Pooled Energy ARENA Report

May 2021

This Activity received funding from the Australian Renewable Energy Agency (ARENA) as part of their Advancing Renewables Program.

Executive Summary

Pooled Energy is a purpose-built electricity provider in Australia that helps home pool owners reduce the amount of energy required to run their pools. Pooled Energy has developed a technology platform for remote control of swimming pools and their equipment, which allows it to manage energy demand and provide grid stabilization services.

Pooled Energy differentiates itself from other retailers and demand response providers by offering a new business model that promotes the consumer benefits in its pool services and de-emphasizes the technical aspects of grid management.

This report provides an overview, progress update and key lessons learnt of the *Pooled Energy Demand Management and Modulation Project* supported by the Australian Renewable Energy Agency (ARENA). The Project aims to manage a discretionary virtual load of swimming pools providing flexibility in the electricity grid to support the increasing share of renewable energy. Using networked swimming pools and running them more efficiently, Pooled Energy is able to provide additional flexibility to help the electricity grid accommodate more renewables, as well as indirectly reduce greenhouse gas emissions.

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1. Introduction

1.1. Background Pooled Energy

Based in New South Wales, Pooled Energy was developed to ‘pool’ the energy demand of approximately 1 million backyard swimming pools into a single virtual load that can be turned up or down in response to grid conditions, leveraging the theoretical swimming pool load available in Australia of around 2 GW.

Pooled Energy is a retail electricity company serving customers that have domestic swimming pools. In addition to the electricity supply business, Pooled Energy installs sensors and controllers and provides swimming pool monitoring and automation services. Customers subscribe to electricity supply and pool services as a complete bundle.

Customers are motivated by the opportunity for superior swimming pool quality, the convenience of reduced swimming pool maintenance, reduced swimming pool energy consumption, and savings on the electricity bill.

In order to be able to manage pools remotely and to achieve business scale, Pooled Energy has designed a chemical regime that greatly reduces pool chemical use and testing and produces water that looks and feels great. A smartphone app provides information about, and remote control of, the pool.

Pooled Energy is also a demand management (DM) business where it orchestrates, via its remote control system, optimal times to operate pool pump and sanitation regimes. This is to reduce energy consumption during high grid demand periods, moving the more intensive activities to low demand periods. This report focuses on the demand management side of Pooled Energy’s business.

Pooled Energy’s view is that quite often demand management propositions is negative: “We will inconvenience you slightly (e.g. by reducing your air-conditioning or asking you to pay attention to your usage patterns) but compensate you for it”. Pooled Energy has focused on demand management that actually delivers consumer benefits, such as better pool water quality, that are intrinsically valuable to consumers, independent of financial benefits.

As a swimming pool is a fully discretionary load, unlike air conditioning, for example, it doesn’t much matter when it runs. So changing the times at which the swimming pool runs generally does not concern the pool owner. Pooled Energy is able to defer or advance the load as needed, by many days in some cases, at times of high electricity use on the grid.

The Pooled Energy customer proposition is: “choose us as your electricity retailer, and we will automate your pool, give you better water quality, and save you time and money”. We sell a consumer benefit, rather than compensating for an impost.

As of May 2021, Pooled Energy has had a total of 2062 connected systems, 1650 of which are currently active customers. This equates to a total household load of approximately 2.5 MW, of

which the discretionary pool load peaks at approximately 1.0 MW. With this discretionary pool load, Pooled Energy has the ability to turn swimming pools off in periods of high demand on the electricity grid and shift the load to periods of low demand where there is excess supply. This helps stabilize the electricity grid to avoid blackouts and power shortage events.

Pooled Energy also realises energy and emissions savings by operating swimming pools more efficiently. Energy savings from efficiency upgrades and smarter pool operation are estimated to be about 2.8 MWh per pool per year. Swimming pool CO2 savings are about 2.3 tCO2 / pool / year.

1.2. Overview – ARENA Project

In December 2017 Pooled Energy was awarded a $2.5 million grant from the Australian Renewable Energy Agency (ARENA).

The Pooled Energy Demonstration Project is focused on increasing the value of renewable energy to the grid by using swimming pools as a discretionary electrical load for Demand Management and Modulation (DM&M). This helps stabilise the grid by providing a new source of demand response that can be used to provide DM&M services. In addition, the Project intends to demonstrate reduced energy use in residential pools based in Sydney.

The ARENA funded Project is a trial at scale, aiming for 3,000 to 5,000 swimming pools (3MW-5MW) to be used to demonstrate demand management. Swimming pools with the Pooled Energy system can be centrally managed from Pooled Energy's Network Operating Centre (NOC) to reduce grid demand at peak times.

The goals of the Project are to

i) acquire 5 MW of load, approximately 5000 customers

(ii) quantify the potential for load management in domestic swimming pools

(iii) demonstrate the capacity to move this load in time without impacting customer satisfaction, swimming pool performance and biological safety.

The Project involves all aspects of setting up the test bed including marketing and selling the technology so as to obtain customers and their consent to participating in the trial. This includes manufacturing, installing and adjusting the necessary customer premises equipment, setting up the required telecommunications and providing any necessary customer services and support to retain the customer.

1.2.1. Energy Management System & Demand Management and Modulation

The Pooled Energy system is an energy management system designed to aggregate and manage the electricity consumption of residential swimming pools. Swimming pools present a large electrical load, which can be operated in a discretionary mode provided their water quality is not impaired. The key requirement of the DM&M system is the ability to shed electrical load in response to grid conditions.

Pooled Energy's DM&M technology comprises a cloud-based computing and communications infrastructure and customer-sited local controllers, which Pooled Energy installs, operates and maintains. The equipment installed consists of sensors and a Pool Controller which, as part of an overall system operated via the Internet, delivers pool automation and monitors water chemistry.

Pooled Energy manages the pool and pool equipment electrical load using the NOC. The NOC has the ability to perform DM&M for the grid using the aggregated pool load.

Through the ARENA Project, Pooled Energy is trialing:

1. Demand Management and Modulation
2. Shutting off discretionary load remotely
3. Varying the discretionary load available up and down from a minimum level determined by minimum pump speed up to full power with multiple pools running in a controlled manner
4. Varying the load fast and slow where fast and slow have the meanings required by the National Electricity Market (NEM), for NEM Ancillary Services such as Frequency Control Ancillary Services (FCAS).
5. Performing the above while maintaining biological safety and water quality in customer's pools
6. The speed and scale of an emergency shut-down of pools in times of grid crisis.
7. The ability of the system to suppress demand and in-rush currents during a restart from a system black-out in the grid. An in-rush current is a momentary input current surge, measured during the initial turn-on of the power supply.

The Demand Management & Modulation system must be able to shed electrical load and shift electrical load in time.

The control of electrical load can occur across the entire customer base to meet NEM-scale load requirements, or alternatively at the postcode level to meet the requirements of electricity distributors. These load requirements include the ability to add and shed swimming pool load.

The level of controllable load available will vary as a function of time. Pools are normally managed to maximise energy efficiency, so the equipment is operated at less than full power. When an increase in load is required the pool equipment can be operated at its maximum power.

The fleet pool load will be available for reduction within five minutes of a request for grid services. The ‘available for control consumption’ items are retained within the historical data base of the NOC for trending, analysis and forecasting. The available load is partitioned by postcode and feeder, as well as the predicted swimming pool load looking forward 48 hours.

