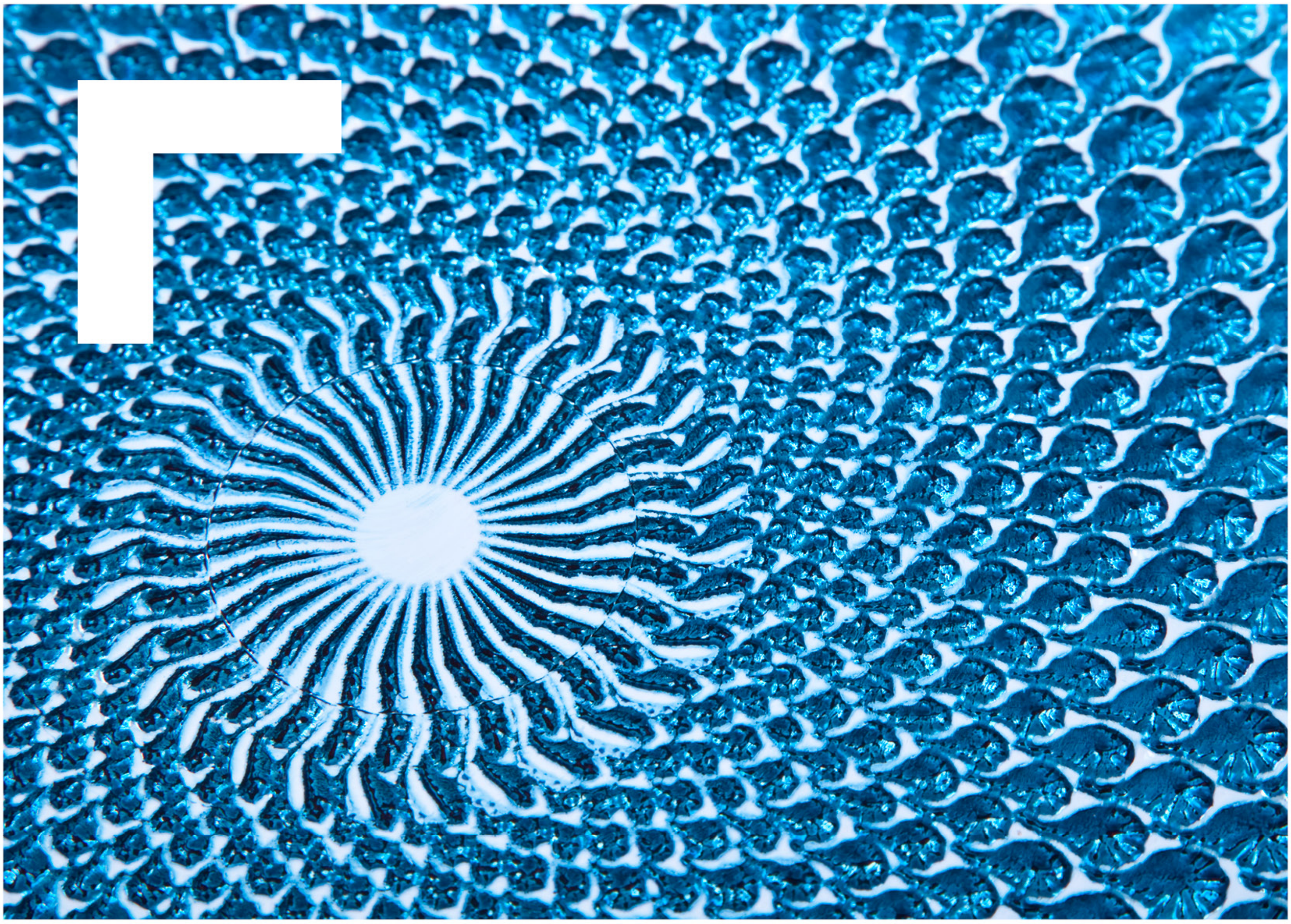
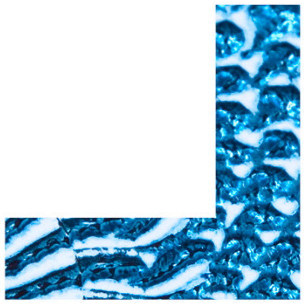


Renewable Energy and Load Management

REALM for Industry Report



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GLOSSARY

TERM	MEANING
Ancillary services	Services used by AEMO that are essential for: • managing power system security • facilitating orderly trading, and • ensuring electricity supplies are of an acceptable quality. This includes services used to control frequency, voltage, network loading and system restart processes, which would not otherwise be voluntarily provided by market participants on the basis of energy prices alone. Ancillary services may be obtained by AEMO through either market or non-market arrangements.
ARP	ARENA's Advancing Renewables Program
Energy efficiency	The level of service for energy input, which can be increased either by delivering more services for the same energy input or the same services for less energy input
Energy productivity (EP)	Energy productivity is measured by the ratio of energy input to economic output or value added. At an economy-wide level, this is primary energy (PJ) relative to GDP or GSP. Energy productivity can be measured for sectors, enterprises and projects using different denominators. Energy productivity is about the return on energy investment and therefore includes not just energy efficiency but also demand management, renewable energy, smart controls and energy management systems, as well as non-energy measures that increase economic output by more than energy consumption increases.
Demand management	Deliberate action by power utilities and consumers to reduce or shift their electricity use as an alternative to providing new electricity supply
Demand response	This report uses the definition provided in ARENA's Demand Response Competitive Round: a reduction in demand measured as the difference between a baseline and the actual metered quantity. It is also defined as a temporary reduction in demand.
Demand tariff	Network charge based on the peak demand over a set period, usually monthly
FCAS	Frequency Control Ancillary Services. Competitive markets are managed by AEMO for several kinds of FCAS. They are bid every 5 minutes and settled (paid) on the basis of availability. Usually this means being paid to be on standby, but they ***must*** be delivered when required to maintain system security.
Time-of-use tariff	Electricity tariff that varies by time-of-use, generally off-peak, peak and shoulder. Other structures exist such as a critical peak tariff with higher rates focussed on a time of high demand.

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Renewable energy, especially rooftop solar, is now significantly cheaper than grid electricity for the business peak period. However, as solar PV is a daytime-only electricity source, there are still many types of loads and business operations which cannot take advantage of the cheaper power. Load Management is a means of identifying and shifting electrical loads to reduce power bills – making more use of solar PV generation on-site, flattening demand peaks to avoid network charges and taking advantage of lower off-peak rates.

Traditionally, the energy system has treated consumer demand as 'fixed' and used centralised supply options to manage variable demand. Now, better data systems and emerging onsite storage and generation technologies can combine with advanced, automated demand control software to pro-actively manage demand and respond to energy market prices. New technologies enable energy to be stored and used at different times without adversely affecting operations, opening up opportunities for businesses to save money or earn energy market revenue.

The proportion of variable renewable electricity generation in the Australia is rising quickly and this transition is likely to accelerate. Accordingly, energy market regulators are currently implementing or considering reforms to increase flexible capacity to accommodate the growth of variable renewable energy. Large-scale flexible resources include gas-fired generators, pumped hydro storage and grid-scale batteries. However, it is important that Australia develop a portfolio of capacity resources which includes demand-side flexibility as current evidence suggests it is often likely to be cheaper than large-scale, centralised options.

The Renewable Energy and Load Management (REALM) project is a feasibility study to assess the capacity of customers to develop load flexibility in combination with renewable energy: how can electricity customers optimise and integrate variable renewable energy, battery and thermal storage, demand-controls and energy efficiency to create low-cost demand-side flexibility?

Eight major categories of flexible loads with numerous examples are presented in the demand site stocktake in this report. This provides a resource for business customers, equipment suppliers and consultants to identify opportunities for their specific areas of interest and applicability. Pre-feasibility assessments were undertaken at seven large customer pilot sites in manufacturing, retail, tele-communications and food sectors to test the technical and economic potential for integrated REALM systems at a site level.

The key findings of the REALM study were:

- **there is significant potential for commercial and industrial sites to deliver load flexibility:** at two of the sites, solar and energy efficiency alone delivered the highest returns but across the majority of the sites there was significant scope for load flexibility using *existing* on-site storage (especially thermal storage such as cold tanks or boiler plant);
- **REALM configurations improved the business case for renewable energy: the returns were better than** solar PV alone and generally batteries, facilitating higher levels of renewable energy on-site and across the grid by accommodating variable supply.
- **Existing tariffs generally do not provide an effective incentive for sites to use or develop load flexibility:** financial returns were improved by REALM systems but still generally beyond standard commercial benchmarks (5 – 8 year paybacks). Returns typically ranged from 12% to 15% for promising opportunities (noting the returns are likely to be more stable and less risky than other business investments that might reasonably require a higher return threshold to warrant investment).

These business cases were assessed under existing, relatively flat electricity tariffs combined with monthly peak network demand charges and did not include revenue for delivering energy market services.

- **The business case for REALM systems will improve**: As technology costs continue to fall and energy market value streams are opened up to demand-side participants, REALM solutions will become more widely cost-effective. The shift towards cost-reflective tariffs means the flexibility of REALM systems will become more valuable for businesses to manage their exposure to energy price changes.

Australia is now in the early-stages of a building wave of business renewable energy investment and is forecast to have one of the most decentralised energy systems globally. This presents unique challenges and opportunities. The hosting capacity of networks could become a major constraint on the growth of renewable energy for commercial and industrial businesses as it has become in residential network feeders. Australia's special characteristics position it well to become an international leader in decentralised energy to reduce energy costs and create innovative new businesses, products and exports.

However, three key changes are needed to unlock the value from decentralised energy systems:

- **Electricity supply agreements and tariffs need to be remodelled** to provide genuine, focussed incentives for consumers that unlock value for energy markets and networks;
- **Business and market capacity needs to be developed**. Pilot projects are required to demonstrate the value and practicality of decentralised renewable energy and load management systems for businesses and energy networks, retailers and aggregators. These are required to develop business and market capacity and relationships and to commercialise demand-side technologies;
- **Energy market reform must open up the energy market revenue streams for load flexibility**, which is likely to be delivered to participating businesses much more cheaply than supply-side options flexible capacity.

Energy efficiency or solar projects without demand management are better understood and lower-risk. Demonstration projects are needed to test different market, technology, pricing, institutional and regulatory aspects (through collaborations with technology providers, networks and retailers, and/or energy market aggregators) in order to accelerate the deployment of low cost decentralised renewable energy and load management systems.

2 INTRODUCTION: THE POTENTIAL FOR RENEWABLE ENERGY AND LOAD MANAGEMENT (REALM)

The energy supply industry and regulators have tended to treat customers as fixed load profiles and operated on the premise that volatility must necessarily be managed by supply system services. The demand-side has rarely been considered in much depth and usually the focus has been on reducing overall consumption through energy efficiency measures. There is now a body of reports highlighting the value of combining renewable energy and energy efficiency together[1] and some network demand response with large users such as aluminium smelters. However, there has been little research at site level to investigate how to optimise variable renewable energy generation and energy consumption to create flexible load profiles that add value for the customer and energy system.

There is agreement amongst a wide range of Australia's energy market institutions that there is significant untapped potential for low-cost demand or load flexibility to improve the efficiency, security and reliability of our energy system (see AEMO 2017; AEMC 2018; CSIRO; Commonwealth of Australia 2017). The emergence of new decentralised energy technologies is increasing the opportunities for flexible and modified load profiles by customers. Clean energy supply and demand can be integrated at the users' premises through efficiency improvements (focussed on activities that contribute to peak loads), on-site renewable energy (usually solar PV), battery and existing non-battery thermal storage and the use of demand management controls to optimise integration. Demand management and even modest energy storage capacity can add value to renewable energy by:

- reducing energy bills (especially demand charges based on monthly peak demand when solar output is not always coincident);
- increasing the capacity to install and use renewable energy behind the meter by avoiding exports which are paid at lower rates; and
- enabling consumers to participate in emerging energy market options such as wholesale demand response, network support, ancillary services, system reserves, peer-to-peer energy trading and off-site renewable energy power purchase agreements with solar and wind farms (by better matching load to the generators output profile).

In addition to increasing the value and capacity to install renewable energy at a site level, demand-side flexibility will increase the penetration of renewable energy across Australia by increasing the capacity of energy markets and networks to accommodate higher levels of variable supply.

However, as the Australian Energy Market Commission has observed, there is a 'lack of transparency' about the level of demand-side response, its cost and potential. While energy market regulators consider how to create market rules and structures to facilitate demand-side participation, the REALM project is investigating the other side of the equation: how can sites optimise renewable energy, storage and demand management to create demand-side flexibility?

ARENA commissioned ISF and A2EP to undertake a feasibility study to test and demonstrate the potential for integrated REALM and examine how its value could be unlocked at a site level. In addition to desktop research, 7 pilot studies were undertaken for sites in the manufacturing, retail

[1] For example, IRENA (2017), *Synergies between renewable energy and energy efficiency: a working paper based on REmap*, International Renewable Energy Agency (IRENA), Abu Dhabi, www.irena.org/remap.

(household goods, supermarket), telecommunications, and food sector (a food manufacturing site, cold storage site and a typical edge of grid food/agri-business operation). Assessments of the opportunities for integrating renewable energy and load management were undertaken for each site in partnership with the host business, using an optimisation model developed by ISF to test the business case for different configurations of PV, thermal and battery storage for each site.

This key finding is that customers can deliver load flexibility to respond to variable supply with the right price signals. This flexibility can support increased renewable energy supply both on-site and across the grid by responding to and accommodating variable renewable energy generation. Energy users can also change the fundamentals driving demand profiles by improving thermal performance of buildings, infrastructure and equipment, and efficiencies and controllability of equipment installed.

However, different market participants all have a role to play in helping to realise the potential in Australia for REALM solutions:

Business:

- Businesses exploring REALM systems need good data on their operations and their energy use to mount the case for renewable energy and load management capital upgrades

Suppliers:

- Pilot projects that demonstrate the value and operationalisation of REALM systems for businesses and energy networks, retailers and aggregators, develop business and market capacity and relationships and the commercialisation of demand-side technologies;

Networks and Regulators

- Energy market reform to open up the energy market revenue streams for load flexibility that can be delivered more cheaply than supply-side options to participating businesses.
- Electricity supply agreements and tariffs need to be remodelled to provide genuine, focussed incentives for consumers that unlock value for energy market and networks;

2.1 Integrating Renewable Energy with Load Management

The case for Renewable Energy and Load Management (REALM), lies in the integration and optimisation of distributed energy technologies on-site. This report, and the pilots it proposes, seeks to demonstrate that a systems approach to onsite energy generation and demand will deliver greater benefits than evaluating individual technologies. Traditional levelised cost or marginal abatement cost curves for determining the best energy technology solution only capture some of the value of different technologies. While they are useful to compare the cost of technologies in isolation, by their nature they cannot consider the interdependencies or complementarities that inherently exist in a real-world system.

Energy generation and use is becoming more variable and inter-meshed as renewable energy supply increases and new opportunities for load flexibility emerge from control technologies, digitalisation and internet-of-things. Newly available control technologies can allow medium to small-scale consumers to align flexible loads with variable supply, lowering their costs and potentially opening up new revenue streams.

New control technologies. Leveraging demand resources to most cheaply address the needs of evolving energy systems worldwide has driven the development of advanced control technologies.

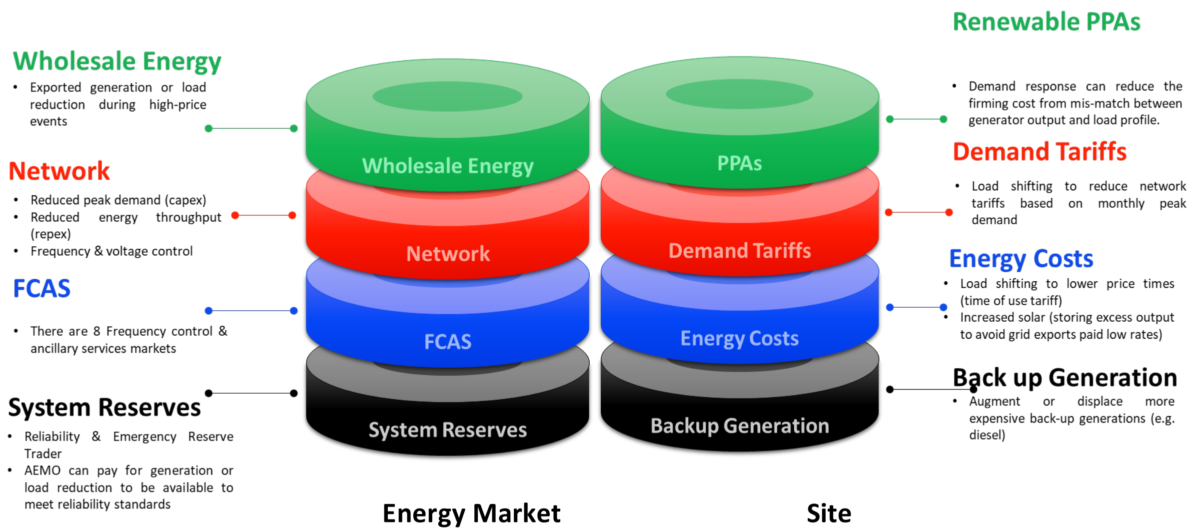
For its report to the US Office of Electricity Deliverability and Electricity Reliability[2], the Lawrence Berkeley National Laboratory chose to categorise these new capabilities as Automated Demand Response (ADR), Direct Load Control (DLC), smart thermostats, variable frequency drive, lighting control (e.g. luminaire and zonal), automated load shedding, process interruption, and base switch. These technologies meet the needs of electricity systems by shedding, shifting and shimmying demand for local and system benefit. Commercial and residential consumers are already beginning to capitalise on these technologies in large-scale demand response programs in Australia (Queensland), New Zealand, the United Kingdom, Ireland and many states in the US.

However, our preliminary research has shown that many consumers lack a sufficient understanding of their own energy system (e.g. the timing and cost of energy use, the services being provided, the onsite options for flexibility, the revenue and performance of onsite generation) to fully capitalise on the benefits these new technologies offer.

Consumer benefit. A successful REALM project should benefit consumers by reducing the cost of energy, increasing energy revenue or both, while improving business productivity. Energy costs can be reduced by efficiencies, load shifting (e.g. away from peak or into times of high onsite generation), displacing more expensive forms of backup generation and reducing the costs of a RE PPA (by reducing the firming costs from the mis-match between generator output and load profile). Local electricity trading is not yet facilitated by the energy market rules but offers another potential future option.

