods, as prices can fall as low as -$1,000/MWh (or -$1/kWh). A key aspect of this approach is proper consideration of a customers' other site charges, such as network tariffs and market charges. The price threshold set for a customer should ensure that they yield enough benefit to offset any additional charges they may receive for their increased consumption. Load ramp-up response helps the grid in times of surplus renewable energy, by increasing usage to "soak" up the oversupply of electricity and alleviating voltage and grid stability issues.

TYPES OF FLEXIBLE DEMAND CAPACITY

Building load-shed capacity consists of recruiting customers with either backup generators or discretionary equipment loads, such as irrigation pumps, refrigeration or manufacturing processes. These assets are controlled via integration with Flow Power's kWatch Intelligent Controller®, which interfaces between a customer's site and Flow Power's DR system. This features either direct integration of the controller with assets, or connection to a customer's onsite control and/or SCADA systems.

During a DR event, load-shed assets or their control systems are signalled remotely to switch on (in the case of backup generators) or off (in the case of equipment loads) at the beginning of the event. Then the reverse signal is relayed at the end of the event to return each asset to its prior state. This process is enacted with either zero customer intervention (fully automated), or via an opt-in/opt-out framework, where a customer can decide whether to participate at their discretion (semi-automated).

Building load-ramp up capacity consists of recruiting customers with assets that can be leveraged to increase a customer's site load during negative wholesale market price periods. The prevailing method for achieving load ramp-up is via onsite solar ramp-down (SRD), where a solar PV system's inverters are ramped down to zero generation. Other methods include ramping down cogeneration plant and ramping up thermoelectrical systems. These methods can reduce potential charges for exporting energy into the market during negative price periods and enable customers to receive payment for the additional energy consumed within those times. This type of flexible demand capacity has been made viable by recent evolutions in wholesale market price dynamics, where large surpluses of renewable generation at times of low demand cause prices to go negative.

AUTOMATING FLEXIBLE ASSETS

To enable the automation of customer assets responding to wholesale market pricing, all controllers are configured to provide one or more data streams containing dispatch price, pre-dispatch price, or a bespoke variation of pricing according to a customer's specific needs, to achieve a financially beneficial outcome. Each system also incorporates one or more secondary input parameters, typically in the form of remote bypass capability for load-shed assets and additional network and market charge parameters for load-ramp up assets.

The remote bypass capability for load-shed assets allows customers to bypass the standard configuration of the controller at their discretion if they do not intend to participate in a DR event. The additional charge parameters for load-ramp up systems, which are usually fully automated, are to ensure that assets are only curtailed if the net value of increasing load in a given price interval is positive.

In tandem with developing demand response automation capabilities, Flow Power also scoped and refined integration plans that can be applied across multiple customer types, from rudimentary or direct asset control to sophisticated SCADA-based control systems. The standardisation of these plans enabled the development of a commercial model for contracting and maintaining automated flexible load capacity, based on the cost of ongoing signalling services and the financial performance of a customer's demand response system.

ASSESSMENT AND REPORTING OF SYSTEM PERFORMANCE

To support the development of automated system control and a robust commercial model, Flow Power sought to create tools and processes for assessing and reporting on the technical and financial performance of each system. This included customer facing reporting accessible via a web portal, and internal tools to measure and verify the effectiveness of each system. These tools help increase customer confidence in the operation of these systems and offer visibility of financial outcomes to clarify the returns on their investment.

Achievements

Over the 5-year duration of The Project, Flow Power recruited a total of 20.1MW of flexible demand capacity, consisting of:

12.1MW of load-shed capacity, leveraging the following assets:

- Backup generators
- Mechanical manufacturing loads
- Chillers
- Cool rooms
- Wastewater systems
- Irrigation pumps
- Thermal systems

8.0MW of load ramp-up capacity, leveraging the following assets:

- Solar PV systems
- Cogeneration plant
- Thermal systems

This flexible demand capacity was contracted from 43 customer sites using 85 different systems integrated with kWatch Intelligent Controllers, from the smallest individual capacity at 28kW and the largest at 2.3MW.