The period of load reduction will be dependent on the notice period. A notice period of twenty-four hours will allow the load reduction to extend for a period of up to four hours with a review during the request to potentially extend. A notice period of five minutes will allow a reduction period of up to two hours with ongoing review to potentially extend it albeit with some reduction in the size of the load reduction.

Demand Management and Modulation operations occur automatically via the use of price signals (section 3.2.1) which are provided by AEMO. The most common operation is load shedding due to high pricing where there is low energy supply and high demand in the grid. In addition to automatic operations, manual requests can be made for services through email or telephone communications to Pooled Energy. Once a manual request has been received, the applicable operation will occur. To this date, Pooled Energy has had no manual requests from AEMO or DNSPs.

The available and predicted available load 48 hours in advance will be available via a weblink from the NOC to facilitate planning by the appropriate network operator as well as the current state of any request made for services.

1.2.2. Raise or Lower Demand

The availability of a pool to be used in a Demand Management Group is determined by the state of its sanitation as well as its circulation level, as well as the pool equipment state and telecommunications availability. Another consideration is the tariff under which the pool is operated. Under a Time of Use (ToU) tariff, a pool will be freely available during the off-peak and shoulder periods to be used to satisfy a demand response request. If it is necessary to operate it during a peak period to respond to a demand response request or to recover a pool from a demand response request, any additional cost of providing this service to the pool owner will be recorded and the pool owner compensated.

Maintaining sanitation and circulation is critical to ensure the pool does not suffer algae growth (a “green pool”) or expose users to water-borne infection or owners to the cost of remediation to restore a green pool. Sanitation state is determined on a continuous basis by a combination of chemical parameters which are monitored by chemical sensors. Data is reported on a two minute basis to the NOC. The pool water will be briefly automatically sampled with supplementary burst circulation at configurable intervals (typically 1- 2 hours) to ensure its sanitation level is maintained during a demand event. A predicted expiration time will be maintained for the pool availability from the commencement of its availability in a demand management operation.

Each “available pool” has a potential capacity for raising load (turning swimming pools on to consume available load in the grid) and lowering load (turning swimming pools off to increase available load in the grid). The total aggregated load of aggregated pools for raising or lowering is maintained as a state variable and is retained in the historical database as well as on a real time basis for analysis, control and optimization.

Load reduction or increase quantity, as well as period of request, can be determined by reference to the quantities available as documented by the NOC weblink. Total requests are expected to be in quanta of 1MW of power and intervals ranging from 5 minutes to 4 hours. Requests that exceed the level of availability can only be satisfied to the current level. Load changes will normally be affected within five minutes of requested time of commencement.

1.2.3. Ramp Rate

Loads may be progressively increased or decreased at a ramp rate in blocks of 100 KW up to the requested level dependent on the request received from the operator. Similarly at the end of a demand response request, the restoration of operation can be ramped at a rate requested by the network operator.

If there is a loss of power to a feeder or postcode on restoration of power will occur progressively at a ramp rate selectable by the network operator. Pool operation will be restored to minimise load stress on the local feeder by controlling the rate of restoration of pools as well as restricting the use of high power consuming equipment such as pool sweeps and heaters.

Whilst there is an active internet connection between the NOC and the pool system, the pool system is able to respond to demand response requests. In the event that internet connectivity is lost, the pool system will revert back to its normal pool operating mode until internet connectivity to the NOC is restored.

Dependent on the period and time of the demand response request, pools may require a recovery period to restore the pool and ensure it can be made available for future demand response requests.

1.2.4. Operation

Implementation of the core software for the DM&M services was completed in August 2019. As of May 2021, there has been 856 unique events in which Pooled Energy was able to reduce the swimming pools energy load from the grid in response to price signals (section 3.2.1). This includes the total turning off of swimming pools, reducing load by specific amounts (e.g.: 1 MW), all of which have been successful and have not compromised the water quality of the swimming pool.

Pooled Energy has been able to successfully perform demand management events, however; testing on larger scales requires around 3,000 swimming pools under management.

As we achieve our customer critical mass target, we will perform further testing around customer load profiles and the instantaneous capacity available for DM&M and FCAS activities at different times of day and seasonally. Until then, Pooled Energy's focus of testing activities demonstrates that we can overcome one of the dominant shortcomings of present residential load demand management systems which is to provide a scalable demand management response facility that does not impact customer satisfaction.

2. Methodology

2.1. Predicates

Pooled Energy's technology development follows a series of predicates described below, that starts with the swimming pool and ends with the electricity grid.

In order to build a demand management service, it is necessary to acquire a sufficiently large controllable load. Pooled Energy set out to acquire the load of a large number of networked and controllable swimming pool pumps and pool equipment.

In order to bring a swimming pool onto the network where it can be controlled, we need the assent of the pool owner. So there needs to be some clear consumer benefit. Bringing a pool onto a control system offers opportunities for remote monitoring and automation. Pooled Energy decided to focus on developing a remote monitoring, automation, and energy savings offer. This offer has value to the consumer independent of their interest in or support of energy conservation measures or emissions reduction.

In order to remotely manage a pool, the chemically intensive approach to pool management has to be replaced. Swimming pools require frequent water testing and addition of quantities of chemicals, especially dangerous chemicals such as concentrated hydrochloric acid and chlorine, as well as benign chemicals such as calcium chloride and sodium bicarbonate. The conventional approach to pool chemical management is materially intensive and requires physical presence of a pool service technician. This approach is not scalable, and it would not be possible to acquire sufficient electrical load on this basis. So, it was necessary to develop a new approach to pool chemistry that eliminated the on-site chemical and labor inputs.

In order to remotely monitor a pool a remote sensing system needs to be built. The data from the pool needs to be interpreted and offered to the customer. This requires translation of sensor output to customer insights, offered to the customer through a mobile phone app. Pool chemical sensors only provide indirect information about chemical status, and also suffer from calibration drift. So it was necessary to find alternative modes of extracting information from sensor data, and ways of interpreting that information that are robust to calibration drift. Pool equipment such

as pumps or chlorinators can wear out or fail, so we need to monitor the equipment health as well, and alert customers to issues.

We cannot participate in demand management if we cannot acquire load. We cannot acquire load if we cannot acquire and keep customers. We cannot acquire and keep customers if we cannot guarantee a spectacular pool and an outstanding customer experience. So, our methodology has been as follows:

- Develop a new pool chemistry that requires no (or little) chemical input
- Develop a chemical monitoring system that provides useful feedback to customers
- Develop an equipment monitoring system that detects early signs of failure
- Develop a control system that reliably maintains pools and is robust towards sensor drift
- Develop a customer app that provides water quality and equipment monitoring, automation functions, control overrides, notifications about required maintenance actions, etc.
- Develop a technical service centre that can offer provide phone based technical support based on our sensor telemetry, and provide on-site service where necessary
- Ensure we can reliably deliver a high-quality pool experience that attracts new customers and delights existing customers
- Ensure we can deliver energy savings and cost savings within the constraint of good pool performance
- Bundle all the above as a compelling service for our electricity customers
- Demonstrate the ability to alter and move runtimes in response to Grid events.