A REALM project also can provide low-cost, off-site energy services - wholesale energy, networks, system reserves and ancillary services (e.g. FCAS or voltage support). Figure 1 illustrates the value-stack from REALM systems.

Figure 1: The Value Stack for REALM systems



For a REALM project to minimise cost and maximise revenue the system needs to be optimised, which requires longitudinal data for both energy use across all loads and onsite generation (including storage) to match load and variable supply. In the pilots conducted for this study, there were consistent issues with data quality, access and understanding of load flexibility opportunities. However, there are exciting developments in data analytics and machine learning that will open up opportunities for more sophisticated systems. With this data, consumers will be able to install more renewable energy at lower cost and in a way that better complements the surrounding network.

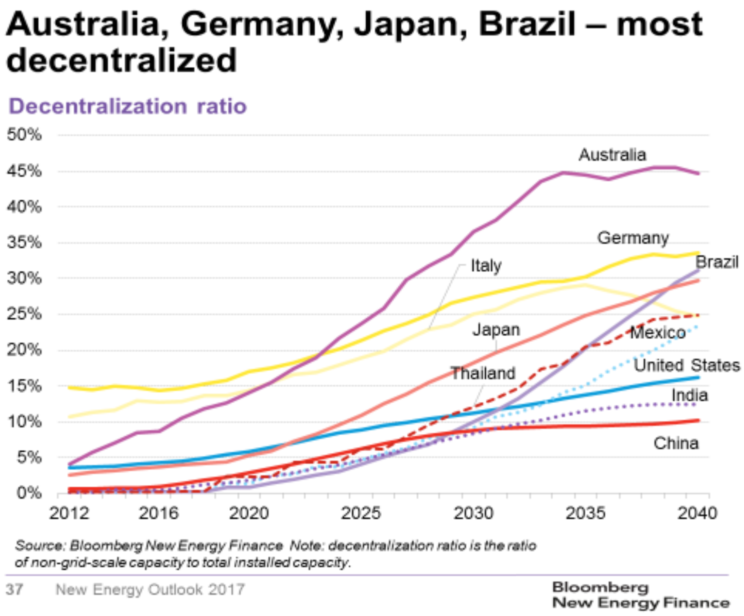
[2] https://eta.lbl.gov/sites/default/files/publications/dr_advanced_controls_database_user_manual_final_8_28_17.pdf

2.2 Pioneering REALM: the Challenges and Opportunities

Australia has a very high penetration of distributed renewable energy by international standards. To date, this has primarily been driven by households but Australia is now in the early-stages of a building wave of business renewable energy investment (underpinned by growth in energy prices, falling costs of renewables and increasing focus on management of climate impacts). The capacity of renewable energy installed by Australian businesses has doubled since 2016 and major organisations are signing Renewable Energy Power Purchase Agreements (RE PPAs). The cost reductions in renewable energy continue to outstrip forecasts. Recent major surveys by the Climate Council and ARENA have found 40-50% of leading businesses are planning on acquiring or investing in renewable energy. ARENA's 2017 business survey found while almost half of Australian businesses are actively pursuing renewable energy alternatives, it still only accounts for less than 10 percent of their average total end use.[3]

Figure 2 illustrates that leading forecaster Bloomberg New Energy Finance project that from the early 2020's onwards Australia will have the most decentralised energy system (by some margin) of the major economies analysed.

Figure 2: Energy Decentralisation Ratio



Source: Bloomberg New Energy Finance (2017) New Energy Outlook[4]

The scale of distributed, variable renewable energy in Australia presents both challenges and opportunities.

Challenges

If poorly managed and uncoordinated, distributed renewable energy could add significantly to energy costs. The Electricity Network Transformation Roadmap developed by CSIRO and Energy

3 https://arena.gov.au/assets/2017/07/AU21476-ARENA-Corporate-Report-REVISED-v1-1.pdf

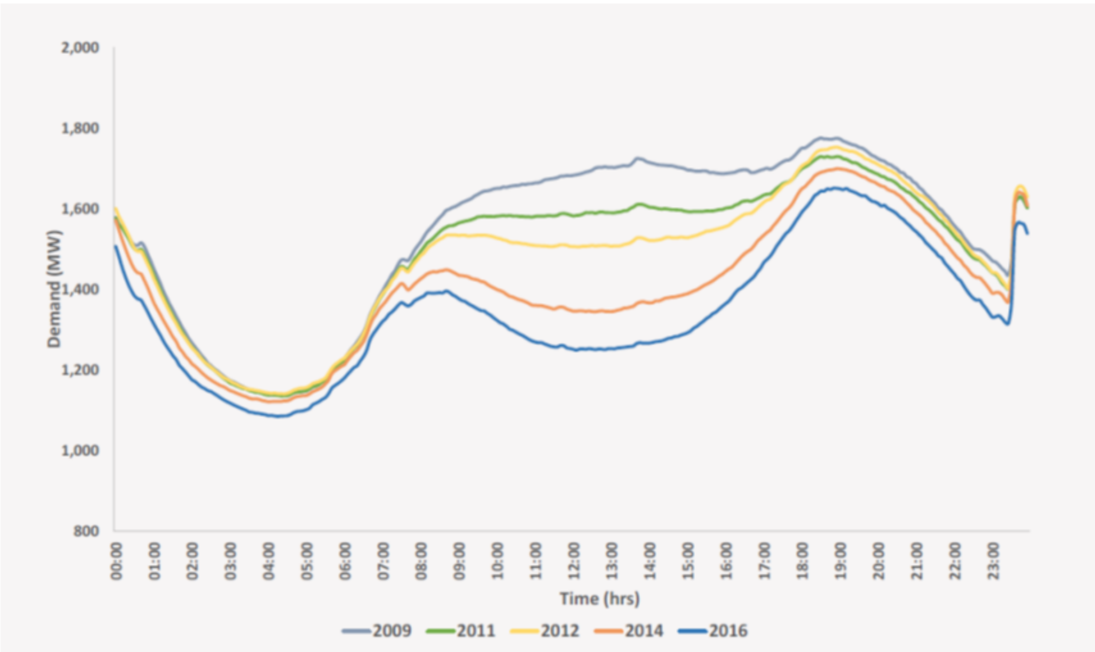
4 https://about.bnef.com/blog/henbest-energy-2040-faster-shift-clean-dynamic-distributed/. Accessed May 15 2018.

Networks Association estimates consumers will determine how $200 billion out of a forecast $1 trillion of energy investment is spend by 2050. Over $16 billion in network expenditure could be avoided through effective orchestration of distributed energy resources (CSIRO & Energy Networks Australia 2017). Expenditure on appliances, equipment and buildings (potentially more energy-efficient, smarter) will far exceed supply side energy infrastructure investment.

The hosting capacity of networks could become a major constraint on the growth of renewable energy for commercial and industrial businesses. The residential solar boom has led to voltage management issues on feeders dominated by households with a range of network responses including prohibitions on additional solar installations. Similar network issues are likely to arise as commercial and industrial solar grows.

The growth of intermittent renewable energy gives rise to challenging "ramping" issues as illustrated in the now famous 'duck curve'. Due to the strong growth in rooftop solar installations, AEMO expects that demand on the grid in the middle of the day will fall further, resulting in a rapid increase in demand in the lead-up to the evening peak as the sun sets (AEMO, 2017b).

Figure 3: The "Duck Curve" in South Australia



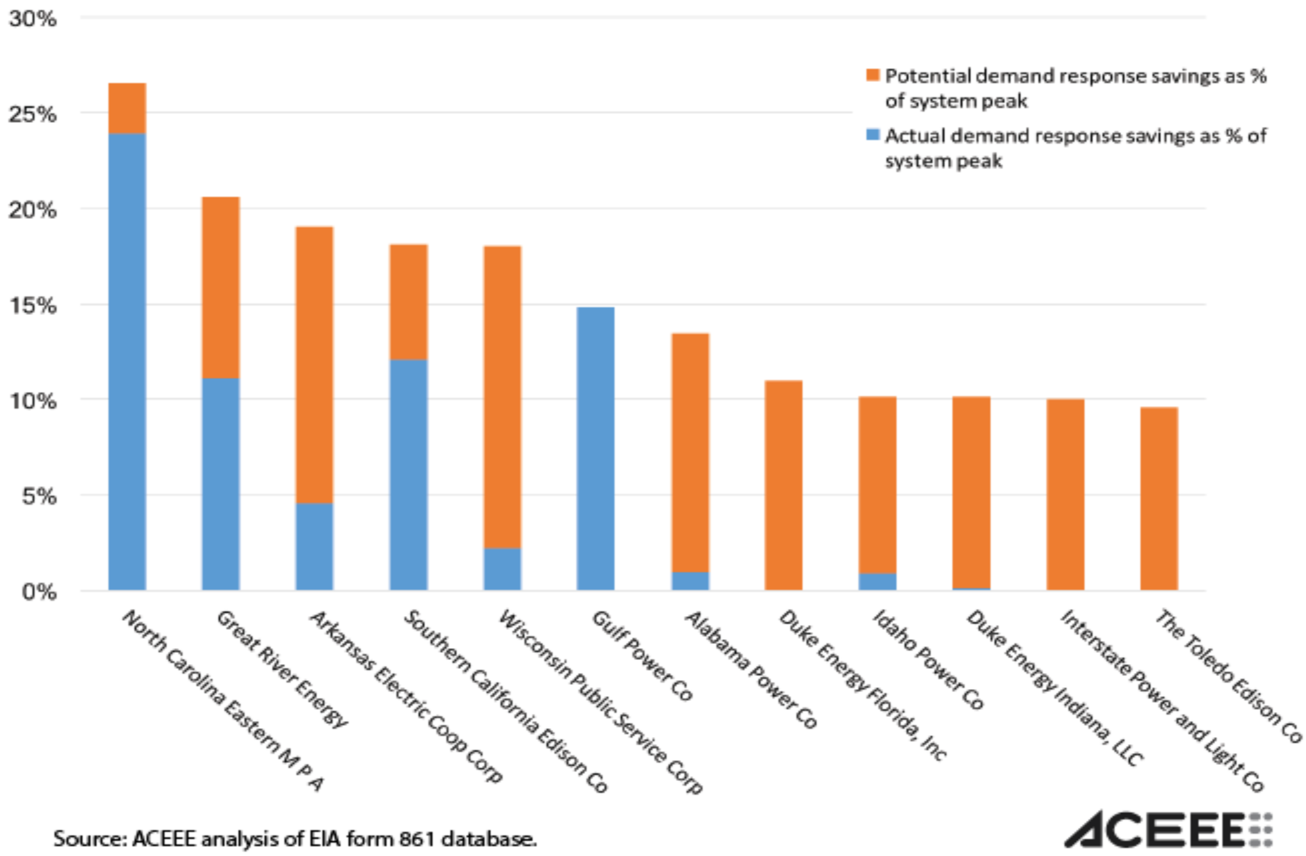
Demand-side flexibility is also an important resource to manage the 'duck curve' arising from the growth of solar energy – and for businesses to manage exposure to cost-reflective tariffs which would increase for the later afternoon when their solar output recedes.

The scale of the opportunity

The low level of demand-side flexibility and the high penetration of distributed renewable energy also present a major opportunity for the deployment of REALM to reduce energy costs and create innovative new businesses, products and exports. As coal-fired power stations retire and additional capacity is required to maintain network reliability and security, while the volume of intermittent renewable energy increases, demand-side flexibility is the cheapest source.

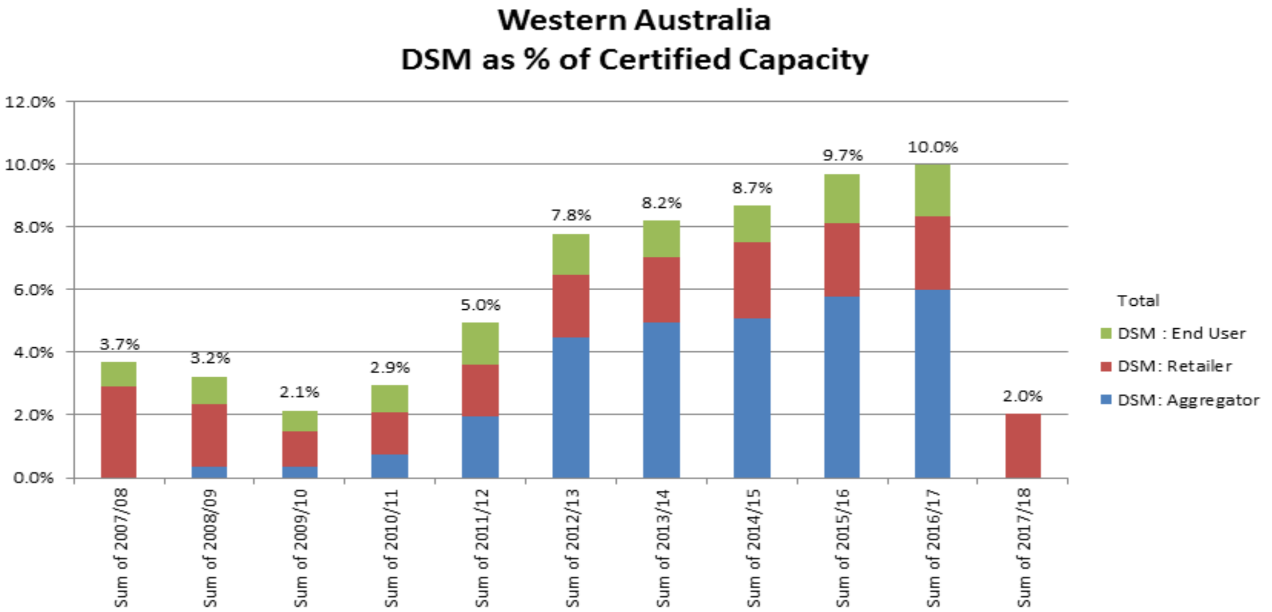
Load (or demand) management alone could provide enormous economic benefit to Australia by reducing peak demand. The American for an Energy Efficient Economy (ACEEE) examination of the US utility-sector demand management and energy efficiency programs over 20 years gives a good indication of the potential for load management in the local market. ACEEE has estimated that demand response programs can be used to reduce peak demand by 10% or more, above and beyond the peak savings from energy efficiency programs. Based on data collected by the EIA for over a decade, ACEEE found that, for 28 utilities, demand response savings ranged from 2-27% of the utility's peak demand, with 10% peak demand savings being the average. Of the 28 utilities, 59% reported potential peak demand savings of 10% or more. Data on the top dozen utilities are reported in the Figure 4 below.

Figure 4: Demand management, United States. Potential and actual peak demand savings in 2015 for utilities with leading demand response programs.



In the WA capacity market, demand side management (DSM) equivalent to 10% of the system peak demand has been committed over just 4 years - mostly from the commercial and industrial sectors.

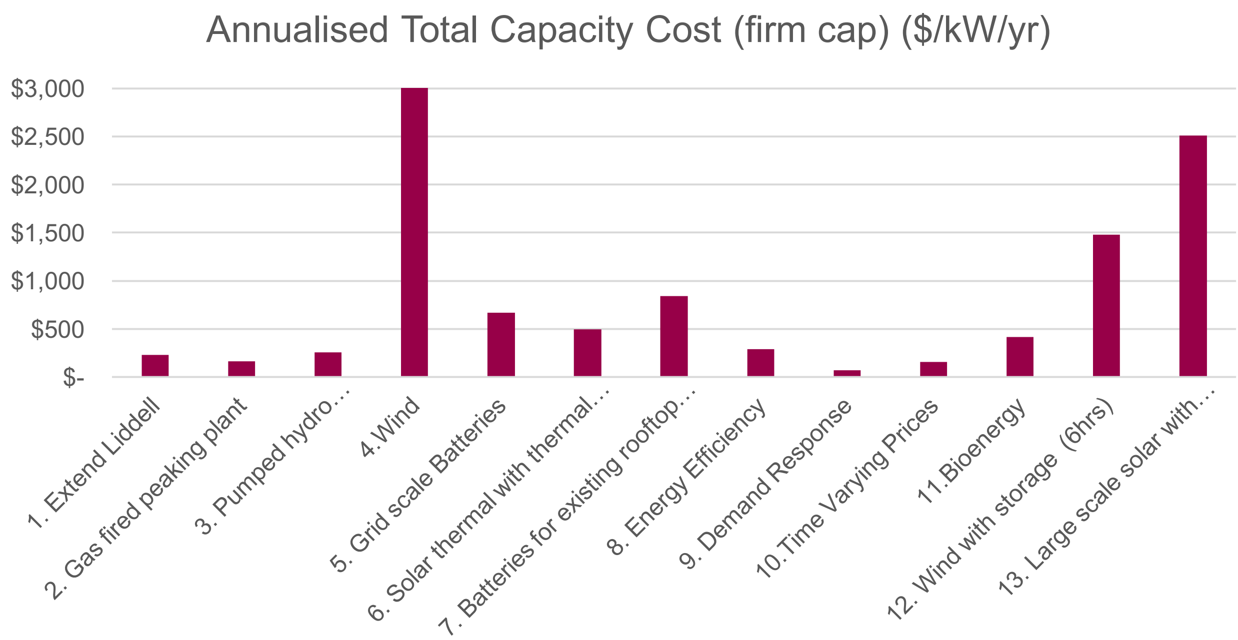
Figure 5: Demand Management, Western Australia



If the NEM had access to the same average capacity level of demand management as the as US states, there would be around 3000MW of demand management - more than Snowy 2.0 at 2000MW and almost double the capacity of Hazelwood power station at 1600MW (Dunstan et. al. 2017

ISF analysis of alternatives for providing firm capacity also demonstrates the value of demand-side response as the cheapest resource.

Figure 6: Comparisons of Cost of Technology Options,



Under the Reserve Emergency Reliability Trader scheme operated by AEMO (in conjunction with ARENA's demand response pilots), 1000MW of capacity was procured at $50 million - lower than the estimated cost above (ARENA/AEMO 2018).

While the potential for network and wholesale peak load management is well-demonstrated, there has been far less work done globally on the additional load management possible when also utilising on-site renewable energy. There are many other benefits that could be generated from a REALM system that truly optimises generation and load including:

- Load shifting to complement renewable generation, reducing the cost of energy to the consumer as well as smoothing import/export variability on the network;
- Reducing the need for network infrastructure as the system can reliably provide a greater portion of a consumer's energy service need onsite; and/or
- Providing additional network support services (e.g. if the system includes components, such as batteries, that can moderate voltage, frequency etc).

It is vital that the early investments in business-led renewables work for both on-site and for the energy system serving the wider business community. REALM projects can provide this. Business-led REALM projects will drive down the cost for business, while simultaneously easing the transition for network businesses e.g. by reducing the impact of distributed generation on the local infrastructure and/or providing a new source of network support services.