The Project enlisted a diverse range of participants from many different industries, including:

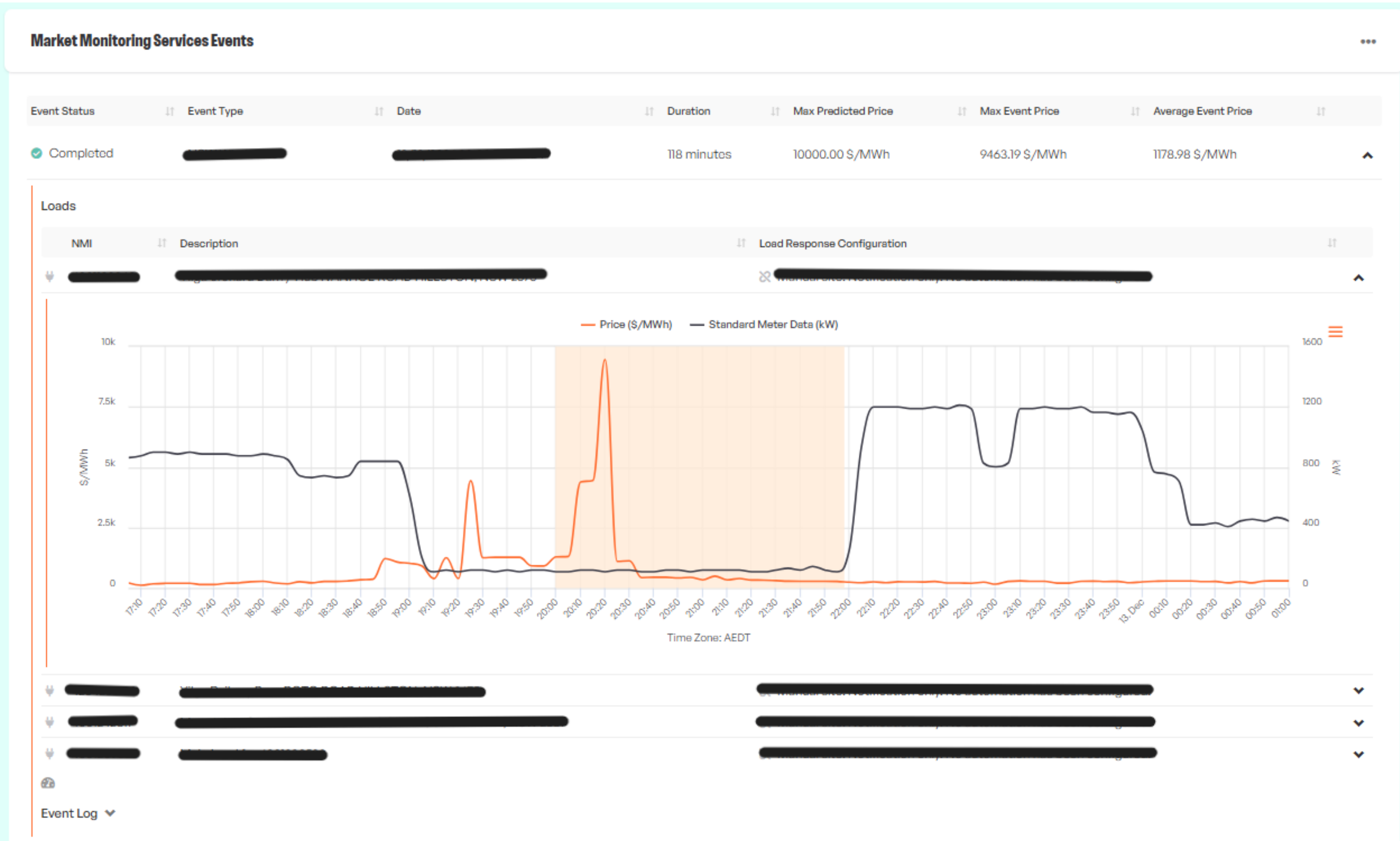
- Hospitality venues
- Dairies
- Brick manufacturing
- Wineries
- Vegetable farming
- Wool manufacturing
- Councils
- Clothing manufacturing
- Breweries
- Poultry farming
- Piggeries
- Schools and colleges
- Mills
- Sports facilities
- Thermal storage facilities

All systems utilised at least two input signals or site parameters; the electricity wholesale market price and inputs dependent on the specific asset integrated, including opt in/opt out feedback, remote bypass capabilities or site-specific network, market and other charges.

During The Project, Flow Power developed new demand response strategies allowing automated response to high or low-price signals, using real-time and forecast market pricing and specific price setpoints optimised for financial benefit to customers. We also produced standardised integration plans and documentation for asset control that can be applied and adapted to new systems with relative ease.

Alongside the development of implementation capabilities, Flow Power devised a commercial model for ongoing service provision. This is priced on a per controller basis, with additional service costs dependent on customer performance, via a revenue share mechanism. In this way, we provide a service that covers base signalling costs, but further revenue is dependent on supporting the success of customers in utilising their demand response systems.