2.2. Technologies

2.2.1. New chemistry for remote management

Swimming pools use chlorine as a disinfectant. However, chlorine loses efficacy at high *p*H, and swimming pools tend to drift to a high *p*H equilibrium. Chlorine pools therefore require constant addition of acid. Pools also require addition of calcium chloride and sodium bicarbonate in order to protect concrete surfaces. Unfortunately, acid additions destroy sodium bicarbonate, and low *p*H pools require high levels of calcium. So, this approach requires high chemical inputs, and is not suitable for remote management.

Pooled Energy has developed bromine as an alternative disinfectant for backyard pools. Bromine works very much like chlorine as a disinfectant, but it is active at high *p*H, where pools naturally want to equilibrate. This means pools do not require acid additions. Without acid additions, carbonate levels remain stable. At high *p*H only low levels of calcium and carbonate are required – in fact dissolved CO_2 from atmospheric carbon dioxide, and calcium in the water supply provide sufficient levels of these chemicals.

The only chemicals required for a Pooled Energy pool are a source of bromine, some phosphate remover, and water clarifier. These chemicals fit in a shoebox sized package and are delivered by courier twice a year.

Developing the bromine product, acquiring chemical registration, learning how to sense it and how to control pools using bromine, has been a substantial undertaking that is largely complete as of summer 2020.

2.2.2. Local controller and instrumentation

Pooled Energy installs a local controller at a customer site that controls equipment, monitors sensor input, and communicates over the internet with the NOC (Figure 2). The local controller can operate independently of a network connection with Pooled Energy servers. It will be unable to respond to weather information and other updates, but the pool operation is unlikely to suffer. Local wireless communication with a mobile phone app is provided as a fallback in the event of a telecommunications network outage.

The local controller is based on a SBC (single board computer), which controls the pool pump via a VFD (variable frequency drive), allowing reduced power operation for energy efficiency. Other pool equipment is operated by switching power to using wirelessly controlled smart switches, which also provide power metering. The local controller also takes input from a chemical sensor module, an electronic interface to a chemical sensor and a flow sensor.

The chemical sensor is a custom four-point sensor measuring *p*H, salinity, temperature, and Oxidation Reduction Potential (a measure of sanitiser performance). The flow sensor is a differential pressure sensor registering pressure drop across pipework when there is flow.

Pooled Energy developed the chemical sensor with an Australian supplier, and developed the flow sensor itself. Power, control, sensor interface electronics and all embedded software was developed internally.

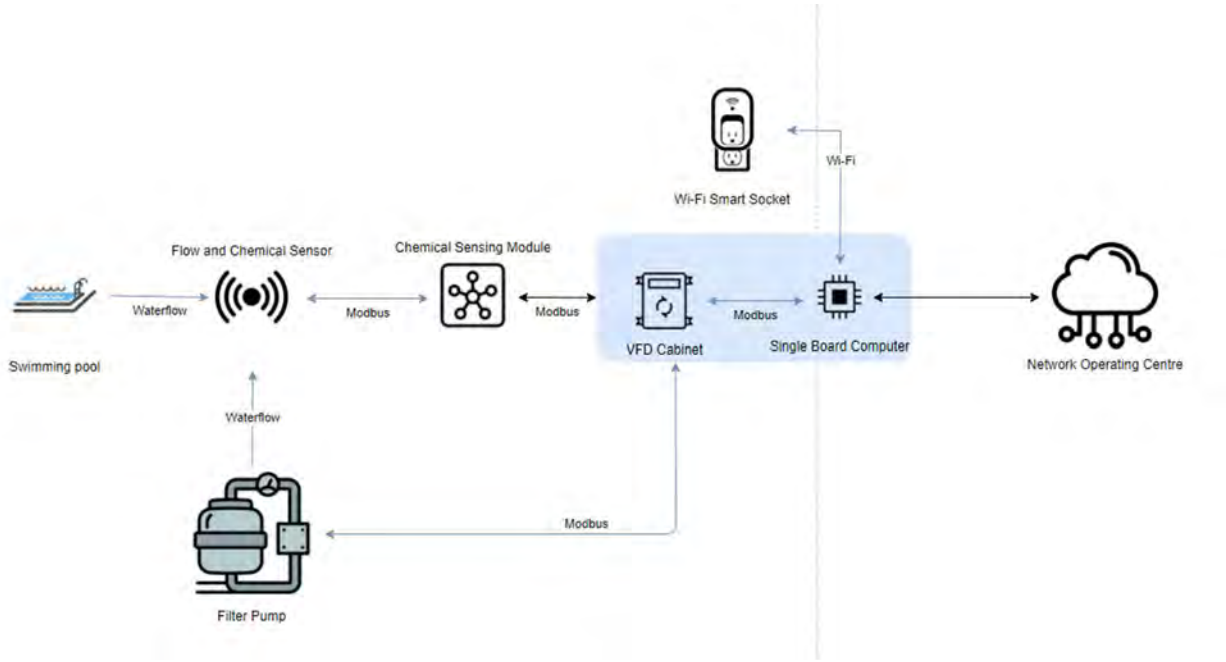


Figure 2. Block diagram of Pooled Energy local controller. Illustrates internet connected sensors and control systems interacting bi-directional with a cloud-server.

2.2.3. Chemical control algorithms

Swimming pools require bromine levels to be kept within a certain range. Too low and the pool with suffer from algae growth, too high and the pool will be unpleasant to swim in and cause skin and eye irritation. Disinfection performance and bather comfort are also a factor of *p*H and salt levels. UV irradiation destroys bromine so sunlight exposure is a factor in control, as is pool volume, water temperature, the presence of a pool cover, and many other things.

Pooled Energy has a large number of pools reporting data. We have sufficient data that we can develop robust statistical control models that determine equipment runtimes in each pool. We have applied different mathematical techniques to use uncompensated sensor values to determine the balance between bromine demand and bromine production in each pool, and adjust production accordingly. A pool cover has a large effect on the rate of loss of bromine from a pool, and we have applied machine learning to sensor signals to detect the presence of a cover and adjust bromine production.

Development of these stochastic and machine learning control models has been a substantial development activity through 2020.

2.2.4. Load control

Demand management requires the ability to control load in the swimming pool without compromising the quality of the pool water. There is no problem adding more load if required – additional filtration will always be ok. Dropping load however runs the risk of under-filtration leaving a dirty pool, or under-bromination allowing algae growth.

We need to demonstrate we can drop load without compromising pool water quality. From shutdown tests, and observing the response of pools with equipment failures, we know that we can tolerate transient shutdowns of at least a day, and generally much longer outside of peak summer.

Power meters report the power consumption of all connected equipment at site. So, we can measure the power draw across the customer pool base at any instant, and also calculate the maximum possible power draw at any instant, if all equipment were turned on. This lets us calculate the amount of power we can add, or drop, at any time. We can adjust power consumption across the field at any time and set out to automate this process based on energy pricing.

3. Progress update

3.1. Achievements to date

3.1.1. Customer growth

Since going commercial in 2014, Pooled Energy has had a total of 2062 connected systems, 1650 of which are currently active customers (as at May 2021). Our growth history is summarized below (Figure 3). We launched based on personal contacts and word of mouth and began our initial sales activities.

In 2016-2017, we completely changed the hardware base from a high-cost bespoke PLC (programmable logic controller) to a low cost SBC. We paused sales activity while this technical pivot was implemented.

A sales force was hired in 2017 and rapid expansion followed, until COVID-19 impacted, including a lockdown in the greater Sydney area reducing opportunities to acquire new customers. During 2020, a lot of the customer information and technical infrastructure was redesigned, preparing for relaunch in summer 2020-2021.