Alongside business interest in energy management, innovative energy start-ups and technology companies are emerging. The AEMO/ARENA demand response pilot program has piqued the interest of global leaders in demand management (e.g. Schneider Electric and ENERNOC) as well as fostering local technology developers to meet the growing market (e.g. Greensync and ZEN energy). Demand response is now a central feature of an emerging retailer for its wholesale customers (Flow Energy). New battery storage companies, projects and platforms are emerging within Australia. Our research has also identified commercial interest in developing demand control hardware and software to fill gaps such as optimising multiple loads on-site in response to different price signals and coordinating fragmented loads in response to price signals across large organisations with many sites.

Australia is in a prime position to drive first-of-a-kind REALM pilots

Australia's special characteristics position it well to become an international leader in REALM; high-quality renewable energy resources, high penetrations and now emerging changes to energy market rules and strong national expertise in technology development and large-scale projects. Steep increases in energy prices and price volatility, and recognition of the need for climate response have lifted the profile of energy management within commercial and industrial businesses. On-site renewable energy and off-site RE PPA's are now cost-competitive with grid electricity and this trend will continue as the cost of renewable and enabling technologies continues to fall, making REALM projects attractive to more businesses. Companies who have an interest in sustainability and/or have a large energy cost will be at the forefront of this trend and are likely to be excellent partners for testing early REALM projects.

For the first time, energy market trends are now being re-shaped to support demand-side innovation. Considering each of the offsite elements of the value-stack outlined in Figure 1, all are now in the process of being opened up:

- Ancillary services provided by energy users has grown strongly in recent years following regulatory change that opened the FCAS market up to aggregators;

- Network services: a $1 billion opportunity for network demand management to avoid capital expenditure, replacement expenditure and ancillary services management costs exists following the approval of the Demand Management Incentive Scheme in April 2018;
- ARENA and AEMO's RERT/demand-response pilot for summer 2017/18 demonstrated resources could be mobilised for system reserves; and
- Wholesale markets: the Australian Energy Market Commission (2018) has released a discussion paper on which model should be implemented to facilitate wholesale market demand response. Energy rule changes also require retailers and networks to transition to cost-reflective tariffs which should lead to better alignment between price signals and wholesale peaks.

Now is the perfect time to capitalise on the new market opportunity to test innovative REALM proposals with motivated first-mover businesses, energy retailers, networks and aggregators, software and hardware vendors and technology providers.

2.3 REALM Pilots: Key Findings

Pilots to test and demonstrate the potential for REALM were undertaken in seven sites:

- A Supermarket in South-West Sydney (Woolworths);
- A telecommunications aggregation node in Melbourne (nbn);
- An edge-of-grid agri-business, in-land Queensland (Teys);
- A retail outlet, Inner-Sydney (Ikea);
- A food manufacturing facility (Goodman Fielders);
- A greenfield cold-store site (V&C Foods);
- A light manufacturing site (Schneider Electric).

The pilot sites represent a cross-section of industries (retail, manufacturing, agri-business, food distribution and manufacturing, supermarket, telecommunications), network contexts (including an edge-of-grid operation) and includes one greenfield site. The pilot sites for REALM contain a variety of the potential flexible loads (with the exception of materials storage).

It is important to underline that the feasibility assessments have been undertaken based on current retail energy tariffs and assuming no revenue from providing energy market services. There is little or no effective price signal in current supply agreements. The primary incentive for businesses is to avoid demand-based network tariffs based on maximum demand across a month – which often do not coincide with network and/or wholesale market peak events. Energy tariffs are flat or provide coarse time-of-use signals that also do not correspond to wholesale price events.

With these qualifications in mind, the pilots found substantial potential for REALM. At four of the sites, there are existing thermal storage opportunities that were cheaper than battery storage and could be used to increase the value of on-site renewable energy. At two sites, efficiency measures and solar were the optimum solution without additional storage capacity (thermal or battery) and on one site there was limited opportunity for on-site REALM but potential for large-supply demand energy market services. The key technology configuration was a combination of demand controls, solar PV and existing, augmented or new cold tank storage.

Table 1: REALM Pilot Studies – a Snapshot

Site	Key Findings
IKEA	Optimal configuration is an upgrade of chiller controls to utilise existing cold-water tank storage plus additional solar PV. An additional battery storage delivers a low but positive return. Upgraded controls to alter the charging and discharging of electric forklift batteries may offer an alternative. Improvements to building thermal efficiency and building management system important complements.
nbn	Limited opportunity for onsite REALM as solar constitutes small portion of relatively flat load with over-sized batteries and back-up generation for reliability purposes. Opportunities for energy efficiency, a RE PPA and DR services (in part dependent on upgrading batteries).
TEYS	Optimal configuration is an additional solar PV plus an investment in additional capacity for the boiler pre-heat which can store excess solar PV output. If battery prices were to fall to $500/kw, batteries may become marginally more cost-effective in using excess solar PV output. Both storage options improve the financial returns from additional solar. The fringe-of-grid location may create opportunity for a project with the distribution network company, with applicability to other contexts.
Woolworths	Little opportunity for on-site REALM due to well-sized solar array, low off-peak tariffs and flat, high-capacity use of chillers 24/7. Cold tank storage may be an option in new stores. The pilot has investigated opportunities to provide energy market services (e.g. UPS batteries). No projects yet due to a combination of coordination issues across stores (and absence of suitable demand control technology) and absence of suitable offerings (e.g. network demand management, RERT).
V&C Foods	The optimal configuration is around 80kw of solar combined with High efficiency refrigeration which removed case for storage. neither phase change materials or battery storage were cost-effective. Heat capture from the refrigeration cycle presents an opportunity for further efficiency for using reclaimed hot water in space heating and site hot water needs.
Schneider Electric	Modelling found the optimal solution is an additional 900kW of solar. Returns from the additional of a small cold tank or a battery are marginally lower but would provide flexibility to add value under different tariffs or to provide energy market services. There may be a case for a combination of battery and cold tank if tariffs change, with the cold tank focussed on arbitrage opportunities and the battery focussed on peak shaving. Returns were not particularly sensitive to battery size and enable larger storage to be pursed to open up opportunities to become a prosumer micro-grid

Goodman Fielder	Optimal configuration is additional solar at a similar capacity to site peaks and additional of a small cold tank, which is cheaper than battery storage, as relatively little storage time is required to reduce the site's peaks through time-shifting the chiller's operation. A heat pump to recover heat from the main ammonia chiller condensers and supply 80+ degree water to replace the boiler and steam system is likely to be feasible. Additional potential for energy market DR options also present.

2.4 Structure of the Report

The major sections of the report include:

- a Demand-Side stocktake (Chapter 2): a review of options to create flexible load profiles;
- Integration of renewable energy and load management (Chapter 3): a review of technologies and methodologies to integrate on-site supply and demand, the value stack and revenue streams that may be achieved;
- The results of the pilot studies (Chapter 4) – the optimal configurations of REALM and business cases under existing tariffs;
- Barriers to REALM (Chapter 5);
- Implications of REALM for ARENA's Energy Productivity Strategy (Chapter 6)

3 DEMAND-SIDE 'STOCK TAKE': FLEXIBLE LOAD OPPORTUNITIES

Commercial and industrial sites have a range of options for load flexibility. Load management is far more sophisticated than simply switching loads on and off. It can include modelling and modulation of variable loads and on-line process optimisation in response to data on energy demand and other factors. For example, in the case of controlling multiple induction melters, it could involve monitoring the operating state of the plant, and only reducing load when the melters are in a specific stage of the process or the molten metal is sufficiently hot to do so without loss of production. The control of solar generation can be similarly sophisticated, including weather forecasting to predict loads.

It is important to note that the scale and duration of feasible load management is often quite site specific - depending on existing equipment performance and flexibility, the nature of the services, local decisions influencing the amount of storage available and how much surplus capacity exists in related processes and plant. Advanced data analytics, machine learning and intelligent automated control will play important roles.

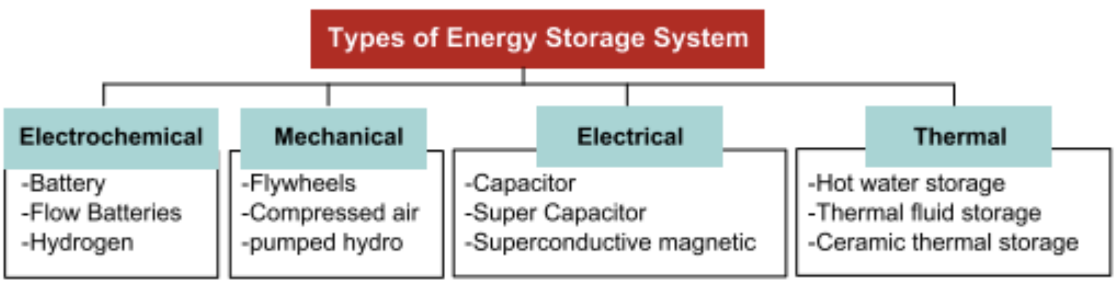
A review of major projects internationally at sites and networks was undertaken which informs this demand-side stocktake (see Appendix A & B).

3.1 Load Flexibility Options: an Introduction

The major generic options are described beneath:

- **Energy Storage in Processes & Operations.** Non-battery storage inherent to processes and operations is very common. Typical examples are paper pulping prior to pulp storage and the paper machine, ice/chilled water storage in an air conditioning system or use of the full temperature band in cold storage operations (particularly in freezers) with large thermal inertia. Some sites also have existing battery storage (e.g. batteries in UPS in telco operations or data centres) and electric vehicles (e.g. fork lifts). In some cases, it is economical to invest in additional storage through increased processing capacity, new chilled or hot water storage tanks, or new battery installations (which may make sense when other cheaper inherent storage is not available, supply costs are particularly high [e.g. edge of grid operations], or to shave peaks where short spikes of high demand increase demand charges).

Figure 7: Types of Energy Storage Systems



Of the types of energy storage systems, thermal energy storage is at present the most widely applicable solution on commercial or industrial sites. However, the evolution and improvement in cost-effectiveness of all types of energy storage solutions is rapid and we are still learning where and how they can be applied to capture benefits. It is important to regularly review options.

- **Loads which are intermittent and whose operating times are somewhat discretionary** as they are not constantly required for the operation of the central process or business activity, and there is surplus capacity to conduct their function in a limited number of hours. These loads include staff services like hot water, irrigation pumping, some waste water treatment activities, and some materials handling activities. Note that it may not be necessary to switch loads off: slight reductions can offer disproportionate savings, for example reducing pipe or air flow by 10% can deliver 25% pump or fan energy savings.
- Increasingly the availability of **on-site generation** also provides great load flexibility. The focus of this study is on solar PV, which has specific time of day and seasonal generation characteristics that limit its use for load shaping, and also often create a 'duck curve' in the remaining net site profile as grid electricity consumption falls in the middle of the day. PV also introduces risk of short or rapid changes in output, as well as seasonal variations, so energy storage, smart demand management or other measures can be used to complement PV to smooth demand for grid electricity. Other generation options include gas engines utilising biogas, co-generation (less attractive with the increases in gas prices and requires high utilisation rates to be viable so not a load shaping option unless linked to electric and/or thermal storage) and standby gensets (viable for peak shaving if the incentive is sufficiently high).
- **Targeted energy efficiency improvement** can reduce demand from specific equipment at certain times. Improving the thermal performance of a building envelope disproportionately reduces peak demand in hot weather, while also slowing the building's response to heat so that cycling of cooling equipment can be more widely used while maintaining occupant comfort. Many measures can be added-on or adjustable, such as external shading.

A key finding of this study is the potential for energy efficiency, demand management, energy storage and on-site generation to complement each other, compensate for problems other elements create or enhance the benefits from other actions. In many cases, smarter management systems, more data and more flexible equipment (such as variable speed motors) underpin the capability to capture maximum benefits. A later section of this report discusses software packages for optimal integrated load management.

Table 2 contains an inventory of flexible demand management options and their key characteristics.

Table 2: Generic Flexible Load Opportunities - Summary

Type	Process	Industry	Length of storage hrs	Cost
Storing heat	Melter process heat, hot water	Metals and minerals, H/W food, many other	Up to several	Low
Storing Cool	Cold water/ice in HVAC, cold storage	Commercial buildings, cold stores, food chain	Up to several	Low
Storing materials	Resource pre-processing, in-line storage	Paper, minerals, light manufacturing	Up to several	Low

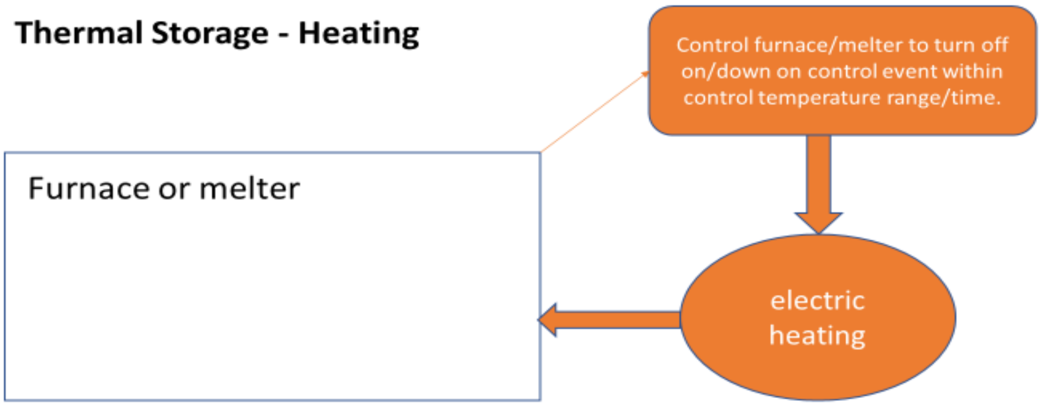
Discretionary loads	Material transfers, staff amenities	Many – site specific	Peaks only	Low
Existing batteries New batteries	Existing storage for UPS	Mainly telco, data centres Any	Peaks only	Low V high
On-site generation	Solar, standby, cogeneration and tri-generation	Any except cogen mainly food, chemicals, paper	Up to several	Varies
Targeted energy efficiency improvement	Building HVAC, cold storage, lights, motors etc	All	Peaks to continuous	Low to medium

Each of these load types is outlined in more detail below.

3.2 Heat storage

Examples: Electric furnaces and melters in the steel, silicon and other metals and glass industries

Figure 8: Thermal Storage - Heating



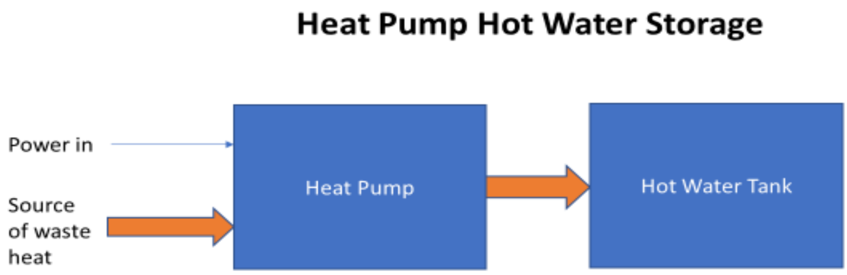
Electric furnaces/melters for metals (e.g. electric arc, induction) and glass usually have significant thermal mass. Melters are also used for plastics (Schneider Electric case study), but tend to have lower thermal mass and thus are generally less valuable for load management.

Hot water storage is only beneficial for electrical load control if it is normally supplied by electricity (e.g. a heat pump). However, even if the water is heated using steam from fossil fuel combustion, water heating could be used to store surplus solar PV using supplementary resistance heating elements where the opportunity value of the surplus solar is low – e.g. in case of a very low feed-in tariff (though if the heater has sufficiently high utilisation, a heat pump may be a better solution).

In the case study sites, Teys' boiler feedwater tank, and Goodman Fielder's hot water tanks for CIP and its boiler feedwater tank, all currently heated with steam, are examples of potential hot storage applications. These tanks are common in food processing, but hot water and boiler feedwater tanks are not generally heated electrically. Many retail operations also have hot water storage, though generally too limited in capacity to provide much load management capacity.

However, the advent of high temperature heat pumps is likely to increase the use of electric water heating due to the continued high price of natural gas, the high efficiency (COP) of heat pump water heaters and the ongoing relative decline in heat pump costs. Heat pumps can provide both heat and cooling at very high efficiencies as long as suitable loads or storage are available. These heaters can be coupled with hot water storage tanks to provide load management opportunities and avoid them contributing to peak loads. See below:

Figure 9: Heat Pump Hot Water Storage

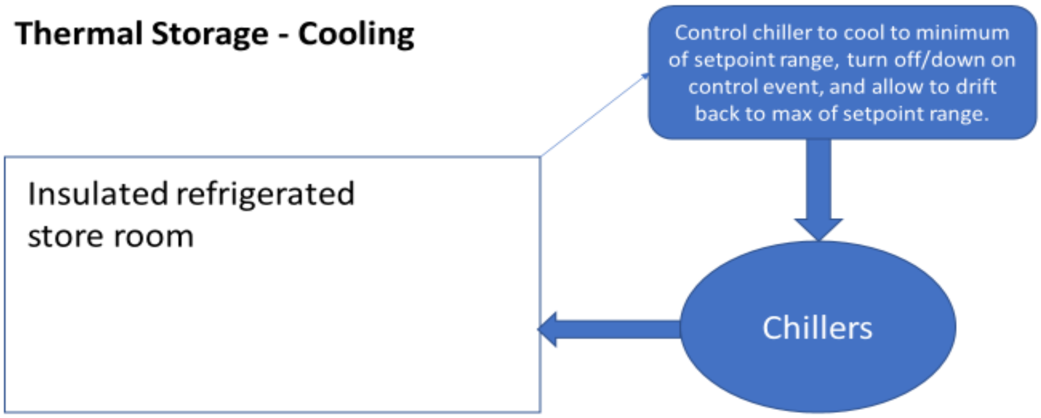


3.3 Cold storage applications

There are widespread opportunities in the food industry and retail applications to store electricity via refrigeration in cold storage to take advantage of existing thermal mass (or to add to this thermal mass using phase change materials, including ice). Typical applications can include:

- Cold stores/distribution centres – particularly freezers, in the food cold chain and particularly in major distribution centres.
- Refrigerated storage in retail stores, on farms, and in food and pharmaceutical manufacturing operations.
- Refrigerated processing lines with a substantial thermal mass – e.g. spiral chillers and tunnel chillers in the food industry in frozen packaged foods, chicken and beef processing/ packaging operations.