To improve visibility of demand response performance to customers and other stakeholders, Flow Power developed the Market Monitoring Services Hub. This is a web-based portal for customers to view and analyse performance during demand response events, giving access to their site load and the wholesale market price for the duration of the events. An example of this portal is shown in the screenshot below.



Finally, in 2024, Flow Power was recognised by the Energy Efficiency Council (EEC) as winner of the Leading Energy Management Innovation Award, for a case study detailing outcomes for a customer who participated in The Project.

Performance

TECHNICAL PERFORMANCE

After contracting, installation and commissioning of each flexible demand asset, a trial period of at least 6 months was conducted to demonstrate the effectiveness of each system at delivering flexible demand capacity. During this period, interval data from each site was used to assess the amount of capacity, load-shed or load ramp-up, that each system provided during high price events and negative price events respectively.

Out of the 85 individual assets commissioned, 81 (over 95%) successfully delivered flexible demand capacity during the trial period. The table below outlines the capacity demonstrated for each type of flexible demand.

Technical results of flexible demand capacity

Flexible demand type	Contracted capacity (MW)	Peak load/generation during trial period (MW)	Flexible demand capacity recorded (MW)
Load-shed	12.1	12.1	7.2
Load ramp-up	8.0	5.6	5.2
TOTAL	**20.1**	**17.7**	**12.4**

The table compares the recorded flexible demand capacity against both the contracted capacity and peak load or generation recorded during the trial period. The comparison is important, as it highlights potential issues with contracting flexible demand and the practical delivery of capacity. Note the methods for determining the recorded capacity are explored further in the following section.

For load-shed, the recorded capacity achieved was 59.5% of both contracted capacity and the peak load over the duration of the trial period. The discrepancy here points to a key issue of contracting load-shed capacity. A system's potential load-shed capacity had been assessed based on the peak demand of a customer, to understand the maximum potential capacity that could be delivered by that system. However, in practice, the timing of high wholesale market price events may not necessarily align with the peak demand of individual systems. While it is possible that given sufficient time and number of load-shed events, the system may eventually demonstrate its peak capacity, it is important to be aware of the typical capacity that can be delivered by a system.

As an example, while an irrigation system contracted for load-shed may be well suited at delivering flexible demand capacity during its main irrigation season (typically late spring to mid-autumn), its ability to provide capacity in its off season is strongly diminished. With many high price events now occurring in the winter months in South Australia, this becomes an important consideration when assessing and contracting load-shed capacity from irrigation systems. The same care must be taken for any type of load-shed system, to understand the potential capacity delivery during specific periods or seasons.

With load ramp-up, the recorded capacity achieved was 65% of contracted capacity, but almost 93% of peak generation during the trial period. This highlights that while these systems are very effective at delivering close to their maximum capacity (i.e. peak generation), there are issues involved with determining the true delivery capacity of these systems.

The first issue is obtaining sufficient information about the systems prior to contracting. In the case of solar PV systems, this means understanding the peak AC inverter power output, that can directly contribute to increasing site load when the system is curtailed. Several instances of scoping load ramp-up capacity had insufficient information to accurately assess this capacity. This information was lost by the system stakeholders (typically for smaller systems), or there was confusion in relation to the different parameters of the system – most often mistakenly recording peak DC panel power output in place of the peak AC inverter power output.

The second issue concerns the risk of using nameplate parameters to assess contracted capacity, without considering the specific performance and maintenance of these systems. In several instances, it was discovered that the peak output of a system was significantly lower than the nameplate capacity, particularly in the cases where solar PV systems were either shaded, soiled, or had degraded due to their age.

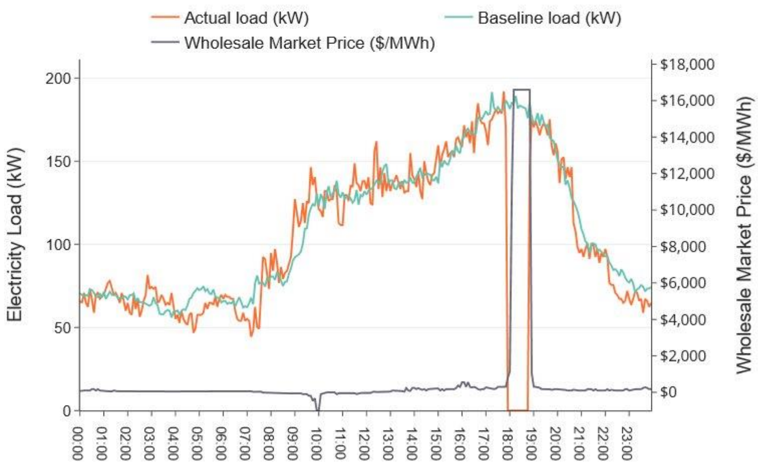
The two issues above highlight the importance of having detailed information about systems before contracting, but also understanding the current performance and health of those systems. This indicates the need for a more data-driven approach when assessing the capacity of these systems, although this is not always feasible, as access to system data may not be readily available.