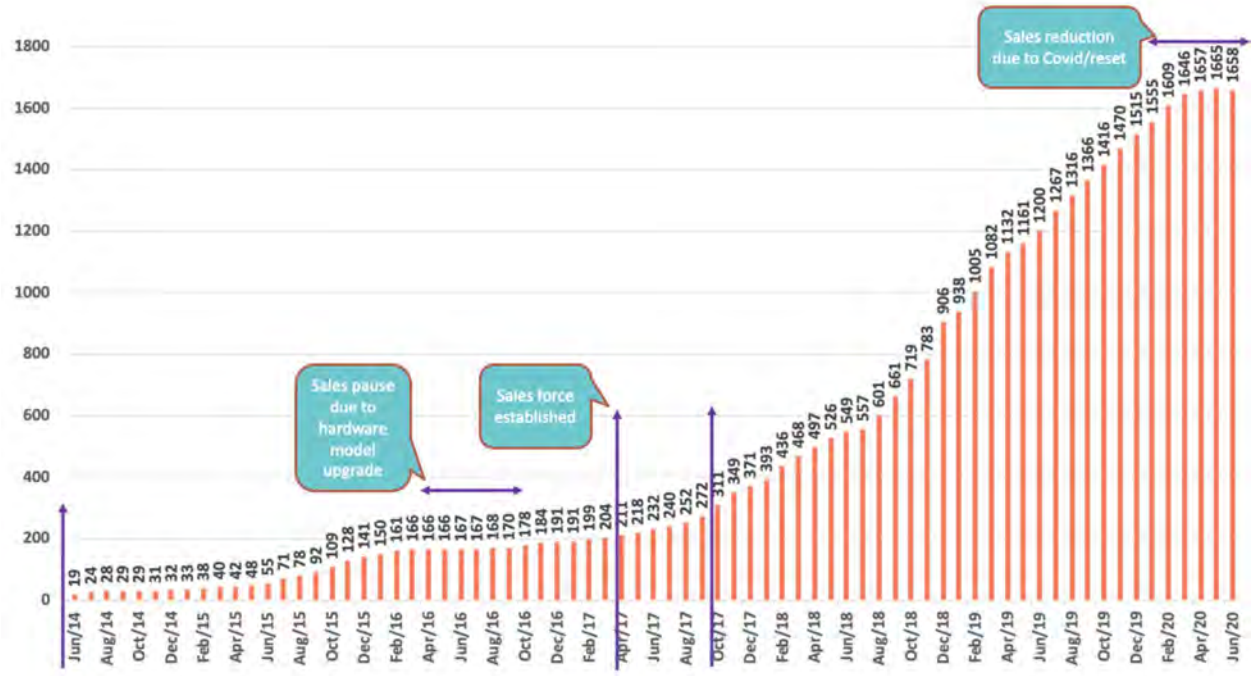


Figure 3. Customer base over time showing fast growth prior to COVID-19 lockdowns in mid 2020.

3.1.2. Discretionary load under management

As of May 2021, total household load across the Pooled Energy customer base is approximately 2.5 MW. The discretionary pool load is about 20% of this household load.

The peak load from all the swimming pools in the customer base, when they are running, was measured during the course of the Project at approximately 1 MW. Not all pool equipment is running at full power at this peak, and there is ability to take more load. Figure 3 shows the capacity to drop or absorb load throughout a typical day.

3.1.3. Load shedding / capacity to absorb load

The electrical load of the swimming pools is discretionary. Pool equipment can be turned off or on in response to grid conditions.

The pools are very robust towards occasional deviations from normal operation. Outside of high summer it does not create a problem if pool pumps, chlorinators and other attached pool equipment are turned off for a day or more (and much longer in winter). Conversely, if the grid requires more load the pool equipment can be turned on.

The following chart shows the aggregate load profile of the pool equipment on a representative weekday (Wednesday 26/8/2020) for approximately 1600 pools. Pooled Energy can drop pool

load at any instant, up to about 0.9 MW. The pools can also be turned up by about 1.5 - 2.5 MW at any instant.

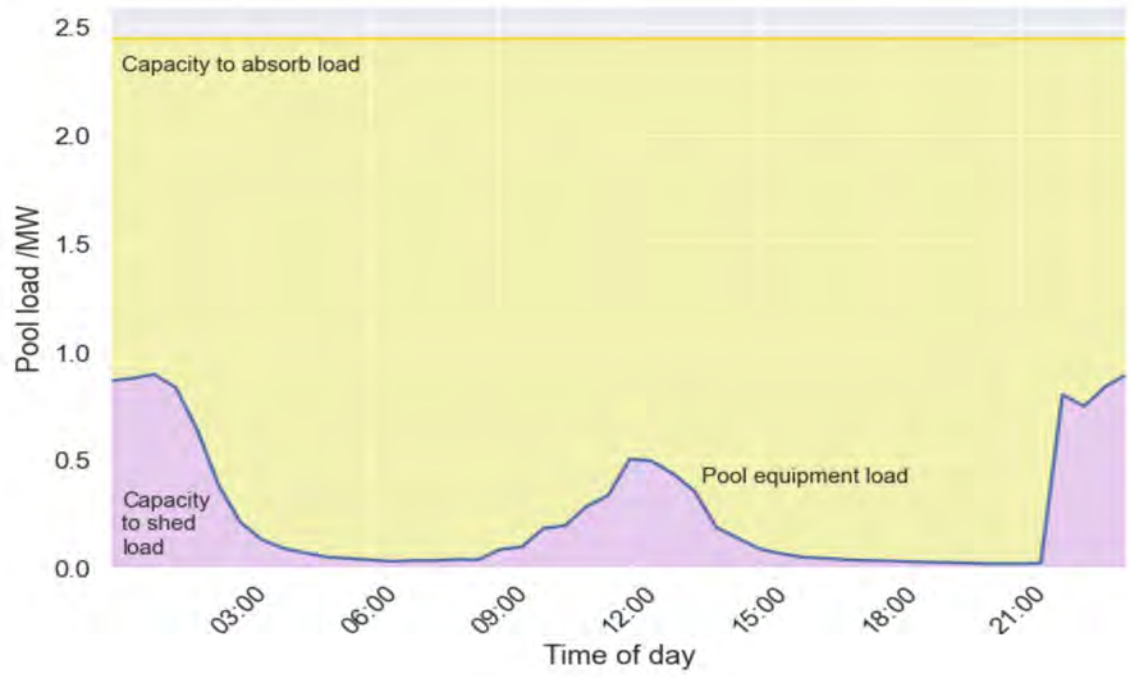


Figure 3. Representative daily load (winter, off-season). Load can be shed to 0 MW or raised to about 2.4 MW.

The capacity to absorb load is valuable. AEMO's 2020 Electricity Statement of Opportunity indicates Minimum Operational Load is forecast to drop, and is approaching the minimum load required to keep system strength units operational (Figure 4). The ability to take load by turning on pool equipment will become valuable in this situation. Pooled Energy monitors and forecasts the amount of load available to shed or absorb at any time (Figure 5).