Figure 10: Thermal Storage - Cooling

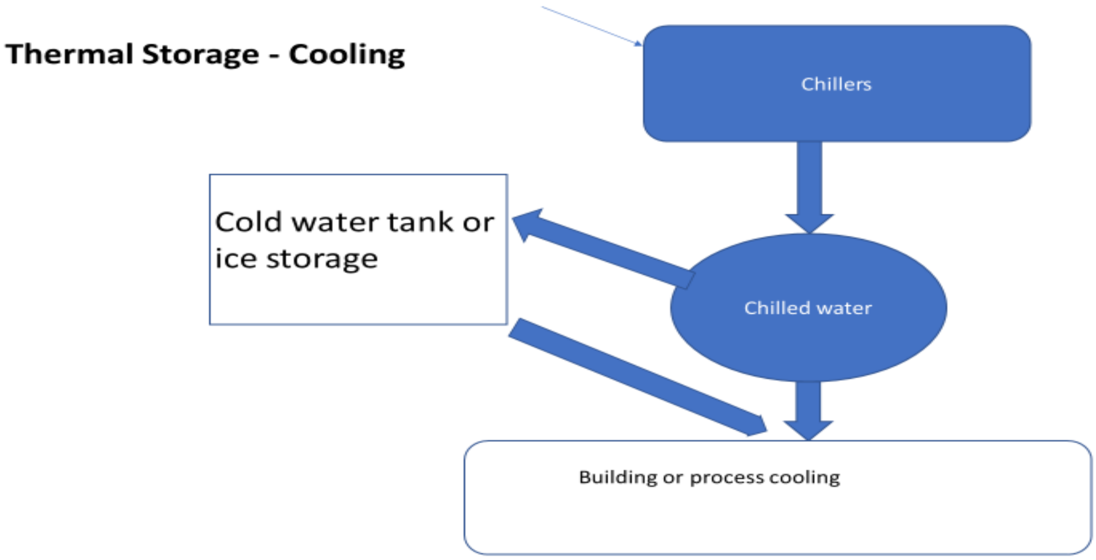


Generally, the most suitable applications are those with large thermal mass and a wide acceptable setpoint range. Frozen storage tends to allow greater thermal temperature swings than chilled coolrooms. Frozen meat for example is also quite insensitive to overcooling, though this is not the case with ice cream. Heat losses, a function of the quality of the insulation and the time doors are open are also important considerations in determining the opportunities for load management. The control strategy is generally to pre-cool to the minimum set-point and then switch off/down chillers until the temperature drifts towards the upper setpoint before switching the chiller back on (allowing enough time to stabilise temperatures without overshooting).

There is examination in the industry at present of the potential use of phase change materials (PCMs) in coolrooms to enhance the thermal mass of these systems to provide significantly increased load flexibility and there is some evidence that the economics of these investments is starting to look attractive in areas with high demand charges or periods with low cost energy (e.g. where surplus PV is available). PCMs may also be useful to stabilise food temperatures in areas subject to temperature fluctuations, such as near cold room doors.

Refrigerated process lines may also be suitable for short term load management, but each case needs to be examined on its own merits to determine the suitability for stopping/modulating and the allowable frequency and delay time. The greater the dwell time and the more surplus freezing capacity in the operation, the greater the opportunity for turning off/down chillers without losing plant capacity. While these types of loads are common in the food processing industry, they have relatively limited ability for load management to avoid production delays or risk of product loss. For example, the Goodman Fielder Artisan Line spiral chiller has an 80 minute residence time and with careful testing it could be possible to shut down the chillers for say 15 minutes at a time. However, there are regular longer stoppages during product changes (1 hour delay, 10 times a week) and twice weekly cleaning (3 hour delay each time), and these longer delays could be scheduled for evening peak periods during Summer to increase load management potential.

Figure 11: Thermal Storage - Cooling Cold Water Tank



In retail or office centrally air-conditioned systems and some process cooling applications, chilled water (or glycol) is often used as the cooling fluid, and some systems have been designed with chiller water (or glycol) or ice storage, for load management purposes. They were originally designed to charge storage during low energy price periods at night, to provide operational flexibility, or to deliver increased capacity to meet peak cooling loads with smaller chillers.

In these cases, the chillers can be controlled so they cool storage tanks down to their lowest temperature during low energy cost periods (which can now be times when there is surplus solar generation capacity on site). The chillers are turned off, or at least modulated down, during high energy cost periods, and the cooling load is met from stored cold in ice or chilled water. These systems can sometimes have substantial energy storage capacity.

The IKEA chilled water storage tanks are a classic example. With 1.8Gl of storage capacity the chilled water offers maximum storage of around 22 MWh – the equivalent of over 320Tesla 2 batteries (or at $350/kWh for a commercial battery, it is the equivalent of a $1.5M battery) if it could be fully discharged. Note though that the charging of chilled water or ice storage during hot days when there is surplus solar available, may incur an energy efficiency penalty, which needs to be considered, as the COP of the chillers may be lower at these times than when operated during the night.

Another more limited opportunity for thermal storage based on inertia, is the control of air conditioning in commercial operations, where air conditioning can be run towards the bottom end of the acceptable control band immediately before expected load management periods and then allowed to drift to the top of the band when load control is required by turning off/down chillers. Consideration can also be given to allowing the band to be increased during these control periods. Here, improved thermal performance of the building and/or reduced heat input from equipment would enhance the potential for use of this strategy.

The case study Woolworths supermarket cold storage, and much larger frozen storage rooms in their regional distribution centres, are classic examples of cold store thermal inertia that could be used for load management.

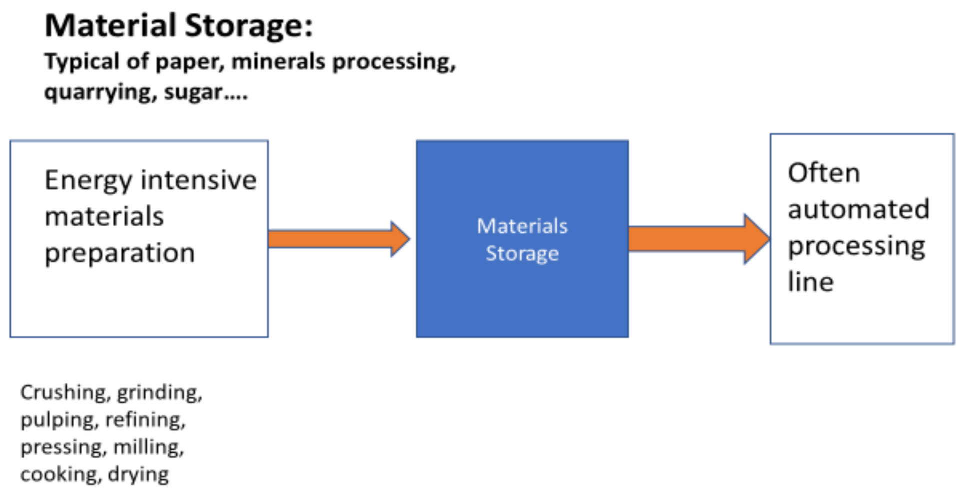
It is challenging to assess the size of potential for this type of control across industry. The IKEA type of operation with very large ice or chilled water storage (installed at 5 of the 12 Australian IKEA stores, and combined with water storage for fire fighting) is not that common (and we are seeking some statistics on this), as it tends to have a significant cost in terms of space occupied, which made it less popular in CBD office buildings. Also, this type of load control became less attractive in the last decade when the relative electrical energy rate differential between day and night contracted. On the other hand, all cold stores with reasonable insulation would have some ability to control load. There are also may process plants with chilled water circuits and some chilled water storage, many of which could install more tanks at a much lower price than batteries. The potential to utiliseutiise existing fire storage tanks, as IKEA has done, may also open up more potential applications.

3.4 Materials storage

Another common class of energy storage is material storage, where there is surplus processing capacity followed by materials storage before the next process stage. This is common in resource processing, manufacturing, mining and quarries. In some cases, there may be large volumes of existing storage capacity and thus the opportunity for substantial load shaping, particularly where there is energy intensive preparation of materials prior to the main refining/processing activity, for example in these industries:

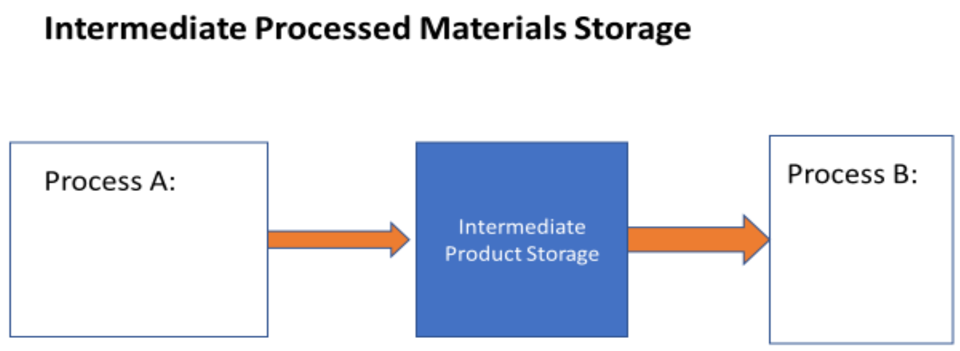
- Cement Milling
- Refiners (mining)
- Milling (Fertiliser, food such as sugar, wheat/grains)
- Pulpers (paper)

Figure 12: Material Storage



The storage element can also occur between process steps in any industry. The main criteria to determine whether they are worth controlling is that the processing steps are sufficiently energy intensive and there is sufficient intermediate storage to justify control. This approach can also be seen as a risk management activity, where access to stockpiled material provides a buffer in case of failure or maintenance shutdowns of plant upstream in the process.

Figure 13: Intermediate Processed Materials Storage



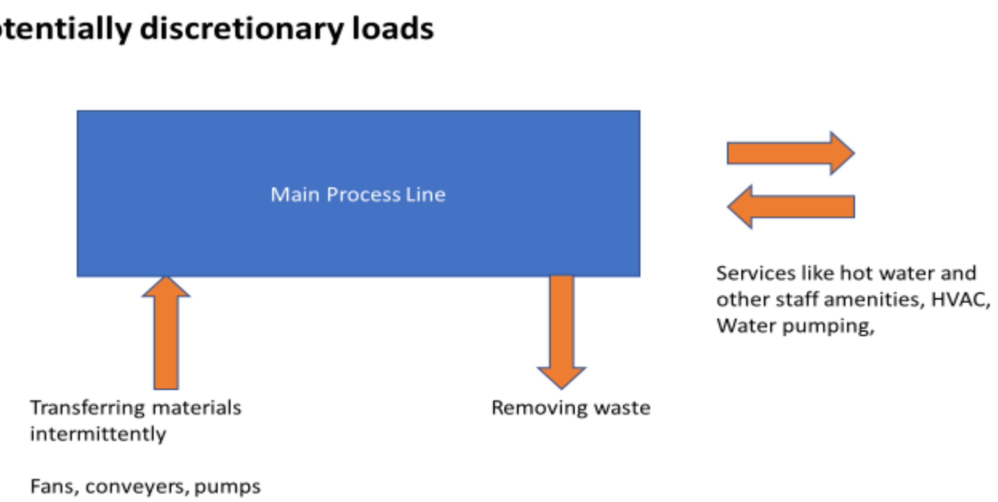
This is commonplace in manufacturing and assembly plants (e.g. Schneider Electric), though in many factories there is limited space for intermediate product storage (and in fact this is being minimised in Just in Time manufacturing operations. It is also not possible to exert load control in many food processing plants where the food is perishable e.g. the Goodman Fielder Artisan Bread line because it is not possible to store dough at ambient temperature after mixing.

3.5 Discretionary loads

These loads tend to either be activities where there is ample capacity for moving materials so they are run intermittently or loads which are somewhat discretionary in nature like staff amenity loads. Typical of these loads are:

- Fans (mining, timber, food/other particle blowing to/from storage)
- Materials transfers using conveyors conveyers
- Gas compression
- Water pumping
- Staff amenities like electric water heaters, air conditioning in less sensitive areas.
- Waste treatment plants

Figure 14: Potential Discretionary Loads

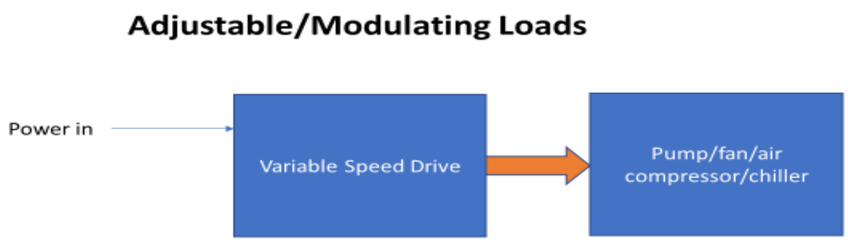


There may also be some batch processing operations where there is surplus processing capacity so they do not have to be run for the whole available operating shift, and by delaying their operation some load flexibility can be created. This type of load management is possible in light manufacturing operations like Goodman Fielder and Schneider Electric (and somewhat applicable at Teys too), but if extended too far can have labour and other cost penalties such as space for storage or material handling that need to be taken into account when planning load flexibility.

3.6 Adjustable/modulating loads

Increasingly industry is becoming digitally controlled and infinitely adjustable. This provides opportunities for more variable load control of motors and drives, LED lighting and other controllable loads, rather than relying on crude on/off controls or use of flow restriction, which can actually increase energy use as flow declines. This is not a separate type of load management but the ability to provide much more variable loads through modulation instead of on/off switching can increase scope for load management.

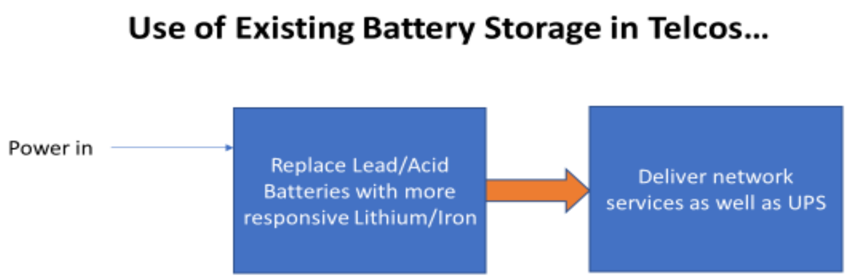
Figure 15: Adjustable Loads



3.7 Use of Existing Battery Storage

The final type of storage that may already be available without investment, is utilising existing battery storage for load management. One key factor here is the type of battery storage installed. In many older telco and other operations using batteries for UPS like data centres, the main storage is lead acid batteries which have more limited ability to provide network services due to their relatively slow rate of charge and discharge and limited depth of discharge. The planned replacement of these batteries (typically on 5-10 year cycles) with lithium iron or other more flexible options such as flow batteries or less compact but still reasonably priced options such as salt or aluminium-air batteries would make these a source of potential energy system services.

Figure 16: Existing Battery Storage



3.8 On-site/stand-by generation

On-site power generation is another powerful source of on-site load flexibility. The next chapter covers the integration of renewable (largely solar PV) on-site generation with load management and energy productivity. Most manufacturing and many large commercial sites also have diesel or gas engines installed for emergency standby processes and these can be used more for load management subject to conditions:

- They are allowed to operate extra hours without losing their reliability – note that these units have to be 'exercised' a number of hours per month in any case, to ensure reliability.
- They do not cause too much vibration, noise or pollution if run more routinely
- They are wired up to be able to readily cut in and out without disrupting normal operations of the facility – ideally, they will be synchronous – but to convert islanded plant to synchronous operation is expensive. Converting back-up generators to charge batteries in isolation from the grid, then allowing the batteries to operate with the grid may be one low cost solution.
- Their cost of operation is not excessive
- The value of the electricity they displace is high: for example, if use of a back-up generator for short periods avoids demand charges, the value per kWh is much higher. Also, if a consumer is exposed to wholesale prices, the operating cost of a diesel generator is around $300/MWh, which may often be exceeded in high price events. Capture of waste heat from a generator for on-site use can also enhance its value.

Some operations have cogeneration plants which generate power and heat for the facility. These are not generally applicable for load management to any great extent as they are generally justified economically by having very high operating hours at full load, so these plants are only usable for load management when they normally run below full capacity for one reason or another and can be ramped to peak capacity when required. Given past and expected changes in electricity and gas prices, regular review of the operation of cogeneration plant is a useful strategy.

3.9 **Energy Productivity and REALM**

We use the term energy productivity (EP) to include all behind the meter energy measures which can be implemented to improve business productivity. EP is value added/energy, which includes a focus on value created as well as energy saved. It includes improving energy efficiency in addition to controlling demand and on-site generation which is often not recognised for its ability to impact electrical demand curves (and is largely omitted from demand response initiatives).

When energy efficiency is improved and energy consumption reduced, consumer demand is reduced at all times the affected equipment operates. Reducing those loads that operate primarily on Summer evenings like air conditioning (a strong driver of demand peaks – often contributing over 30% to peak demands) are particularly important for load profile management. Lighting also tends to have its operating hours focused during evening peaks, and its heat output adds to cooling loads. Improving the efficiency of other base loads like motors and drives also will cut peak loads in operations of 2 or 3 shifts.

It has been demonstrated by ACEEE in US DM programs, that for every 1% that electricity demand is reduced by efficiency programs, it reduces peak demand by 0.66% (Nadel 2017).

Energy productivity contributions to demand management can be broadly characterised to include:

- *More energy efficient electricity using technologies for processes focused during summer peak period* e.g. high efficiency HVAC/chillers (supported by improving home insulation and changing the control band of air conditioning). We have identified opportunities for these types of improved energy performance in the retail case operations.
- *Technologies to reduce baseloads* (e.g. variable speed drives on fans, pumps, chillers and air compressors, better insulation on chilled lines, tanks and cold rooms). Where these are

part of plant which operates 2 or 3 shifts/day, they are also likely to be running at evening summer peaks, even though their operation is not focused in these periods. LED lighting also fits in this category. We identified significant opportunities for these types of improvements at all sites – for example replacing the oversized motors and the drives for the feed mill at Teys (which is the largest load and also contributes to poor power factor).