FINANCIAL PERFORMANCE

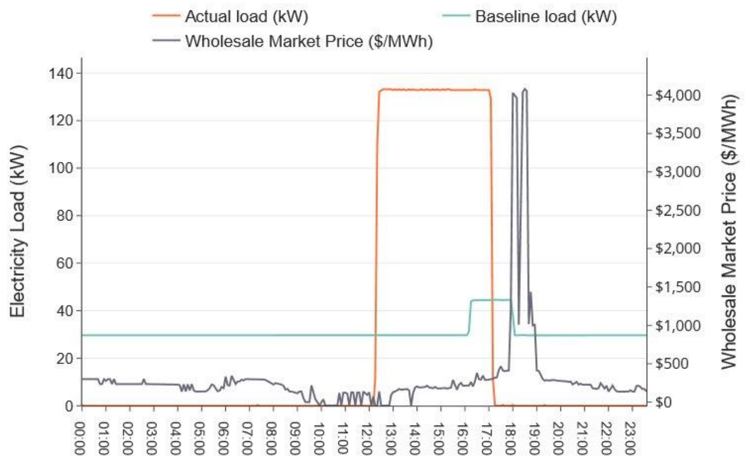
The assessment of financial performance for customers participating in The Project was a challenging undertaking. To understand the exact financial benefit of customer participation relies on the accurate assessment of a counterfactual – or baseline – state for each load-shed or load ramp-up event.

Load-shed

Assessing load-shed performance involves developing a baseline load for a site to understand the demand and usage that would have occurred, had the load-shed system not been activated. For The Project, the baseline methodology used was the same as that which is used by AEMO for their Reliability and Emergency Reserve Trader (RERT) and Wholesale Demand Response Mechanism (WDRM) programs – the CAISO 10-of-10 baseline. This method uses the average of 10 previous working days (or 4 previous non-working days) of a customers' usage, to project what they might have used during a load-shed event. An example of this method is shown below:



While this can be an effective method of estimating customer loads during events, as shown in the example, there are certain cases where this algorithm is not entirely effective. Most commonly this occurs for sites with highly variable or intermittent loads, such as the example below of a pumping site:



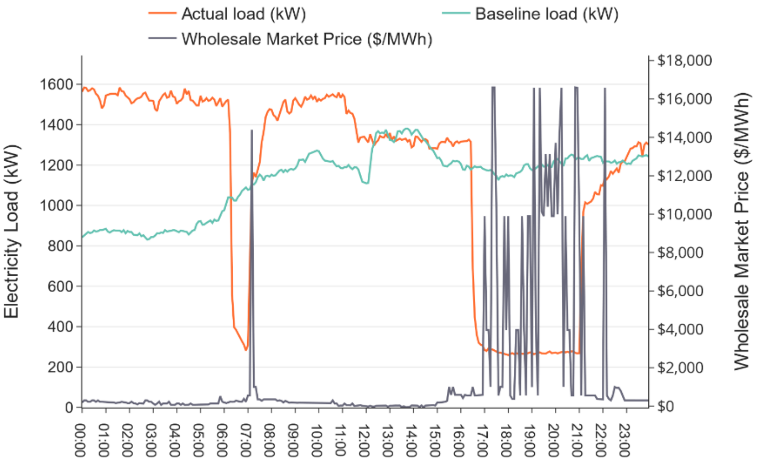
In this example, due to the variability of the load, the calculated baseline shows a result that does not reflect the expected usage of the site during the event period, which is clearly higher than estimated.

Case study: Michell Wool

Flow Power conducted an in-depth analysis of benefit for Michell Wool, Australia's largest exporter of wool fibre, at its main factory and distribution centre in Adelaide's north.

This case study was part of the submission that resulted in Flow Power's Leading Energy Management Innovation Award from the EEC. The site was contracted for just under 1.5MW of load-shed capacity, enabled through semi-automated plant shutdown via SCADA system integration with Flow Power's kWatch controller. The project was initially expected to save approximately $25,000 per annum and have a 3-year payback after government subsidy.