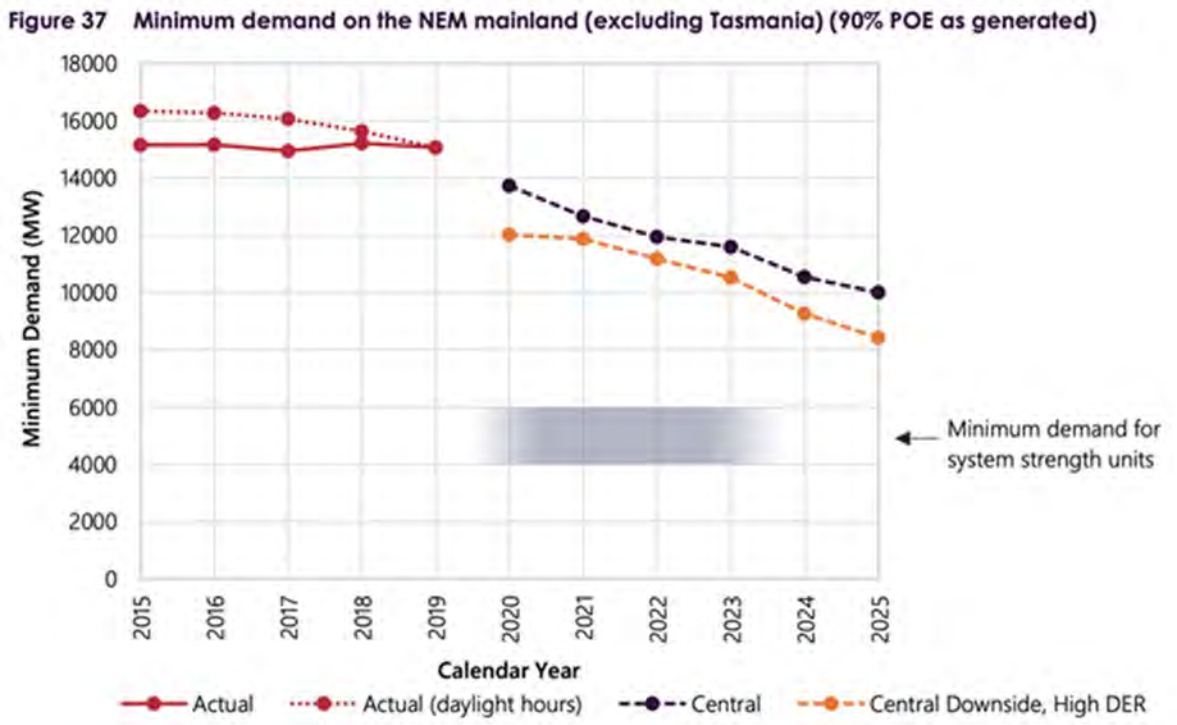
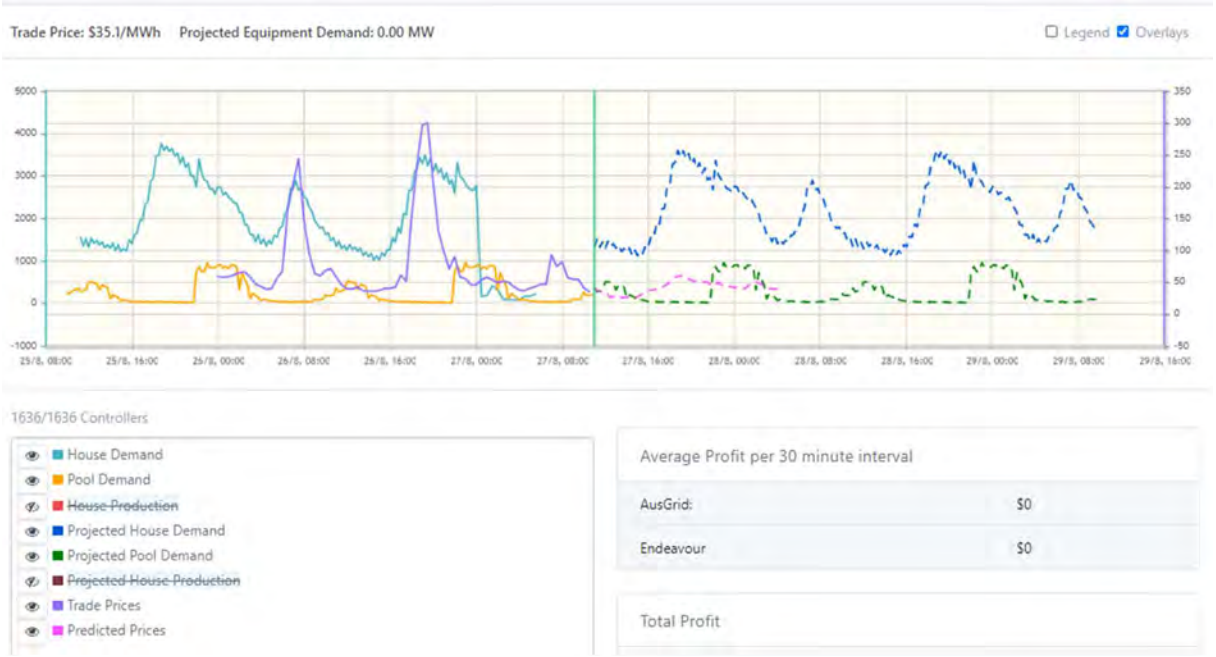
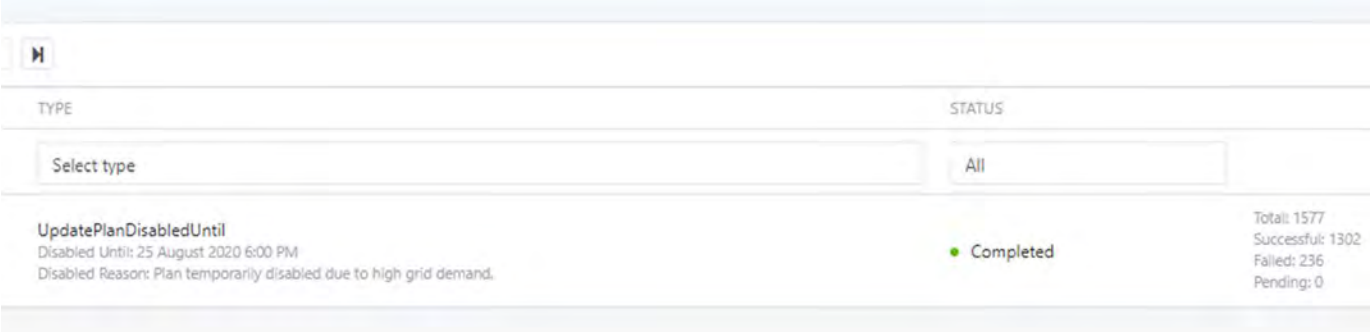


Figure 4. Under AEMO Central Scenario, Minimum Operational Load drops substantially, approaching the minimum load required for system strength units to remain operational. Figure from [AEMO's 2020 Electricity Statement of Opportunity](#).





3.2. Outcomes

3.2.1. Load shedding

Pooled Energy uses price as a signal to drop load. When the wholesale electricity price exceeds $150 /MWh we turn off the pools or inhibit them from running.