- *More efficient controls and operating procedures* also reduce base-loads, including occupancy sensing controls on HVAC and lighting, controlling air compressors and chillers to have a leading machine running all the time and a lagging unit (with a variable speed drive - VSD - installed on the lag machines). More controllable technologies (e.g. LED which can be modulated and VSD) facilitate improved control and allow modulation of usage instead of on-off operation. We identified significant opportunities for these types of improvements at all sites. A key point is that, where valves or dampers are used to reduce flows at times of low demand, they actually increase pump or fan energy consumption, as they increase flow resistance, offsetting some or all of the reduction in flow resistance in the pipes or ducts.
- *Very high efficiency electro-technologies* being installed replacing much less efficient thermal processes, though these new technologies could add a relatively smaller amount of electrical load. Heat pumps are an example which can be installed to recover heat and replace steam loads. Their installation could be accompanied by investment in hot or cold water storage to provide for load management. We found potential for improved technologies of this type at several sites, including Goodman Fielder, where there is potential to replace the boiler and steam system with a heat pump which recovers and upgrades the temperature of the waste heat rejected by the main site chiller compressors.
- *Improving power factor*. Low power factor reduces the effectiveness of power application and increases resistive losses in on-site wiring. Two of the sites had very poor power factors.

4 REALM INTEGRATION

Integration of REALM is a combination of:

- Deploying flexible loads: processes and systems with the potential for storage, loads which can be rescheduled, and ancillary loads which can be moved around
- Deploying storage (on-site and batteries): strategically using the surplus output available relative to the load profile of the site. Quite small amounts of storage, combined with smart demand management can help to smooth variations in demand and output from a renewable energy system (usually PV). While much focus has been placed on battery storage and its falling costs, existing thermal and material storage can often be deployed at a price far lower than battery storage.
- Control investments, strategies and systems to optimally drive the best combination depending on the electricity tariffs, labour and other operational costs

4.1 Integration of Load Management with Renewable Energy and Storage

When sites add generation capacity to the load usage flexibility discussed in the previous chapter, this adds an additional dimension to potential for load profile management. However, as PV has a generation profile that peaks in the middle of the day and tails off toward darkness it has a different role to play than say a cogeneration plant which needs to run with very high utilisation to pay back the investment. Tracking PV and east-west facing PV can extend generation hours but PV typically hollows out the facility daytime load profile - morning and evening load peaks can be left untouched (and therefore demand tariffs). Strategies for managing the interaction between PV and load shape include tracking PV (a longer, flatter ‘top hat’ peak but with additional capital and maintenance costs), east-west facing PV, targeted energy efficiency, demand management and energy storage. The value of even small amounts of load-shaping, efficiency or storage can be surprisingly high for avoiding demand charges.

Given the low energy feed-in rates offered for customers selling power back to the grid, there is a very significant incentive to utilise all power generated on site to displace retail purchases. These characteristics make storage an even more critical part of optimal utilisation of PV. The basic strategy to be applied for integrating load management with PV is to utilise all the PV generated during the day in operations, charge storage any time there is surplus PV, and then operate from this energy storage (allowing energy intensive plant to be turned off/down) when power prices are highest and/or demand charges can be avoided. Care should be taken to ensure that any energy efficiency or other productivity penalties are taken into consideration. These penalties can be obvious, like any requirement for extra labour or any loss in materials, or capital requirements to increase plant capacity or storage capacity. Some penalties are less immediately obvious, like the COP (energy efficiency) penalty of operating chillers more during the day into ice storage compared to operating them at night.

REALM systems will increase the capacity of businesses to install higher levels of renewable energy, primarily as more output can be used cost-effectively but also as revenue streams for energy market services expand. Stored output can be exported to supply power during high-price wholesale events, provide fast-response ancillary services, network services or system reserves. REALM systems increase the potential for renewable energy in Australia.

So, the optimisation routines need to look at the price signals operating at different times of the day and any demand response benefits, the cost penalties for operating in non-standard plant modes and deliver the lowest overall operating cost and highest net business value throughout the year.

4.2 Control Strategies

Control strategies for integration can be categorised based on a spectrum of complexity for implementation at the site:

Table 3: Control Strategies for load management

Control Strategy	Characteristics	Description
Simple	• Low capital investment • No major change in business practices • Implementation through existing/reprogrammed or upgraded control systems	Simple automated on/off load management procedures or reprogramming of existing Building Management Systems or control systems to better optimise existing storage to increase solar and/or shift load. Enhanced control systems will position sites to move into the next category as technology develops and better energy price signals are offered.
Medium	• Some additional monitoring and analysis to fully understand the systems and their operation and optimisation • Low risk capital expenditure • Generally designed with modest impacts on business practices, but there may be some additional operational implications and costs	Most of the site examples of load management in this project fall into this category. They primarily utilise existing plant and equipment but involve: • modest investments in controls or additional investment (e.g. installation or extension of a storage tank); • Investment in additional PV to maximise benefits; • operating implications which need to be assessed. These systems offer reasonable returns on investment under existing tariffs but may require smarter tariffs and/or external revenue streams to meet commercial benchmarks.
Complex	Significant capital investment in some or all of: • additional monitoring and analysis to fully understand the systems and their operation and optimisation • More upstream processing capacity and/or more process storage • battery storage • New plant/technology change	In general, the current price signals do not make the business case attractive, but energy market reform processes are likely to open up opportunities for more complex REALM strategies that can create wider value (e.g. off-grid/micro-grid systems).

4.3 Control Software, tools and equipment

Control software and tools extend from simple maximum demand controllers to the most sophisticated systems to optimise energy costs. The capabilities of more complex software include real-time optimisation including energy consumption, generation output, forecasting of solar generation (based on weather/cloud control), storage capacity, and energy prices. Some of the leading energy companies such as Siemens and Schneider Electric have demand control products in the Australian market.

In the course of the REALM project, we spoke variously to companies that were developing products and aggregators and sites. Some of their observations include:

- Overseas demand controllers are being imported and calibrated to the Australian market in response to emerging opportunities;
- Limitations were noted on the availability of demand control technology functionality, including optimising to multiple price signals on the one site and coordinating loads across large numbers of sites;
- Several companies are working on developing new demand controllers;
- The field is on the cusp of major development from multiple sources such as emerging data analytics and machine learning systems which allow data inputs from a wide variety of sources including financial flows, maintenance requirements and activity levels to be taken into account.

Some load management systems can be dynamic and decide on load control options based on the status of the system at the time. Advanced control software is essential in these situations.

4.4 The Value Stack for REALM – Energy Markets

In addition to reducing on-site energy bills (unit and network demand tariffs), load flexibility has other sources of value for the energy market - and revenue opportunities for businesses. Demand management and demand response can reduce the cost of:

- **wholesale energy**, by meeting peak demand at lower cost than additional generation (e.g. peaking gas plants);
- **transmission and distribution network charges**, by avoiding or deferring network upgrades to meet higher peak demand, replacement expenditure and operating expenditure;
- **ancillary services**, by providing frequency and voltage control at lower-cost than centralised generation;
- **system reserves/emergency services**, by providing low-cost on-demand capacity to the market operator to manage contingencies.

Australia's energy markets have not usually rewarded customers for demand flexibility – they have been treated as 'fixed loads' and supply-side options have been used to manage energy reliability and security. Consequently, there is poor alignment between the energy market value of REALM and the incentives and price signals that shape the behaviour of businesses. The primary incentive for businesses is to avoid demand-based network tariffs based on maximum demand across a month – which often do not coincide with network and wholesale market peak events.

However, that is changing now. Energy market regulators have just approved changes - or are considering how to implement changes - that will open up new opportunities for businesses to earn revenue if they can provide demand flexibility in response to a price signal. Table 4 provides a summary of the value stack for demand management, the current revenue opportunities and how the energy market is changing.

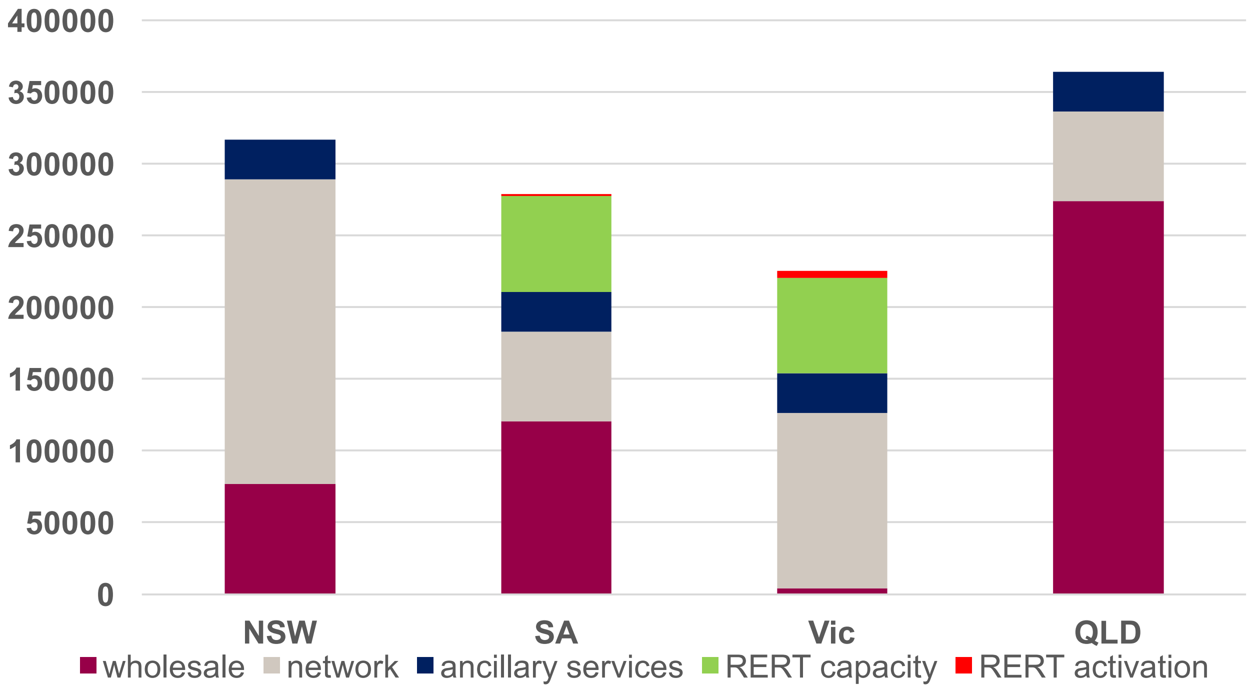
Table 4: Energy Market Services - the Value-Stack for REALM Systems

Energy Domain	Value of Demand Management	Is there currently a revenue opportunity for business?	Current Energy Market Reforms?
Wholesale electricity	**Lower market pool price** Generation or load-reduction could lower prices during major peak events and smooth demand on a daily basis (e.g. moderating the ramp up/down as solar output increases and decreases).	**Rarely** Demand response can occur via contracts with retailers but in practice it is rare. Retail tariffs for businesses generally provide a blunt price signal (at best, a peak price from 2 – 8pm) with only some value available to businesses.	**Yes** The Finkel Review recommended demand-side bidding into the wholesale market be facilitated which was endorsed by the Australian Government. The Australian Energy Market Commission has released a review with 3 different models, including provision to open access to specialist aggregators. Other changes are also being considered or introduced to give businesses better opportunities for wholesale demand response (e.g. a 'day-ahead' market, the introduction of 5-minute settlement period in 2021).
Transmission & Distribution networks	**Lower capital expenditure** Reduced peak demand could defer or avoid network augmentation (and associated operational expenditure).	**Rarely** Network support payments can be negotiated on a case-by-case basis in areas with impending constraints but they are infrequent. Demand-based network tariffs for businesses rarely provide an effective price signal or incentive aligned with actual peak events.	**Yes** The Demand Management Incentive Scheme (DMIS) was approved in April 2018. Networks can access around $1 billion over the next 5 years for demand management where it is cheaper than new capital expenditure. Network pricing is also in the process of transition to cost-reflective pricing which aims to align consumer tariffs with network peaks.
	Lower replacement expenditure Load could be reduced on targeted lines to extend aging asset lifetimes	**Rarely** A notable example is an incentive from Ausgrid to businesses in inner-west Sydney to use solar and energy efficiency to reduce load.	**Yes.** The scope of the DMIS includes aging assets and risks associated with equipment failure.
	Ancillary services (frequency and voltage control) – distribution By adding or withdrawing load (e.g. in lines with high intermittent renewables or edge-of-grid locations)	**No** Whilst there is no regulatory impediment, networks do not	**Yes.** The scope of the DMIS includes voltage, frequency, power quality management, power flows and system security.

	businesses could provide network services.	use business flexibility in practice.	
Frequency Control & Ancillary Services (FCAS)	**Lower FCAS costs** There are 8 markets for the delivery of FCAS.	**Yes**. Demand management has grown strongly in FCAS since it was opened up to specialist aggregators but it remains a small-scale market.	**No proposed changes**
Emergency Services	**Reliability and Emergency Reserve Trader (RERT)** Based on pilots during 2017/18 summer, AEMO found demand management 'a reasonably low-cost way of delivering reserves to the system, providing there is sufficient notice and price certainty'.	**Yes** Subject to various conditions (e.g. 10MW load, 30-minute availability etc.). AEMO can contract subject to demonstration of need to maintain reliability targets. AEMO entered into agreements for 1150 MW of capacity in 2017/18.	**Yes** The AEMC is considering a request for a rule change from AEMO to make it easier to procure demand response for the RERT.
	System Restart Services	**No**	**No**

Revenue streams are location and time-specific. Figure 17 illustrates the revenue that could have been available within each of the major state markets within the NEM during 2017.

Figure 17: DR Revenue, Indicative 2017 ($/MW)



Note 1: wholesale value is based on bidding 1MWh into each half-hour settlement minus a retailer margin of 15%

Note 2: RERT figures based on AEMO/ARENA 2018

Note 3: ancillary services based on information provided by an aggregator

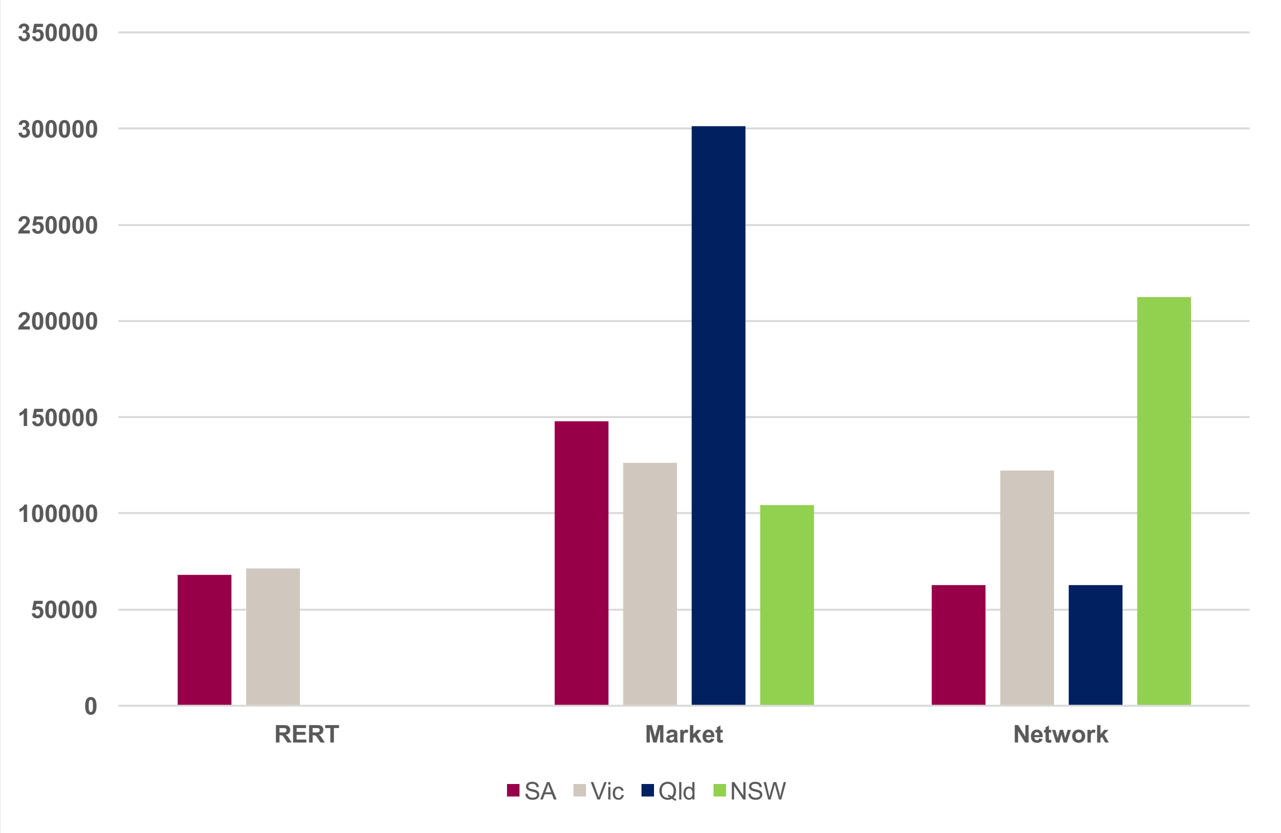
Note 4: networks value based on the average value within a zone which has a deferrable investment in each state using data from the Network Opportunity Maps developed by ISF. 75 per cent of the value is assumed to be available. In practice, the opportunity for a deferrable investment is only available in a small percentage of assets within all networks except Jemena.

There is significant variation between states and of course in future years the revenue from FCAS and wholesale markets is highly uncertain.

In practice, it's also not possible to value-stack in this fashion. RERT capacity must be off-market and not available for wholesale or FCAS markets. RERT is only available subject to demonstration of risks to reliability standards for organisations that have been successful in tendering to be on a short-term and medium-term panel for AEMO. There are also few network zones in which there is a deferrable investment opportunity – less than 5 per cent in most distribution networks.

A more accurate representation is shown beneath, where businesses may be able to access either RERT or market revenues (wholesale and FCAS) and then a network opportunity if they are located in a zone and available to provide the appropriate capacity.

Figure 18: Demand Response, Revenue Sources, 2017 ($/MW)



5 REALM PILOTS

Pilots to test and demonstrate the potential for REALM were undertaken in seven sites:

- A Supermarket in South-West Sydney (Woolworths);
- A telecommunications aggregation node in Melbourne (nbn);
- An edge-of-grid agri-business, in-land Queensland (Teys);
- A retail outlet, Inner-Sydney (Ikea);
- A food manufacturing facility (Goodman Fielders);
- A greenfield cold-store site (V&C Foods);
- A light manufacturing site (Schneider Electric).

The pilot sites represent a cross-section of industries (retail, manufacturing, agri-business, food distribution and manufacturing, supermarket, telecommunications), network contexts (including an edge-of-grid operation) and includes one greenfield site. The pilot sites for REALM contain a variety of the potential flexible loads (with the exception of materials storage).