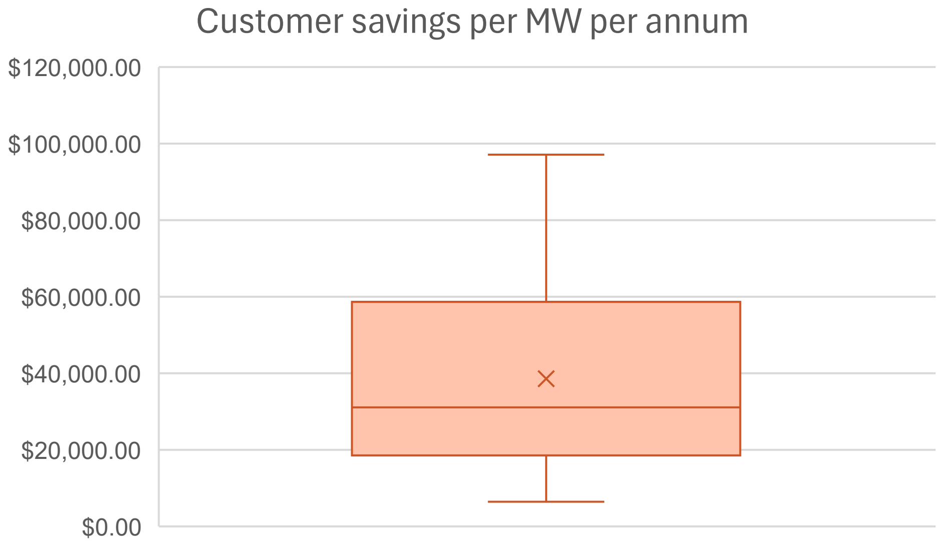
In a period of 18 months from commissioning of the system, 1 September 2022 through to 1 March 2024, the site participated in 19 of the 21 peak price events signalled by Flow Power during that period, for a total of 33 hours and 50 minutes of load-shed events at an average price of $2,500/MWh ($2.50/kWh). The site was assessed to have saved nearly $90,000 in those 18 months, with their largest single saving occurring on 11 August 2023 where it was estimated to have saved over $28,000 in a single load-shed event (pictured below).



This resulted in the project yielding an actual payback period of just over a year and a 5% average reduction in Michell Wool's electricity costs. August 2023 saw the greatest monthly savings, reducing its monthly bill by almost 30%.

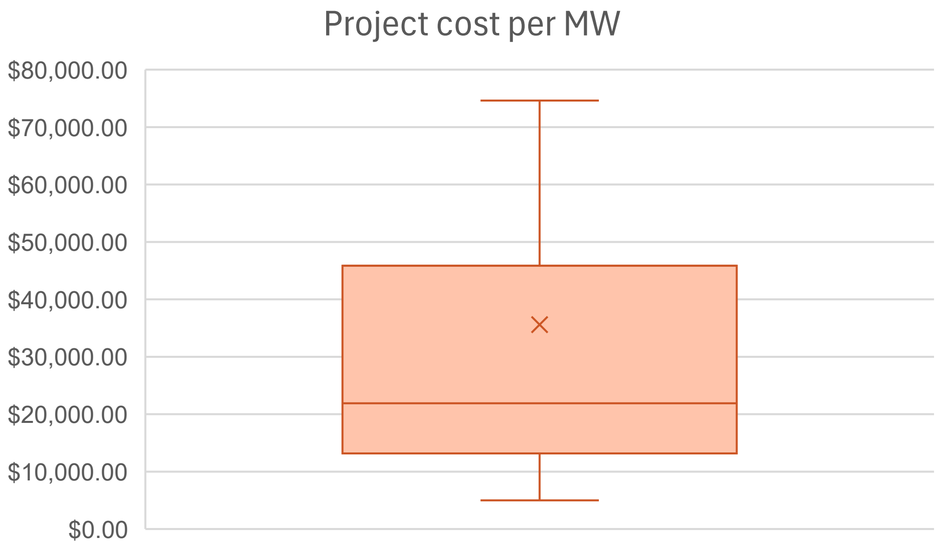
Cost-benefit analysis

To understand the performance of the broader load-shed portfolio, Flow Power measured the annual savings for participating customers, provided their baseline calculation consistently reflected their expected usage during events. To compare across projects, these annual savings were normalised on a per MW basis depending on the size of the contracted load for each customer. The below box and whiskers chart describes the statistical spread of per MW savings for the portfolio.