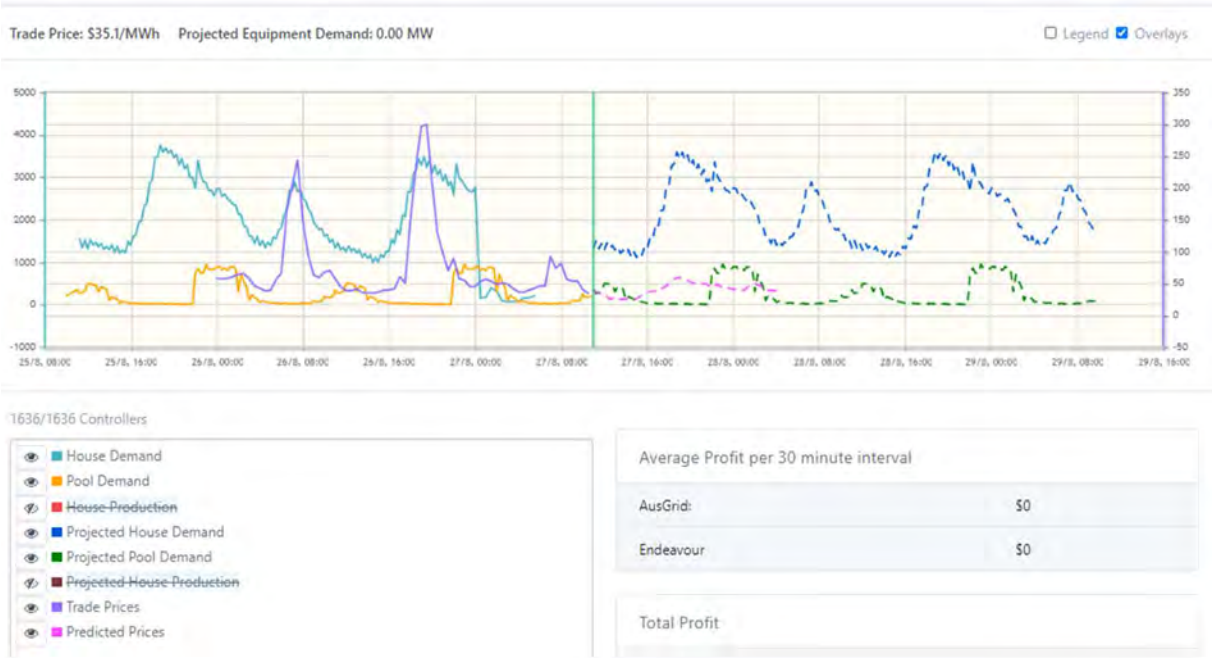


Figure 5. Energy price and load available to shed dashboard, showing historical and forecast data.

Full automation of this process was turned on the 5th of August, 2019 and the threshold was set at $300/MWh. This threshold was lowered to $150/MWh in March 2021. As of May 2021, there has been 856 unique events in which Pooled Energy has shed load.

Figure 6 shows an automatic load shedding event. The wholesale market price exceeded the $300/MWh threshold and 1302 local pool controllers shed load by disabling pool equipment. 236 controllers experienced network connectivity problems during this event and were unable to be reached, so did not participate in the load shedding activity.

Figure 6. Automated pool disabling during a high load event. Note reporting of the number of sites that failed to respond to the request to drop load due to instantaneous connectivity issues. Total of 1577 requests were issued, 1302 successful and 236 failed due to telecommunication issues.

The $300/MWh threshold was set conservatively, a level that would generate infrequent load shedding events, as we gauged performance and customer response. No technical issues were encountered due to service interruptions and no customer complaints generated due to the activity (although communications *about* the activity created some complaints as noted below). As this threshold has been lowered to $150/MWh, there has been no impact on pool sanitation.

Swimming pools are operated by the local controller even when not in communication with the central control system. Although local controllers operate autonomously in running the pool, a network connection is required to override that operation for load management, so load management is limited by the number of sites with open communication. 82% of sites were able to respond to the request in this instance to shed load. Communications uptime improvement is a present research and development focus.

We did experience a problem in communicating the load shedding activity with customers. The following notification was delivered to customers to alert them to the load shed activity:

“Plan temporarily disabled due to high grid demand.”

This notification was delivered via SMS, and also via a push notification in the Pooled Energy mobile phone app. A number of customers interpreted this as meaning a fault in the pool. The mode of communication – an alert appearing on their phone – generated concern. The mode has been changed to a passive indicator in the app, rather than an active notification.

At the time of the bushfires and severe grid demand in summer 2020, the NSW Government made public requests to consumers and business to drop load, specifically mentioning swimming pools. Pooled Energy’s load shedding activity in that period was viewed very positively by our customers and potential customers based on social media activity and direct feedback through the call centre.

3.2.2. Energy savings and emissions reductions

In 2019 we asked consultancy *Energy Conservation* to conduct an independent audit of our energy savings, to support an application to the NSW Independent Pricing and Regulatory Tribunal (IPART) to generate Energy Savings Certificates. We also have baseline data on household energy use from the Australian Government *Energy Made Easy* website (https://www.energymadeeasy.gov.au). AEMO reports data on the carbon intensity of the NEM.

Based on the above data sources, we have derived the following metrics in association with our technology and chemical advances, and DM&M:

Average energy savings: **2.83 MWh / pool / year**
Swimming pool CO_2 savings: **2.264 tCO_2 / pool / year**

3.2.3. Reduce chemical use

For the Pooled Energy business model to work we need to operate pools remotely. That means we need to move away from the traditional chemically intensive approach of on-site chemical testing and on-site chemical additions. We developed a new approach to pool management that requires very little chemical use.

We can consider hydrochloric acid, sodium bicarbonate, calcium chloride, algaecides and cyanuric acid, as part of the chemical reductions. Salt is not reduced.

Chemical usage is quite variable depending on the construction, situation and use of the pool, but a typical 50 kL pool might use roughly 1 L of acid per month, and 4 kg of sodium bicarbonate buffer, 4 kg of calcium chloride, 4 kg of cyanuric acid light stabilizer per year. Various other specialty chemicals such as phosphate removers, flocculants, water clarifiers and algaecides may also be used. This amounts to approximately 30 kg of chemicals per year.

Pooled Energy pools do not in most cases use acid, buffer, calcium chloride or light stabilizer. On the other hand, Pooled Energy pools use sodium bromide (bromine precursor) and a phosphate remover. A 50 kL pool will consume approximately 4 kg of these chemicals a year.

Pooled Energy couriers a small pack of the required pool chemicals twice a year to customers as part of their subscription. Saving pool shop visits and water testing offers a considerable convenience and cost saving to the customer.

Conventional swimming pools use large quantities of concentrated hydrochloric acid, to maintain *p*H balance. This is a dangerous chemical and maintaining household stock around the pool of tens of litres represents a significant hazard, particularly as it is generally accessible to young children.

Pooled Energy has developed a new pool chemistry that does not require acid addition, or only rarely. This is a significant household hazard reduction.

4. Lessons learnt

4.1. Technical

4.1.1. Technology

The Pooled Energy team is led by individuals who have deep experience in a variety of different scientific and engineering disciplines.

The breadth of technical background and lack of preconceived notions around existing practice have led us to quite a different approach to running pools than the rest of the industry. We have encountered and overcome significant technical challenges along the way that would not be resolvable within the typical skillsets found in the pool industry.

In August 2020 Pooled Energy requested global engineering firm Worley Parsons to conduct a technical audit of our chemistry and technology stack. The audit validated our assumptions and approach regarding the technology.

4.1.1.1. Chemical technology

Pooled Energy needed to find a way to eliminate most chemicals from pool chemistry, to enable remote operations.