Table 5: Flexible Loads, REALM Pilot Sites

	Ikea	Schneider Electric	Woolworths	V&C food	nbn	Goodman fielder	Teys
Storing heat			Y	Y		Y	Y
Storing cool	Y	Y	Y	Y	Y	Y	
Storing materials							
Discretionary loads	Y	Y	Y	Y	Y	Y	Y
Existing batteries	Y				Y		
On-site generation	Y	Y	Y	Y	Y	Y	Y
Targeted energy efficiency	Y	Y	Y	Y	Y	Y	Y

5.1 Methodology

For each pilot the following steps have been undertaken:

- A site visit by A2EP and ISF staff;
- Analysis of REALM opportunities by A2EP based on the site visit, tariff and load data;
- Optimisation modelling from a model developed by ISF;
- A workshop to present and discuss the results with each site.

The model was built to determine the total cost for a range of financial metrics of meeting a site's load for a given combination of:

- Generation technologies;

- Load shifting regimes;
- Grid costs through energy tariffs, network tariffs and demand charges.

Optimal sizing and control strategies were converged upon by running the model for a range of sizes and configurations through Monte-Carlo and brute force approaches, Analysis of the costing for every combination with reference to one another allowed the relationships of increasing size of the different technologies to be ascertained. Part of this analysis was the generation of heatmaps (including throughout reports).

The model used a hierarchical approach where the load curve was augmented by generation technology and/or load shift, in order of utilisation preference, for example:

1. PV array direction 1
2. PV array direction 2
3. Cold tank
4. Battery
5. Grid

In this way, the onsite renewable energy generation consumption was maximised, and the cheaper load flexibility was utilised before the more expensive battery storage. Minute by minute solar data was utilised with the Perez et al. cloud model applied, together with the load curve resampled to a one-minute granularity, to maximise the value of the battery and flexible load shifting.

Multiple storage (both battery and cold tank) control strategies were designed, however it became apparent a mix of peak shaving and arbitrage was optimal. Charging of the storage medium was defined to occur when there was excess renewable generation and from the grid when tariffs were at their lowest with preference given to charging from excess renewables generation. An algorithm was written to determine an optimum power each day above which the storage medium discharged such that the maximum peak shaving could occur and the battery state of charge completely exhausted. This charge limit was calculated every 24 hours, with reference to the state of charge at 7am. This time was identified as optimal as it came at the end of both a low demand and low tariff period.

5.2 Site Results

5.2.1 Teys

Teys operate a beef cattle feedlot at Condamine, inland from Brisbane on the fringe of the electricity grid. The facility fattens and standardises the quality of cattle before production of meat for market. The feedlot has the capacity to manage 30,000 head at any one time.

The major energy consuming activity is preparation of food for the cattle. Liquefied Natural Gas is trucked to the site and used to produce steam for cooking. Over 80% of site electricity is used to operate the grain mill and food production equipment. Food preparation usually occurs each day between 6am and 3pm. Water is added to grain which is cooked in steam chests, cracked and flattened in a rolling mill before being mixed with molasses and vegetable oil to produce animal feed. The steam is supplied by burning liquefied natural gas (LNG) in a boiler.

Two electricity meters are installed, one for the main mill, and another for a variety of other activities. Daytime demand for the food processing is reasonably stable (typically 180 to 250 kW over the period from 6am to 6pm) with variations due to changes in stock numbers, operating performance and weather. Other equipment, including pumps, lighting, offices and accommodation creates some demand spikes of up to 50 kW and varies seasonally.

The site has two back-up diesel generators of 150 kW and 157 kW capacity. Neither is synchronised with the grid. After the site analysis was conducted, a 300 kW photovoltaic generation unit was installed.

This plant buys grid electricity at a fixed price per unit, with monthly peak demand charges based on kilowatts, not kVA (kVA increases relative to kW as Power Factor deteriorates). Most electricity usage is from 6am until about 3pm. Time of use pricing is available, but is not utilised, given the dominance of daytime loads. Power Factor is relatively poor, at 0.75 (ideal value is 1.0) but at present this does not impact on electricity pricing. This site is located at the fringe of the electricity grid, where supply reliability can be poor. Present electricity volume prices are relatively similar to the rest of Queensland, however the demand charges could be considered high. The cost of LNG is also reasonably high.[5]

On the present tariff for the grain mill, a significant monthly demand charge is incurred for the highest demand in one half-hour period within the month. The present PV system is unlikely to reduce this demand charge because the peak demand often occurs outside the hours when the PV system is generating. More broadly, even if peak demand did occur during the day, significant cloud on just one day, or even a short time of high demand would set the demand charge for the month. Improved equipment flexibility and intelligent controls, and/or energy storage, could reduce peak demand charges.

The site has significant potential to improve energy efficiency and manage demand by investing in variable speed drives, control hardware and software. However, the lack of electricity pricing signals means that only fairly straightforward measures that reduce electricity consumption and monthly peak demand are likely to be attractive at present. Given rapid changes in energy markets and technologies, in future the site could collaborate with the distribution network or other emerging businesses to provide valuable network support – or even disconnect from the grid. It has excellent solar energy resources, constitutes a large portion of load in an edge-of-grid location and produces a large amount of manure that could supply biogas and/or electricity well beyond the site's requirements.

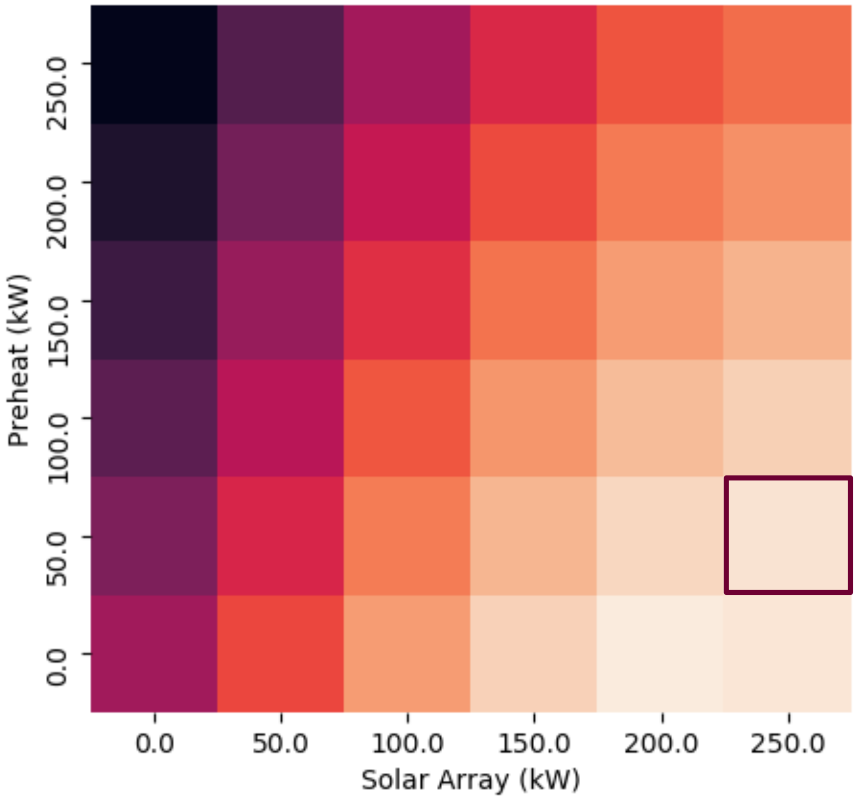
The modelling focused on a simplified demand model and considered:

- Additional PV capacity with variations in orientation;
- Battery storage;
- Pre-heating water for the boiler using excess PV output.

As Figure 19 shows, returns on rooftop solar marginally increase with boiler pre-heat capacity and the optimum combination is 250 kilowatts of solar (north-facing) combined with 50kw of boiler pre-heat capacity.

[5] Oakley Greenwood (2017) "Gas price trends review" accessed at *https://www.energy.gov.au/publications/gas-price-trends-review-report*

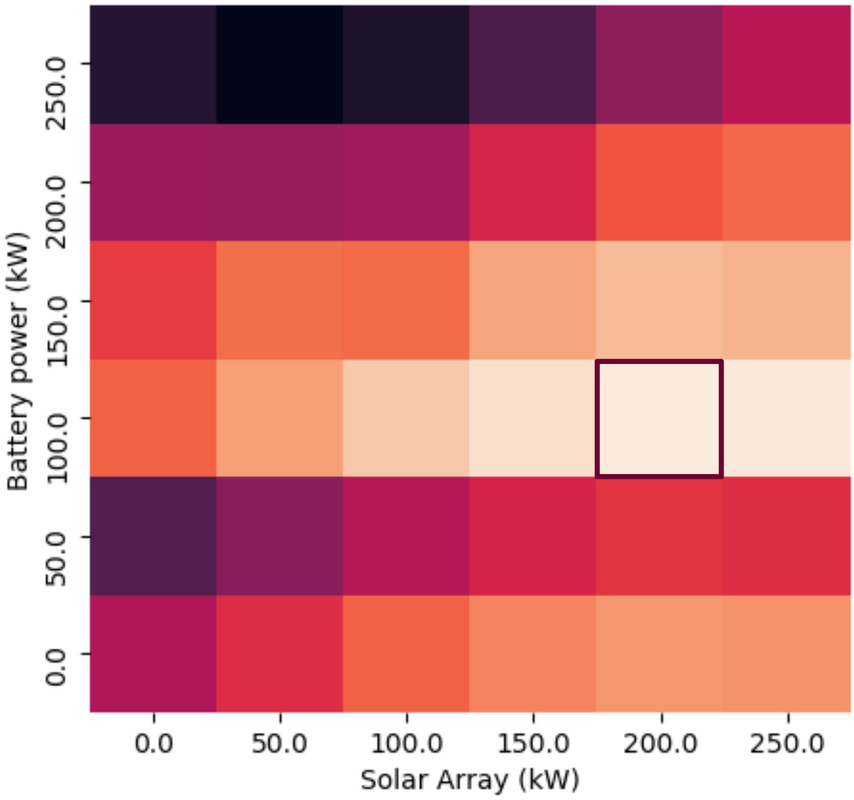
Figure 19: Solar PV capacity and boiler pre-heat capacity, NPV



Note: the lighter the colour, the higher the return.

However, as Figure 20 shows, if battery cost falls to $500/kWh, 100 kW of battery storage is more cost-effective than the boiler pre-heat option.

Figure 20: Solar PV capacity and battery capacity, Internal Rate of Return



The optimal configurations based on battery prices of $500/kWh and $1000/kWh are set out below:

Table 6: Boiler pre-heat & Battery Scenarios with 250kw Solar, Key Indicators

	Capital Expenditure	Simple Payback (years)
S1: Battery $1000/kWh Boiler pre-heat (50kw) + 250kw Solar	$312,500	6
S2: Battery ($500/kWh) 100kw Battery + 250kw	$429,500	5

The capital investment in boiler pre-heat capacity is currently the optimal configuration and hedges against gas price increases. However, if the battery storage price falls to $500/kw, this would be a marginally more cost-effective solution. Both investment in pre-heat boiler capacity and battery storage delivers a superior return to solar PV alone.

5.2.2 IKEA

IKEA's Tempe store in inner Sydney is a 40,000 square metre 'big box' retail facility that combines warehouse, retail, offices and a café and operates 7 days a week for extended hours. Electricity is used for air conditioning (primarily cooling), lighting, operation of a restaurant, office equipment, charging batteries of fork lifts and operating a variety of equipment such as hydraulic waste compressors. The site hosts a 990kw solar PV system, a back-up generator, EV forklifts, a building management system, and 1.8 megalitres of cold water storage tanks.

This IKEA site operates on a time of use tariff with a demand charge. The off-peak price (from 10pm to 7 am) is roughly half the peak price (3-9pm), while the price from morning till mid-afternoon is 83% of the peak price – offering a modest incentive to shift demand. In addition, a monthly demand charge of over $10/kVA of peak demand is paid for the highest half-hourly usage in each month (reducing monthly peak demand by 100 kVA, 10-15% of present monthly peak demand, would save around $13,000 p.a. on demand charges).

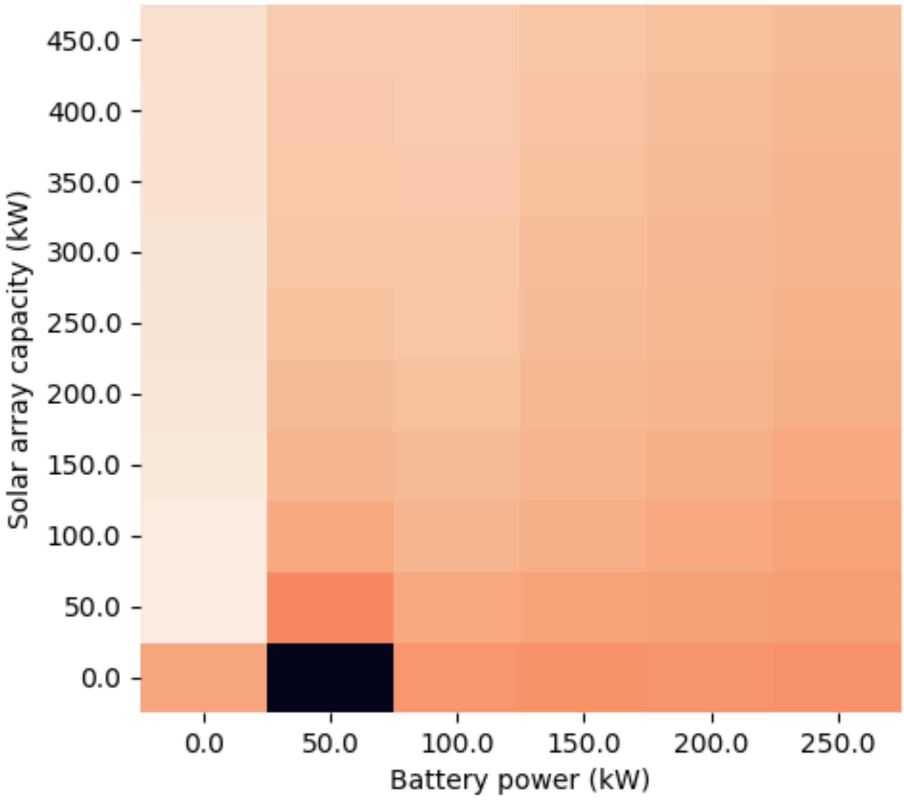
IKEA's load profile reflects a number of factors:

- The chilled water storage is cooled overnight, using relatively cheap off-peak electricity.
- Electricity demand is relatively low until mid-to-late afternoon. During this time, the stored chilled water contributes to cooling the building and the large rooftop solar PV offsets a significant proportion of site electricity consumption. An economy cycle (which uses cool outdoor air to reduce cooling energy consumption) also helps to reduce electricity consumption until outdoor temperature rises above 23C.
- From mid-to-late afternoon, demand increases, reflecting increasing cooling load, declining solar output, depletion of the output of the stored chilled water system, shutdown of the economy cycle, and increased activity in the store.

The site already has a number of best practice energy features but there is significant additional potential for improved integration of clean energy solutions including energy efficiency (building envelope, equipment and operational practices) to reduce total and peak demand, load-shifting, optimising use of the existing chilled water storage to increase rooftop solar and reducing higher-cost afternoon and evening peak demand and potentially battery storage.

For IKEA, the modelling focussed on testing optimum combinations of solar PV, chiller control upgrades to use off-peak power or additional PV output to alter the timing of cooling load, and battery storage. Figure 21 illustrates the returns from different combinations of additional solar and batteries under current prices ($1000/kWh) and without controls to optimise use of the chillers. Additional solar without a battery would deliver returns to low to be worthwhile.

Figure 21: Additional PV & Battery Storage (no chiller controls)



Smaller battery sizes do not have sufficient capacity to adequately address the peaks and consequently there is a considerable jump in IRR between the 50kWh battery size and the next step at 100kWh.

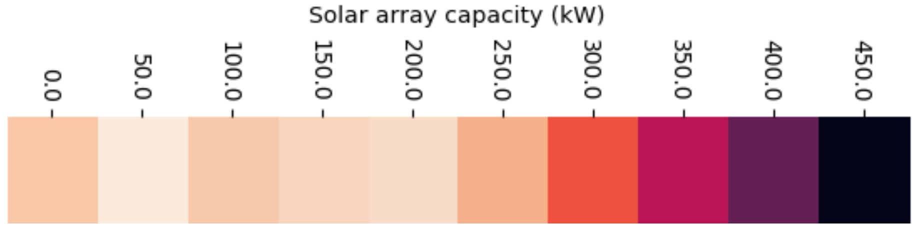
Table 7 compares results for a chiller control upgrade on its own (spreading cold tank discharge across the whole day instead of finishing in the early afternoon) and a chiller control upgrade with an additional 250kw of solar PV (to permit charging of the cold tank with excess generation during the day which is used later in the afternoon). The chiller control upgrade on its own delivers a higher IRR and very quick payback, but the additional PV delivers a higher NPV.

Table 7: Comparison of Chiller Upgrade and Chiller Upgrade + 250kW Solar

	Capital Expenditure	Simple Payback (years)
Chiller Controls Upgrade	$20,000	1
Chiller Controls upgrade + 250KW Solar	$317,500	7

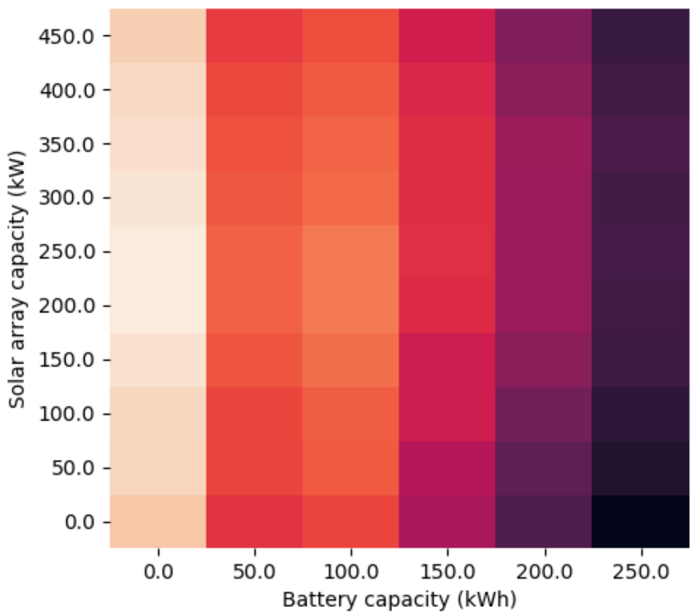
The existing cold-water tank provides adequate storage capacity which removes any case for a battery at present as is illustrated by Figure 22.