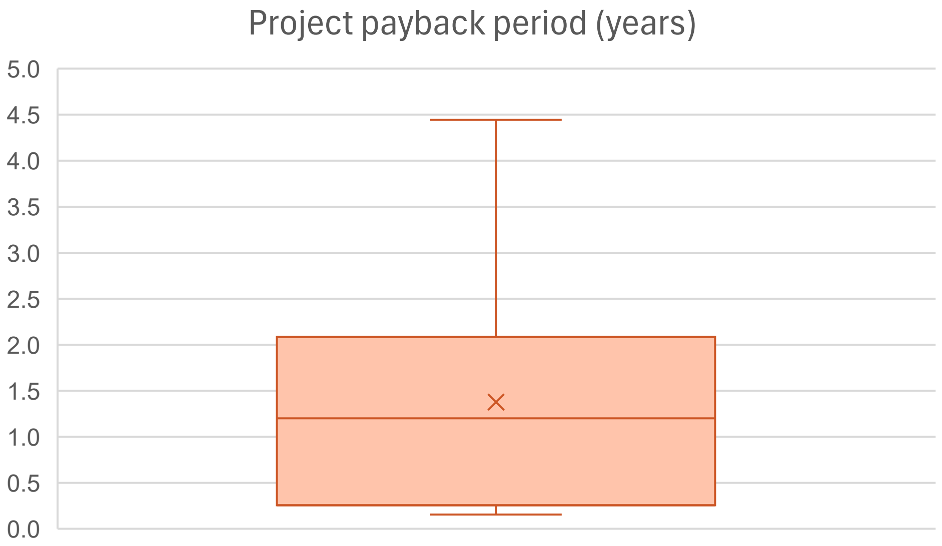
In this representation, the whiskers represent the full spread of savings outcomes, the box shows the interquartile range, and the 'X' represents the average, approximately $38,600/MW/annum.

The savings calculations could then be related back to the project cost for each customer (post-government funding). Similarly, the statistical spread of project costs per MW of contracted load is displayed below:



This shows that the average project cost per MW was approximately $35,600.

Combining these two metrics, Flow Power could determine the statistical spread of simple payback periods for the portfolio. The final chart below demonstrates this spread.



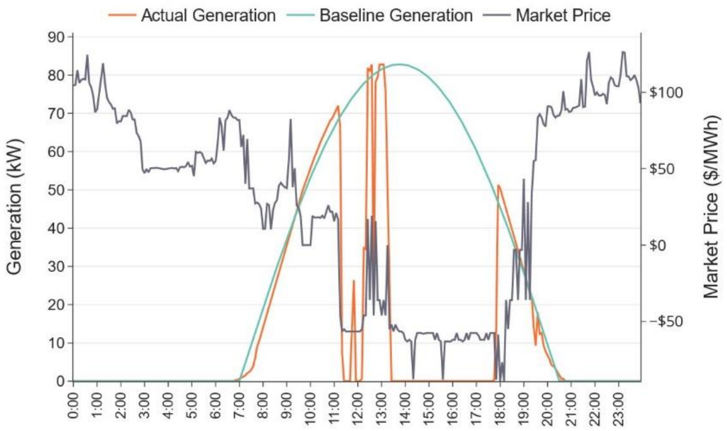
Overall, the average payback period for the portfolio is approximately 1.4 years, with 50% of projects paid back or expected to pay back between 0.3 and 2.1 years.

Load ramp-up

Similarly to load-shed, assessments of load ramp-up performance require a baseline for comparison. However, the baselining method for load-shed – CAISO 10-of-10 – is not generally applicable to load ramp-up scenarios, in particular for the specific application of generator ramp-down.

Assessing generator ramp-down performance requires an estimate of how much a generator would have produced had it not been curtailed. Although this can be reasonably simple for thermal generators with well-defined generation output, it becomes much more challenging for cases where generation is highly variable, as is the case for solar ramp-down.

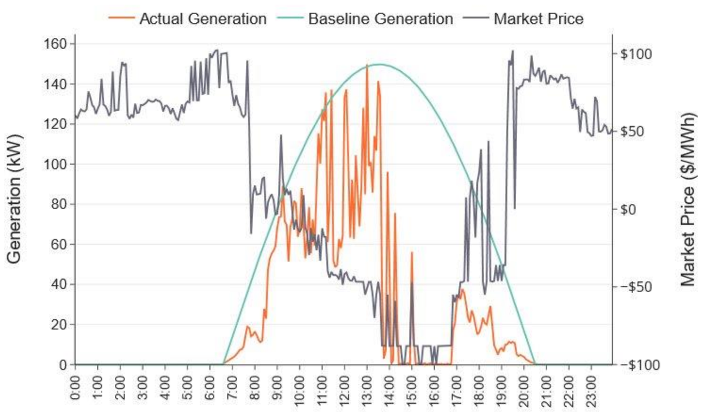
During The Project, Flow Power developed a baselining algorithm for approximating solar generation and assessing the performance of the ramp-down systems. An example of this algorithm is given in the chart below:



In this example, the baseline algorithm can produce a generation estimate that approximates the expected generation quite strongly. We can then identify the periods where ramp-down has been implemented by the kWatch controller, for which the wholesale market price is below a designated, site-specific price threshold.