Switching from chlorine to bromine as the pool sanitizer was a first step. Bromine operates over a wide *p*H range and so does not require *p*H control. That means acid and *p*H buffers are not required. (We did spend some time developing an electrochemical cell to generate acid, but abandoned that approach when it became clear it would require high field maintenance).

Bromine also does not require the UV stabilizers used in chlorine pools, so those chemicals are eliminated.

Pools require dissolved calcium and carbonates to be in equilibrium with concrete pool shells. We chose to operate our pools at high *p*H, where this equilibrium is satisfied by very low concentrations of calcium and carbonate. In fact, there is sufficient calcium in the water supply and carbonate from dissolved carbon dioxide that we do not need to add calcium or bicarbonate, eliminating these chemicals.

Pooled Energy pools suffered for a time from “black spot”, a particularly intransigent form of algae that grows in pools, and caused significant customer and business problems. Black spot looks unsightly, generates customer complaints, and is labor intensive and expensive to remediate. We found we could control black spot by suppressing phosphate levels (a required micronutrient for algae). We have incorporated phosphate removers in our chemical management and the problem has largely disappeared.

At this point, the only specialty chemicals needed to be added to Pooled Energy pools are sodium bromide and phosphate remover, in quantities of about a cup each, even for large pools.

This has allowed Pooled Energy to become completely hands-off with pool chemicals. A small package of these chemicals is shipped to customers twice a year, timed to the onset and midway through the swimming season.

These developments have allowed us to disengage from the material components of the pool, allowing us to scale as an internet business.

4.1.1.2. Sensors and control infrastructure

The original concept was to do limit control of bromine levels based on the instantaneous value of an Oxidation-Reduction Potential (ORP) sensor from which bromine levels were inferred. We have improved on this using a differential read of the ORP sensor and machine learning, which eliminates calibration drift. This scheme monitors chlorine demand in pools. Combined with seasonal and weather inputs we now have an effective control mechanism that is robust towards sensor failures, avoiding under-chlorination which allows growth of algae, and over-chlorination which causes skin and eye irritation.

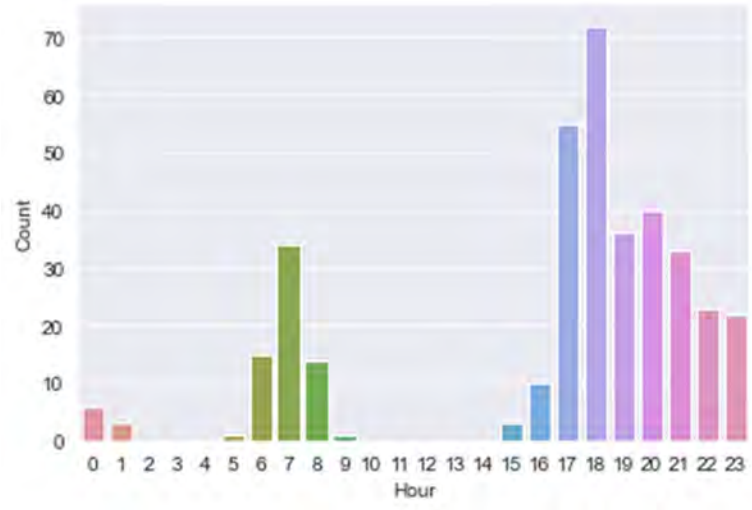
4.1.1.3. Demand Management and Modulation in May 2021

May 2021 saw unusually high amounts of high-pricing. Pooled Energy have an obligation to ensure swimming pools don’t short-run and meet their minimum sanitation and filtration run-times. The high-pricing events highlighted the need to create rules for short-running of swimming pools to allow for an automated response during these periods.

In May 2021, the NEM experienced very low coal generating capacity which resulted in higher than normal high-pricing events. In May 2021, there were 368 unique events in which Pooled Energy disabled swimming pools from running. This was due to the price of electricity exceeding the $150 MWh threshold Pooled Energy has set. As a reference point to highlight the unusually high events, in January 2021, there were only 11 unique events in which the $150/MWh threshold was breached.

During May 2021, swimming pools were disabled for a total of 125 hours, which equated to 25 MWh of scheduled swimming pool demand.

The below chart counts the hourly periods in which swimming pools were disabled in



Pooled Energy's chemistry allows swimming pools to skip scheduled running in a single day, as a transient event. However, this can't be sustained indefinitely as swimming pools require a minimum run-time to ensure biological safety. As a result of the high number of high-pricing events in May 2021, there were 6 events in which Pooled Energy manually intervened to ensure swimming pools ran despite the high price of electricity. This was to ensure that the swimming pools met a minimum amount of run-time. Currently there are no automated rules/responses that perform this task. Future development work is required to create rules for the short-running of swimming pools. The creation of these rules will allow for an automated response and prevent manual intervention in the event swimming pools can no longer obey the high-pricing event and must run to ensure the biological safety of the swimming pool.

4.1.2. Regulatory

4.1.2.1. Retail electricity

Pooled Energy operates within the same regulatory framework as other electricity retailers. While this is a complex regulatory environment, it largely does not impinge on load management using pool equipment. Pool equipment is not subject to specific regulatory treatments, such as those that apply to life support equipment. Freedom to alter pool load is constrained more by consumer acceptability of outcomes than by regulatory considerations.

4.1.2.2. FCAS

The Draft Market Ancillary Services Specification (MASS) specifies that FCAS delivery must be supported by power and frequency measurements at or near the connection point (Section 5.3.1). Practically this requires metering equipment to be installed in the household electricity meter by a licensed electrician.

While this is technically feasible, it is not commercially viable. The cost of the metering equipment and the cost of a site visit by an electrician would need to be passed on to the customer, and the customer would need to arrange access to their meter for the installation. On

top of the installation fee and service visit for the pool controller and sensors, additional fees and service visits will be a bridge too far for many potential customers. Pooled Energy will be unable to deliver FCAS with the current metering requirement.

The Draft MASS is open for submissions and Pooled Energy will submit that metering at the device level (in the pool controller) provides the necessary data to establish the delivery of FCAS. We will also note that with metering at the pool controller, FCAS does not require a smart meter, which approximately doubles the amount of FCAS that could be delivered (approximately half our customers use interval meters).

4.1.2.3. Chemical registrations for swimming pool chemicals

As an electricity retailer, Pooled Energy is unusual in that it is also regulated by the Australian Pesticides and Veterinary Medicines Association (APVMA), the body responsible for regulation of swimming pool chemicals.

There is a registration process for swimming pool chemicals similar to the process of registration of a new drug. Safety, efficacy, Good Manufacturing Practice (GMP) standards of manufacturing, and other requirements all need to be demonstrated and subject to review.

Our key chemical component, sodium bromide, required registration and had not been previously registered for swimming pools in Australia. We embarked on registration of sodium bromide; an activity akin to a new drug registration. The process took almost three years, and approximately $100,000.

We invested considerable effort and expense into field trials developing a registration package. Our initial application was not accepted. We found that the regulator required more information on how modern swimming pools are sanitized with electronic chlorinators. We also found that our chemical approach was quite novel and did not easily fit within the APVMA's model for pool sanitizers. We engaged the regulator and began a process of education, which resulted in the regulator proceeding with and ultimately accepting our initial package. APVMA determined that sodium bromide would also require poisons scheduling, so referred the application to the Poisons Scheduling Board under the NSW Department of Health. Consideration time with the second regulator was 6 months, before gazetting sodium bromide as a Schedule 4 poison (requiring a "Caution" statement on the label, not unusual for pool chemicals).