Figure 22: Solar PV, no battery, with chiller control strategy



However, as battery prices fall, batteries could be combined with this configuration of solar and upgraded chiller controls, with a battery in the range of 100kW being the optimal size. However this would lower both the NPV and the IRR of the resulting investment.

Figure 23: Solar PV & Battery Storage (Chiller Control Strategy), $500/kWh Battery Price



Battery storage at improved prices still deliver a low return but there could be an opportunity to use existing on-site batteries in the forklift fleet as batteries are scheduled for replacement. There are 18 number of electric forklifts that operate from 10pm-10am and charge until mid-afternoon. If the charging and discharging patterns were varied the forklifts could provide around 50KW of storage, reducing the amount of battery storage to reach the optimal level of 100kw.

Development of load flexibility would increase IKEA's capacity to manage electricity costs in the future, as pricing structures and solar feed-in tariffs change. Whilst there is uncertainty over future tariff structures and prices, the broad direction will be towards more variable and 'cost-reflective' electricity pricing. Future electricity prices are likely to be highest at the times when the IKEA store in this study has high demand – unless it proactively manages its demand profile.

5.2.3 Schneider Electric

Schneider Electric's energy audit report for the Gepps Cross site in South Australia is attached. Gepps Cross is a light manufacturing facility (e.g. moulding) which operates 24/7 Monday-Friday and some Saturdays. The site includes a factory, warehouse, distribution centre and the commercial office building. The site has a peak tariff that covers 7am – 10pm. Around 70 per cent of electricity consumption occurs during peak tariff and 30 per cent in off-peak periods.

Energy conservation measures assessed were:

- General lighting upgrade (2.9 year payback);
- Voltage optimisation (2.7 year payback);
- Variable speed drive (4.5 year payback);
- Compressed air (3.3 year payback);
- BMS tuning (1.3 year payback);
- Lighting control upgrade (0.7 payback);
- Material drying (3.6 year payback).

Modelling was undertaken to examine the opportunity to use either additional cold tank storage or battery storage to facilitate additional solar PV. The financial performance of chilled water tank improves under the modelling relative to Schneider Electric’s assessment from over an 11-year payback to around 6 years for a small cold tank (500kl) in concert with PV. Schneider Electric’s assessment appears to have only included shifting consumption from peak to off-peak whereas the ISF model also includes network demand tariff.

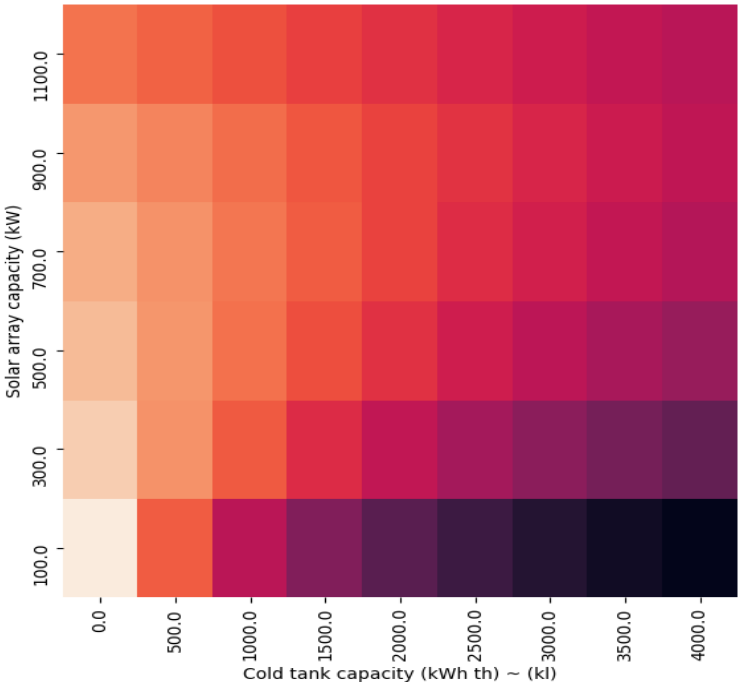
The best returns occur with the installation of additional solar PV without battery or additional cold tank storage but returns from combining this with a small to moderate battery and/or with 500kl cold tank is only narrowly inferior.

Either a cold tank or battery would increase the flexibility of the site, but the battery is the more flexible option as it is able to reduce demand at any point in the day, at its maximum capacity. A cold tank on the other hand can only reduce the load by the amount that the chiller would have otherwise been operating at that time.

Load flexibility will improve Schneider Electric’s ability to manage changes in tariffs in future years (noting Schneider Electric’s current 15-hour peak tariff is especially blunt) and respond to energy market changes. At this point in time however we note that the 15-hour peak tariff (covering 7am to 10pm) works to the advantage of Schneider Electric and a potential investment in solar power, as all of the solar systems generation hours are covered by the peak tariff.

The results vary quite significantly depending on whether maximising IRR or NPV is the goal. Figure 24 illustrates the results for IRR using different combinations of solar PV.

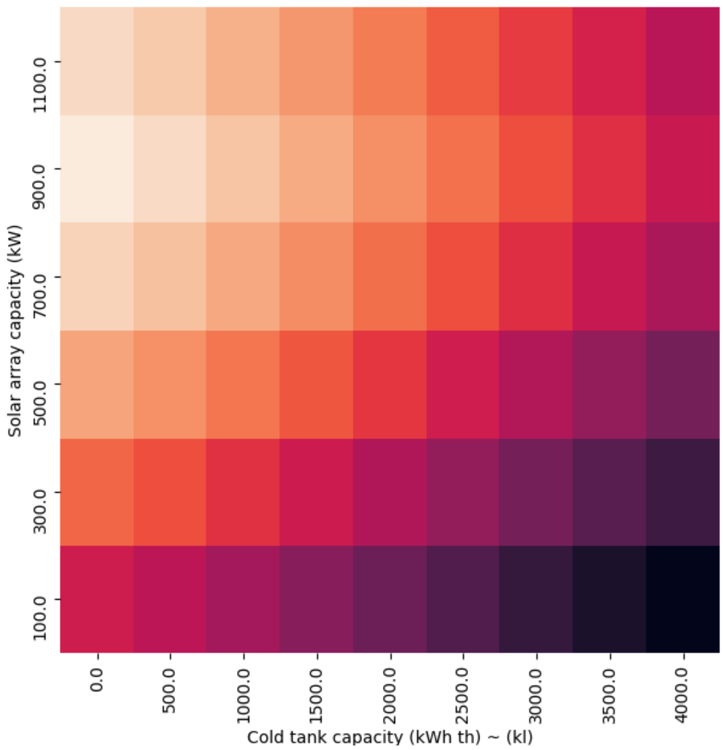
Figure 24: Solar PV & Cold Tank, IRR (%)



To maximize rates of return, only the planned 100kw of PV would be installed. However, as

Figure **25** illustrates, an additional 800kW (900kW total) of solar would deliver a higher NPV. This has been sensitivity tested at PV price points of 1.19 $/W and 1.81 $/W, as upper and lower bounds on the system prices available in the market today, depending on site conditions. The NPV sweet spot remains in the 700kW to 900kW range.

Figure 25: Solar PV & Cold Tank, NPV ($)



As solar prices increase, optimal array size decreases modestly, but in both cases, looking across at the column illustrating results for a 500kl cold tank, the differences between outcomes relative to no load flexibility are modest. Table 8 details the payback indicators for some of the salient scenarios. A two-stage solar installation of 100kW followed by an additional 756 kW has been used to match most closely Schneider Electric's plans for the staging of the array.

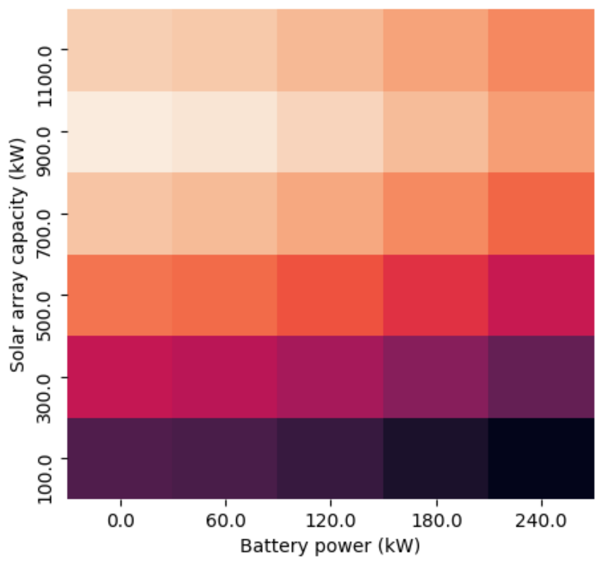
Table 8: Solar PV, Cold Tank and Battery Scenarios, Key Indicators

	Capital Expenditure	Simple Payback
S1: 100kw PV,	$119,000	4
S2: 100+756kW, PV,	$1.02m	5
S3: 100+756kW PV, 500kl cold tank	$1.38m	6
S5: 100+756kW PV, 60kw battery	$1.06m	5

Over the lifetime of these assets, it is likely there will be changes to tariff structures and opportunities to earn additional revenue from energy market services which need to be considered. The cold tank has an options value relative to simply installing solar.

Modelling configurations using a battery price of $500/kWh, the returns improve but the fundamental story remains unchanged. The optimum scenarios are still 100kw of solar and 900kw of solar to maximise IRR and NPV respectively (see Figure 3 on NPV).

Figure 26: Solar array size v battery size, NPV ($)



The cold tank and battery storage are using the same excess output so no scenario involving a combination of the two was returned in the modelling. However if tariffs were to change, a cold-tank focussed on strategy that assisted with peaks but also maximised arbitrage posibilities could be deployed in tandem with a battery focussed on peak shaving.

5.2.4 Woolworths

Supermarkets are relatively energy-intensive compared with most other commercial buildings. Woolworths has an Energy Management Centre with a team of specialists who are monitoring store energy use, developing other improvements on an ongoing basis, and rolling out projects such as use of low-UV LEDs in stores and refrigeration equipment to save energy and slow ageing of vegetables. Woolworths operates around 3,500 stores around Australia, builds between 15 and 30 new stores each year, and refurbishes and upgrades existing stores on a regular basis.

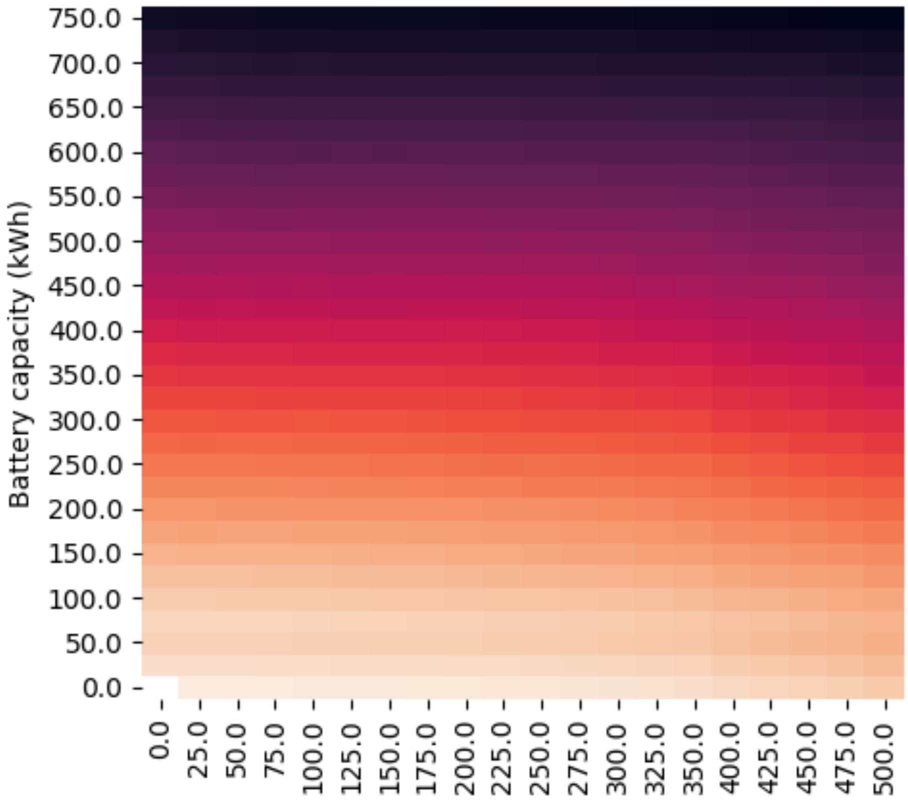
The Engadine store that is the subject of this project does not reflect the features or performance of their new stores and major refurbishments today. Located in a single storey shopping mall in the southern suburbs of Sydney (Engadine), the store has a 100kW rooftop solar system and a small back-up energy system to keep cash registers and lights running during power outages. Its cash register/public entrance area is open to the mall common area, so there is significant air flow between the mall and the store. Net electricity demand typically trends upwards in afternoons and evenings, as solar generation declines, in-store activity increases and (in summer) cooling loads increase (partly driven by thermal inertia of the building). Peak demand occurs around 6am in summer, but later in the morning in winter (possibly partly due to daylight saving). Overnight loads are substantial, presumably reflecting long opening hours, stock replenishment, high refrigeration loads and/or scheduling of activity to take advantage of low off-peak electricity prices. A large portion of the demand could be described as 'base load', but this is not really the case. This demand is comprised of many different activities such as baking, cooking, cleaning and refrigeration. In practice, demand for each of these activities is quite variable, so there is substantial scope to manage these loads to smooth and reduce demand. From an energy bill provided, the metered peak demand on which the demand charge is calculated was 454 kVA in June 2017, well above average demand of around 340 kW. This may be related to the high start-up load of space conditioning and refrigeration equipment, as well as intermittent loads.

In the discussion with Woolworths staff on the preliminary findings of the REALM project, it was clear that they were already adopting many of the energy efficiency measures identified in this project or had trialled them and found them unsuitable for roll-out. Nonetheless, this REALM project site analysis has a number of useful outcomes, including:

- Exploration of how integrated 'behind the meter' energy production, demand management and energy productivity measures may interact with a typical existing supermarket's demand profile
- Improved understanding of barriers to action in a retail mall, and issues for and expectations of a retail sector operator
- Identification of emerging energy productivity and energy market-related opportunities for supermarket and other retail operators.

ISF carried out modelling of a variety of on-site renewable energy and energy storage configurations. However, none of these produced financial benefits that met typical business criteria for returns on investment. The 100kW rooftop solar system is well-sized relative to the daytime load and the site has low off-peak and shoulder tariffs. Consequently, even at lower battery prices of $500/KW, none of the combinations of solar and batteries produce a positive return. The use of existing cold storage is not a viable option because the chillers operate at high capacity around the clock and space constraints also rule out other options such as Phase Change Materials. Figure 27 plots the returns for different combinations of battery and additional solar capacity.

Figure 27: Solar PV & Battery Storage



An array of energy efficiency and demand management opportunities were identified including use of variable speed drives to manage spikes, hot water efficiency, thermal building efficiency, HVAC and refrigeration efficiency. Following review with Woolworths a further workshop will be scheduled to discuss evaluation and implementation of energy efficiency opportunities.

5.2.5 Goodman Fielder

The Goodman Fielders plant at Erskine Park includes two facilities (a baked frozen bread plant and a liquids factory) with shared facilities for steam, hot water and compressed air. In the baked frozen bread plant, cooling is delivered by large refrigeration chillers which are the dominant plant electrical loads (2 x 220 kW ammonia chillers and a 38.5kW chiller for delivering chilled water). There are also 2 x 103 kW chillers for the factory HVAC system (and associated cooling towers) for the whole factory. The liquids factory, which has a less intensive load largely associated with mechanical mixing and blending, has a 150 kW ammonia unit for a chilled water circuit.

There are two separate meters with peak demand between 450-650kW (total load is about 1 MW). Demand on Monday mornings is extremely peaky, with up to 200kVA departures (probably largely a result of the cooling plant being restarted after a weekend shutdown and clean). Fortunately for the site, they are not charged for these deviations as the peak demand is only measured based on the demand from 1-8PM on weekdays. There is not much energy being consumed when the total plant load exceeds 450kVA, so there are opportunities to reduce peak demand under the current network tariff. Importantly though these changes would not necessarily reduce the costs to the network to any degree, and the current tariff does not provide any price signal to encourage load relief, or to avoid infrequent very high generating system energy charges (as the tariff only has annual peak, off peak and shoulder rates). It is likely peak demand can be reduced by 50-100kVA in the short term (saving around $10,000 p.a.).

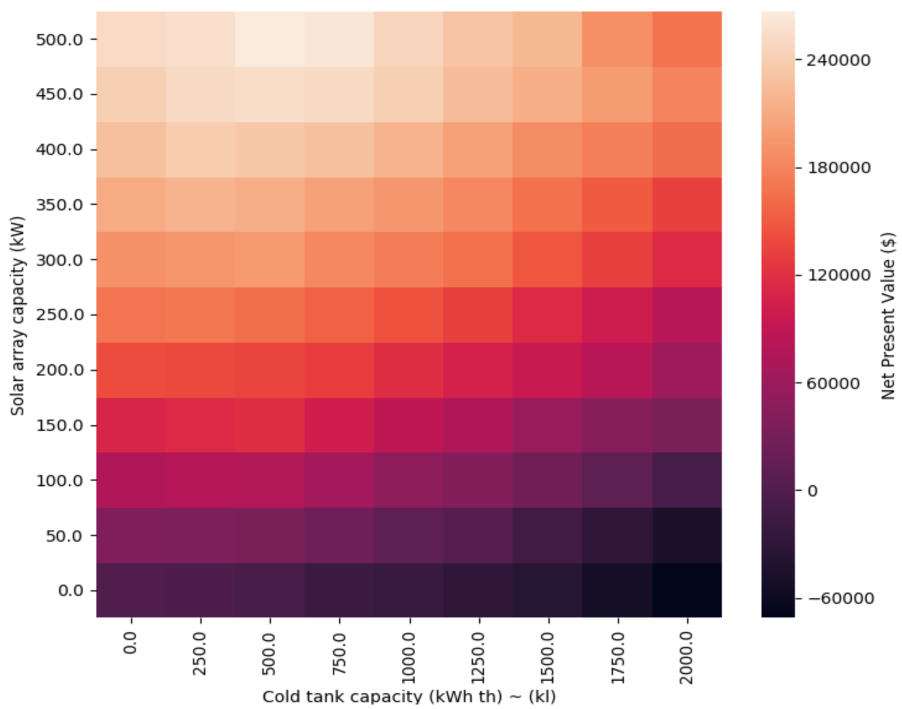
Once the solar is installed, there may be additional load management opportunities as the duration of loads over say 350kVA would be far lower between when the solar generation falls and the 8PM end of the demand period, and this could provide an opportunity for greater savings using the chilled water option, but this will be limited by the existing blunt price signals. A short duration price signal which reflects real system costs would provide better returns and energy market value than the current tariffs.