Lastly, we measure the difference between expected generation and the ramp-down generation (typically 0kW) to understand the avoided energy generation and resulting increased load or reduced export. Comparing this change in energy balance to the wholesale market price, and the site's specific network, market and other charges, in each interval then yields the net financial benefit.

The above scenario is for a day with minimal external influences on the output of the solar PV system. However, the baselining task becomes more challenging when there is high variability in the output, particularly in the presence of shading and cloud cover. The below example uses the same baselining algorithm for a different system:



In this example, there is significant variability in the generation output, which causes the baseline to be a much weaker approximation of expected generation. Unfortunately, without extensive additional metering of local weather data and irradiance levels, it is nearly impossible to produce a strong approximation of generation curves subject to shading.

Due to inconsistent generation approximations, development of financial performance estimates has been treated with caution. Without reasonable accuracy in the baselining method, the financial outcomes produced cannot be considered reliable enough to report. This is an area of continued development and will be discussed further in the following section.

Learnings

Several key learnings and areas for continued development have been highlighted over the course of The Project. These will be discussed here for load-shed and load ramp-up systems, which have differing associated challenges. Broadly, the key learnings can be categorised into:

- Scoping and project implementation
- Operation and maintenance
- Assessment and reporting.

SCOPING AND PROJECT IMPLEMENTATION

As previously described, a key learning from The Project is identifying the potential for a customer or site to deliver flexible demand capacity. Accurate contracting is critical to the operation of a flexible demand portfolio, particularly when participating in programs such as RERT or WDRM. In these instances, there are potential penalties for under delivering on capacity during an event. While there is less risk associated with customer-driven wholesale market price response, it still represents issues with identifying potential financial benefits for customers.

Many issues surrounding incorrect contracting are due to the information available for a flexible demand system. In The Project, contracted capacities frequently relied on the information supplied by participating customers, whether it be nameplate ratings or basic site-level interval data. We found that flexible demand systems rarely conformed to their nameplate ratings, and in some cases deviated significantly. This was especially common among solar PV systems that either experience significant shading or are heavily soiled or degraded. As for site-level interval data assessments, while peak load can be a good analogue for load-shed capacity, it does not necessarily indicate the capacity that could be available during a flexible demand event.

These issues point to the need for greater testing and metering of systems prior to contracting, taking a data driven approach to identifying loads and generator outputs, and improving frameworks for assessing capacities available at typical event times.

For load-shed capacity, this often requires conducting test events at times of day where high market price events are more frequent. For load ramp-up capacity, this can involve acquiring data from generators, such as inverter output for PV systems. However, this presents a new issue of reducing the efficiency of the scoping and implementation process. The resources and time investment required to conduct more accurate assessments of flexible demand capacity may be prohibitive for the increased uptake and participation of automated flexible demand capacity.

Flow Power has sought to find a middle ground for improving scoping capabilities without introducing barriers to uptake and participation. This revolves around seasonal and time-of-day assessments of interval data for load-shed capacity. The same initiative is not easily applied to load ramp-up scenarios, where it is challenging to assess the true output of a generator without metering it directly.

OPERATION AND MAINTENANCE

One of the issues faced with ongoing operation and maintenance of the flexible demand systems was the continuity of staffing at participating businesses. As the operation of these systems is relatively complex, whenever there is a change of personnel and responsibility for these systems, often it requires additional training and testing with the new personnel to ensure that the purpose of the systems is understood and that those systems are used correctly. This is particularly important for more sophisticated integrations, such as semi-automated control via SCADA or other control systems, where there may be a staged process for enabling flexible demand capacity as is typical for large refrigeration or irrigation systems.

While this ongoing training can be readily provided by Flow Power, it is often not budgeted for in the initial project scope or the ongoing commercial agreement. Suggesting a fee for training sessions can present a barrier to ongoing participation. There were also occasions that a change in personnel was not reported to Flow Power, so pursuing new contacts within the business to manage the flexible demand systems became another task to provide at cost. It is possible to increase the proposed service fees to account for these contingency occurrences, but again, this may introduce a barrier to uptake if the service fees increase and diminish the overall business case.