Chemical registration has been an arduous and expensive process. It does however confer a competitive advantage, as competitors do not have access to our registration package and would need to produce their own.

4.1.3. Business Model

Pooled Energy is an electricity retailer for swimming pool owners, and generates revenue streams associated both with electricity and swimming pool services:

- The main source of our revenue is the household electricity bill.

- Electricity services are also bundled with swimming pool monitoring and control. A monthly subscription fee is charged for remote monitoring and management services.
- Sales of pool equipment, pool maintenance and cleaning also generate revenues.
- Once we achieve sufficient scale (approximately 5 MW load under control), we expect to add revenue from grid support services.

Pooled Energy customers are more likely to stay with us because of the multiple services we deliver. With a conventional electricity retailer, a customer may churn if they are unhappy with their electricity bill. A Pooled Energy customer may remain with the company because they value the other benefits than just electricity savings:

- Superior water quality when swimming
- Superior visual appearance of the pool
- Pool automation and lower maintenance
- Reduced chemical use
- Technical support hotline for their pool
- Smartphone app with remote control of the pool, pool status indicators and notifications around maintenance tasks
- Reducing emissions and improving the Grid's ability to accommodate more renewable energy

4.2. Customers

4.2.1. Customer engagement

Pooled Energy offers convenience benefits most pool owners haven't considered so aren't actively seeking. To overcome this barrier to purchase, we have targeted our brand positioning and marketing activity at customers who are less price sensitive and will gain the most benefit from a product that saves them time.

Pooled Energy is a complex sales proposition and requires consultation within the household. We have therefore become more deeply engaged in lead nurturing, an activity aimed at raising brand awareness, educating the customer and providing positive experience at all contact points prior to making a sale.

4.2.2. Customer Journey

An analysis of the customer journey identified a gap in how we nurture new customers once they install Pooled Energy. To maximise the chance of success with a customer, a program of educational and support touchpoints has been implemented in the first 90 days including 'health check' phone calls, bill explainers and general product education.

Over time, the sales process has been redesigned to simplify the presentation, reducing the pool inspection from 90 minutes in-home to 45 minutes. In 2020 Pooled Energy also launched virtual pool inspections which allowed the presentation and inspection to be conducted virtually.

The installation process has been redesigned to engage the customer in the management of their pool. Previously a technician installed equipment, without requiring the customer to be present. A handover was scheduled at a later date to explain the operation of the equipment to the customer. We would often have customers not understanding some aspect of the equipment, app and service. The new installation process requires the customer to be present for the first hour, and we have upskilled our technicians to complete handover of the system to the customer, providing the opportunity to reinforce product education.

Ongoing customer notifications are an important touchpoint. We issue periodic maintenance instructions via SMS as indicated by pool sensor readings. We monitor compliance through sensor readings and have found poor compliance with these requests. Consumers are time poor and pool maintenance infringes on their time, either directly at poolside or to visit pool shops or hardware stores for supplies. There may be a purchase involved which customers may be resistant to. Too many notifications will lead to notification fatigue.

We have therefore revised a lot of notifications. We have removed non-critical notifications to reduce notification fatigue. Notifications for some maintenance activities have been bundled into a regular monthly schedule. Notifications for some chemical additions have been moved from a rolling schedule to targeted times through summer to improve their performance. Significant weather events (such as heavy rain or windstorms or very hot weather), public holidays and weekends informs timing of these notifications for improved compliance. Some notifications require purchase of bulk chemicals like salt, which can be inconvenient for some customers to manage. For these we have set up a delivery service and included a link to purchase within the notification.

We have seen compliance rates roughly double after implementing these changes. Combined with a new control algorithm and other changes described above we have seen our customer service call rate drop by an order of magnitude (Figure 7).

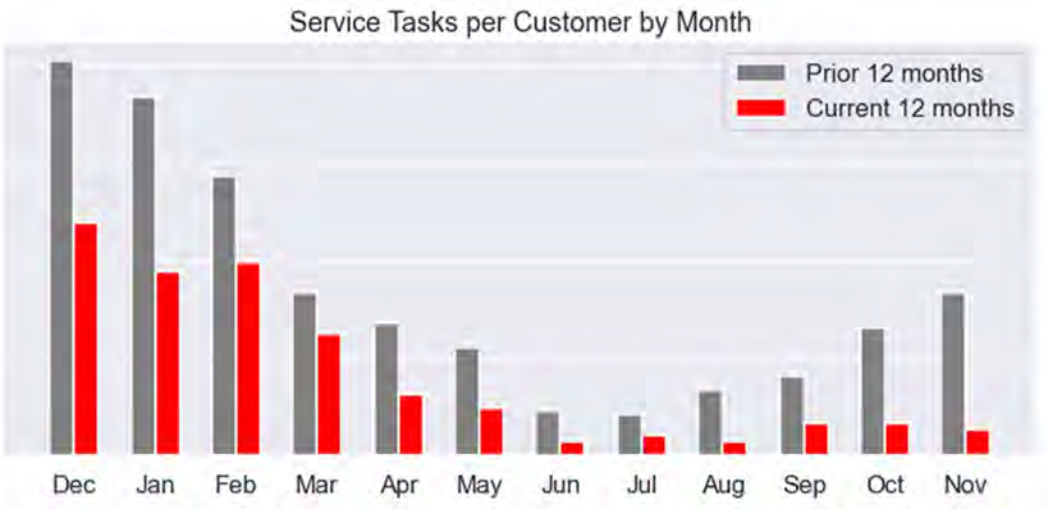


Figure 7. 2019-2020, Year over year improvement in remote management performance as reflected in the rate of service tasks per customer. Large improvements are due to better control algorithms, chemical staging, lead nurturing and customer education, and notification regime changes to improve compliance.

5. Conclusion and next steps

5.1 Conclusion

Pooled Energy has acquired a discretionary controllable load of approximately 1 MW. The key to acquisition of this load is the development of swimming pool remote control technology and an attractive consumer offering built around energy savings, pool automation and water quality.

Swimming pool remote control technology proved to be a much harder problem than originally anticipated. Likewise developing a consumer business to deliver this service had a challenging learning curve. We are now able to monitor and control our pool fleet remotely, and we have an attractive retail electricity bundle that includes pool monitoring, automation, chemical management, app-based service and consumable delivery, and a technical support centre for pool owners.

We presently manage pool load by turning off pool equipment during high price events in the wholesale market. We have demonstrated we can do this without compromising pool quality, in a way that is acceptable to pool owners. This serves the grid by responding to the price signal to drop load, and it serves Pooled Energy as a retailer by acting as a physical hedge against high wholesale price.

Our next steps are to develop new routes to market to more rapidly build the load asset, and to build out the DM&M and FCAS offerings.

5.2 Next Steps

5.2.1 Customer growth

Seek to rapidly expand the customer base by developing new routes to market and opening up new distribution channels.

5.2.2 AEMO knowledge sharing

Conduct a workshop with AEMO to demonstrate present capability and discuss opportunities to expand use of the load asset for grid services.

5.2.3 FCAS

Prepare a submission to the draft Market Ancillary Services Specification in support of device level measurement points for the power and frequency metering required for FCAS delivery.