One solution to address this issue is to ensure there is comprehensive documentation produced for the systems and processes for operation. This at least places the necessary information in the hands of participating businesses should they have a change in personnel. This can provide a first option for service providers to point to, potentially avoiding the need for additional training at the customer’s cost.

Another issue concerning the maintenance of flexible demand systems is the possibility of other works at a participating site impacting the setup of those systems. On several occasions, works completed by a participating customer influenced the flexible demand system, either by altering the physical systems integrated or the communications between the systems and Flow Power’s kWatch controller. Where these works impacted the systems sufficiently to prevent the normal delivery of flexible demand capacity, further works were necessary to rectify or modify the systems to reenable normal operation. These further works were at the customer’s cost, and coordination of those works also required resources from Flow Power. The associated costs can similarly present a barrier to ongoing operation and delivery of flexible demand capacity.

There is no single solution to address this potential barrier. Service contracts between Flow Power and participating customers stipulate that it is the customer’s responsibility to rectify any impacts to systems not introduced by Flow Power directly. While this is made clear prior to contracting, it does not necessarily ensure that a customer is willing to complete those rectification works, particularly if the cost is prohibitive. As such, the onus is on customers to inform any contractors completing works that these systems are installed and their function needs to be preserved, or reinstated should the works cause the systems to cease normal operation. While Flow Power has endeavoured to make this responsibility clear for each project undertaken, there is a limit to our capability to ensure these responsibilities are respected.

ASSESSMENT AND REPORTING

As discussed in the Performance section, assessing and reporting on flexible demand capacity delivery presents several issues. These primarily relate to the necessity of forming estimates of site load or generator output if a flexible demand event not occurred.

The reliance on baselining methodologies and algorithms to produce these estimates means the solution to addressing assessment and reporting issues is strongly linked to the effectiveness of those methodologies and algorithms. While significant developments have been made by Flow Power to improve these processes, there are limitations regarding the amount of information and/or data available to form those baselines.

As with the solutions proposed for improving scoping flexible demand, improving the assessment of flexible demand delivery relies on additional data being made available to inform baseline estimates. In the case of load-shed, this might mean implementing submetering on backup generation to understand the load avoided during an event. For load ramp-up, it could involve installing irradiance sensors on participating solar PV systems to understand the potential output of systems during ramp-down events. Unfortunately, these solutions all entail additional costs and complexity to project implementation, which can again present a potential barrier to uptake and participation.

Another approach is to develop baseline methodologies that do not rely on site or system specific data. A proposed approach involves using local temperature data, which is readily available without additional metering infrastructure, to adjust baselines by comparing usage on days with similar temperature profiles. This can be an effective way of improving baseline estimates for temperature dependent loads, such as refrigeration systems or sites that are heavily reliant on heating, ventilation and air conditioning systems.

However, there are still instances where site loads are not temperature dependent, but still irregular or variable. A key example is irrigation customers, who may have different irrigation schedules depending on other conditions such as rainfall or soil moisture levels. A solution for these scenarios has still not been scoped but may involve more sophisticated approaches such as machine learning and pattern recognition.

What's next?

As a result of The Project, Flow Power successfully achieved its goal of developing automation systems for customers to facilitate their participation in DR events, while improving their performance and benefit. This success is most notable for load-shed systems, which have seen an average payback period of 1.4 years across the portfolio.

Flow Power plans to leverage the learnings and successes from these systems to deliver a commercial product for existing and future customers, with ongoing service fees based on the amount of load contracted. This will then be benchmarked according to customer performance. We hope to recontract all existing customers under this framework and offer the product to new customers wishing to automate their DR participation.

Load ramp-up still requires further work to commercialise. Without reliable and accurate determinations of financial performance for these systems, it is challenging to develop a service model that reflects the benefit of these systems to customers. Furthermore, the regulatory market conditions have changed significantly since the beginning of the project. Additional constraints have been imposed on inverter flexibility by SAPN and the market operator, including a ramping limit of 16.67% per minute (or 6 minutes minimum to ramp from 100% to 0% output). This required investigation of alternative control systems and strategies to account for the constraints.

Finally, the price dynamics of the wholesale electricity market have also evolved. Strong negative pricing was prevalent in earlier stages of the project, but now increasingly more market participants (such as grid-scale renewable projects) have responded to these signals by changing their operating model and bid patterns. This has resulted in strong negative pricing being a rare occurrence in the SA wholesale market.

Due to these considerations, load ramp-up is not progressing as a commercial product at this stage. We plan to initiate lobbying with regulators to potentially ease the constraints imposed and develop new control strategies to account for them. We also plan to improve reporting capabilities in this area, to accurately assess system performance and returns.