The site assessment found scope for additional energy efficiency options; Improving refrigeration plant operations by removing all portable refrigerated containers and replace with proper refrigerated storage, and improved controls, variable speed drive on one (lag) chiller compressor. Implementing real time energy monitoring by connecting existing meters to data storage and reporting tools and set targets and reporting metrics for each area to maximise value of existing investment in data management system.

Installing a heat pump to recover heat from the main ammonia chiller condensers and supply 80+ degree water to replace the boiler and steam system (with support from one or 2 small packaged boilers to supply local steam loads) could potentially halve gas use (with a small increase in electrical demand). The heat pump would be used to charge hot water storage for washing/CIP duties. This project requires a full feasibility study and is well suited to the planned ARENA process heating grant program.

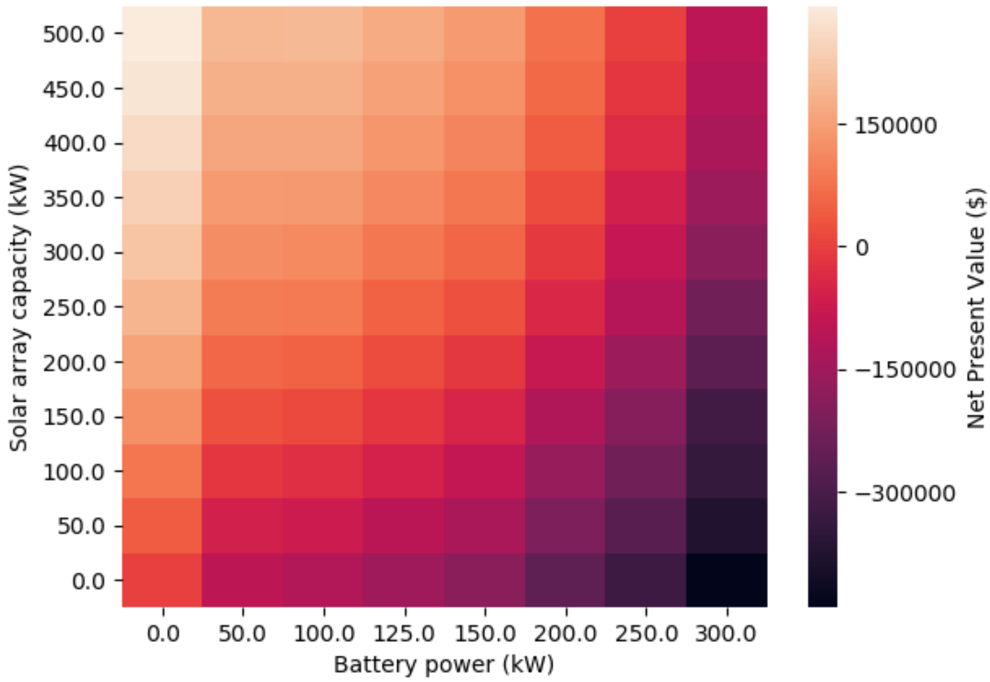
Modelling was undertaken to examine the opportunity to use either additional cold tank storage or battery storage to facilitate additional solar PV. In the midst of the project, a new tariff agreement came into force with significantly higher unit prices. Under both tariffs, the optimum scenario included 500kl of additional cold water tank storage – the difference is the optimum amount of PV increased from 150kw to 450kw.

Figure 28: Solar PV & Cold Tank, NPV ($)



As shown in Figure 29, inclusion of a battery does not improve returns. This is shown by all the brightest (highest return) tiles in the chart being located on the left most side under the solar only section.

Figure 29: Solar array size vs battery size



The cold tank has a fixed 125kWe maximum load it can displace, as this is the load of the chiller which would otherwise meet the relevant thermal load. Larger cold tanks increase the amount of time this load can be avoided, but do not change the power that is shifted. A battery on the otherhand comes in modular units which usually represent approximately 2 hours storage capacity at their rated power output. More storage in kWh is usually accompanied by greater power (kW). In terms of comparing the two charts, a 1250kWh th cold tank (approx 250kWh e) would be roughly equivalent to a 125kW battery. Relatively short-term storage is what the Goodman Fiedler site requires in order to conduct effective peak shaving. As Table 9 illustrates, even at battery prices of $500/kWh, cold tank storage produces better returns.

Table 9: Comparison between Battery and Cold Tank Storage

Type	With 450 kWh solar PV.	With 150kW solar PV.
Battery power equivalent to chiller power Battery 2 hours storage (at $500/kWh) 125kWe battery discharge power	IRR: 1.5% lower than optimum	IRR: 2.9% lower than optimum
Equivalent storage-time cold tank Cold tank : 1250 (kWh th) / approx 2 hours 125 (kWe) chiller displaced	IRR: 0.4% lower than optimum	IRR 0.9% lower than optimum

Optimal cold tank (short storage time) 125 (kWe) chiller displaced cold tank : 500 (kWh th) / approx 0.8 hours	Optimumighest NPV Capex: $591,350 Simple payback: 6 years	IRR: 0.3% higher that optimum combination Lower NPV

Goodman Fielder is also considering energy market revenue opportunities and has commissioned Enernoc for advice.

5.2.6 nbn

nbn's aggregation node in inner Melbourne - one of 10 such facilities around Australia - was assessed. The facility is a repurposed warehouse with office areas at the front. The majority of the site's energy use can be attributed to the network equipment, associated infrastructure and cooling. The site is connected to the electricity grid and has 100 kilowatts of rooftop solar PV (covering about half of the roof area and providing a modest contribution to annual electricity), four back-up diesel generators and substantial battery storage that largely exceeds site peak demand (which reflects the very high priority nbn places on reliable service provision and allowance for demand growth). A Building Energy Management System is installed but data from it was not available at the time of the assessment. The system provides monitoring but not automated control. Interval meter data (half-hourly consumption) for a year was provided by nbn staff.

Whilst there is little scope for on-site optimisation of renewable energy through load management as nbn's load profile is quite flat, a number of energy efficiency opportunities were identified throughout this project. These include improved data monitoring and application of data analytics, ICT cooling, space heating, lighting, office HVAC and generator testing.

In a separate project, A2EP is researching and preparing a guide on Industry 4.0 and Energy Productivity. Examples of business opportunities include improved data monitoring, analysis and control to identify and quantify the value of energy performance measures, as well as support optimisation of operation. Lower cost, more flexible sensors and rapidly developing data analytics and artificial intelligence systems are reducing costs of improved energy management and supporting use of multiple data streams to optimise capital allocation, maintenance and operational practices.

In the context of REALM opportunities, nbn could potentially generate revenue from its gensets and UPS at this site and across its other sites by providing energy market services. nbn will eventually need to replace its fleet of batteries across its telecommunications sites in mid-term as they begin to reach end-of-life. The present lead-acid batteries cannot sustain high rates of charging and discharging and deep discharge shortens life. Lead-acid batteries could be replaced with more flexible battery technologies, such as hybrid batteries (a combination of lead-acid and super-capacitors), flow batteries or lithium-ion batteries for nbn to provide DR services.

A specialist aggregator with experience in DR for data-centres, were consulted twice in the development of this report. Their advice is that generic costs for batteries are not useful for data-centre DR as there is a wide range in costs for different sites, contingent upon factors such as security requirements and grid connection. Each of the four broad types of revenue opportunities (wholesale, networks, ancillary services, system reserves) is location specific. ISF has sourced data on the four broad types of revenue sources for 2017 but there is significant uncertainty on future earnings and each revenue stream is location-specific. For example, wholesale prices will vary based on factors such as the outcome of rule change processes, timing of closure of coal-fired power stations and the volume and cost of demand-side participation.

nbn’s demand response capacity also creates a good platform for a renewable energy power purchase agreement. The ICT sector have been one of the major users of renewable energy power purchase agreements globally. The size of nbn’s load and capacity to use DR to smooth out mis-matches between the output of the generator and load position nbn well to negotiate a RE PPA which are now often cost-competitive with grid electricity.

5.2.7 V&C Foods

The V&C pilot is a greenfield site for their new store in Nowra. Minus40 (a refrigeration specialist) has been engaged by V&C Foods (South Coast Stores) to design and specify their refrigeration system for the new cold store. The new facility will have offices, a butchery and retail area as well as cold and freezer room storage. The plant has been designed with energy optimisation in mind, reclaiming heat from the refrigeration cycle to heat water for various processes in the facility as well as using other integrated technologies and optimised control for energy and operational savings.

The main load for this site was cooling. The modelling considered the cost effectiveness of various solar array sizes and tested the optimum combinations of PCMs and battery storage for deferring cooling loads and absorbing excess solar. The model used synthetic demand curves that were based on a high efficiency HVAC system that is being proposed for the site. Also, as it is a new site, tariffs were modelled based on the tariff agreement of a major supermarket.

The costs of PCM are somewhat uncertain as quotes are still being procured. There are three key elements – the supply and installation, additional costs relating to freezer paneling (higher ceiling to accommodate PCMs) and additional costs for steel racking to support the PCM’s. Consequently, model runs were undertaken for different capital costs.

Notwithstanding the price uncertainty, the results demonstrate that PCM’s are not cost-effective. Figure 30 plots the returns for different combinations of solar capacity and PCM at the higher end of the cost spectrum. With a capital cost of $120,000 for the PCM system, the NPV is substantially negative. The optimum configuration for a solar PV system is 80 kW.

Figure 30: Solar PV capacity and PCM capacity ($120,000 system), NPV

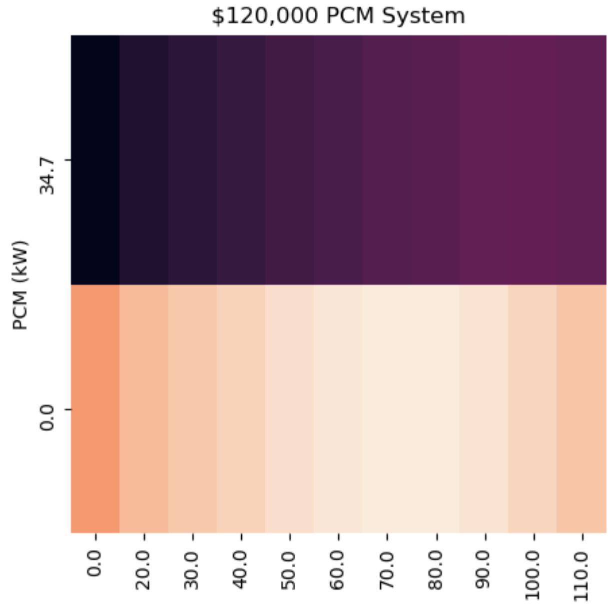
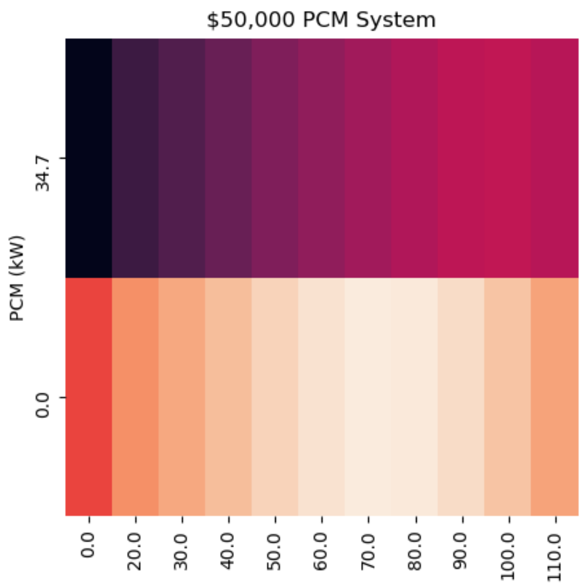


Figure 31 plots the same combinations with the cost of the PCM system at $50,000 which is substantially lower than the current quotes - which delivers a low return with a large PV system of around 100 kW.

Figure 31: Solar PV capacity and PCM capacity ($50,000 system), NPV



The best scenario for a PCM and Solar PV combination includes: North facing solar of 100 kW PCM and 34.7 kW, however at an 8% discount rate this has a negative NPV, and therefore too low a return to consider.

As a result, the best solution is to install solar PV on its own. NPV is highest at around 80kw whilst IRR is highest at smaller system sizes.

An interesting technical aspect of PCM systems that did not fundamentally affect these results, but which should be considered when scoping sites, is that their effectiveness is reduced when paired with a chiller that has a high coefficient of performance (COP). This occurs because the PCM system acts to defer thermal loads, not electrical loads. The higher the COP of a chiller, the lower the amount of electrical energy required to meet thermal load. Therefore, when the deferred thermal load is converted to electrical load, a higher COP will result in a lower electrical load deferral.

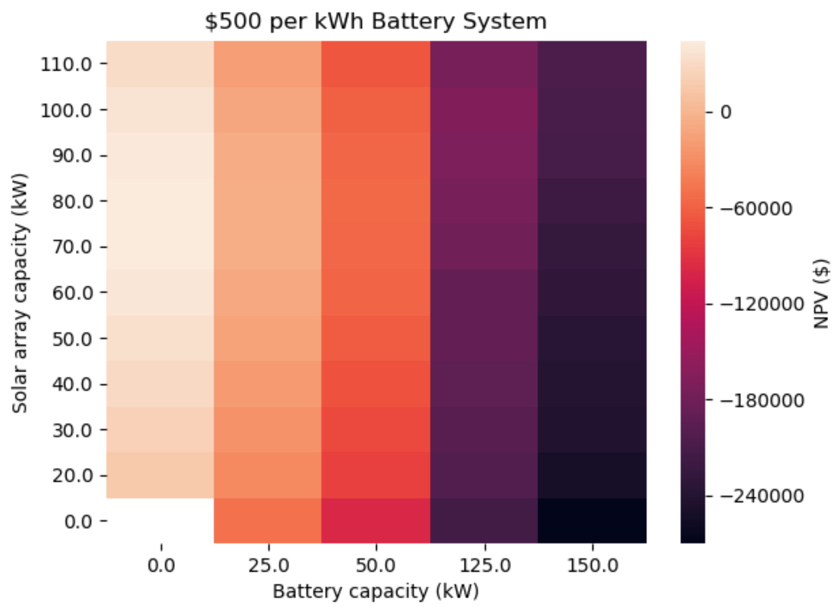
Considering the relationship between PCM systems and the COP of chillers, as well as the results of the modelling, it is reasonable to conclude that PCM systems may be a good option at very specific sites with the following characteristics if the capital costs significantly reduce:

- existing low COP chillers;
- ample room for PCM installation at low cost; and
- an existing oversized solar PV array that is exporting electricity to the grid at a low (or zero) feed-in tariff.

The dispatchability of PCM systems, or lack thereof is a constraint that may also need consideration. For example, the proposed V&C Foods site in Nowra may require a grid connection upgrade if the existing connection does not have the capacity to handle the site's potential peak loads. A PCM system may not be a reliable option to reduce peak loads at the site, particularly if non-cooling loads are present, because it may only operate according to the duty cycle of the chillers. Therefore, a PCM system may not be a reasonable technology to assist the deferral of a grid connection capacity upgrade. A better option for such a need may be a more dispatchable device like a chemical battery.

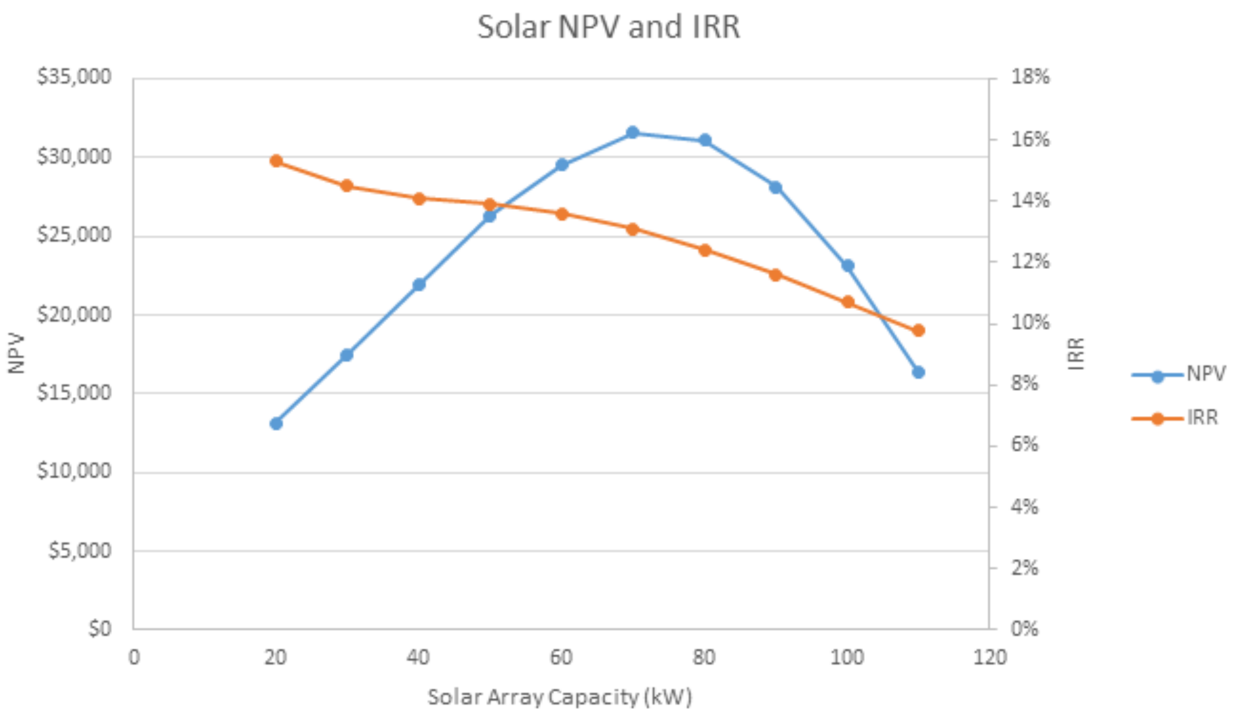
Batteries were also not cost effective. As seen in Figure 32, even at the capital cost of $500/kWh (around half current costs), batteries do not return a positive NPV.

Figure 32: Battery Storage and Solar PV capacity, NPV



The optimal solution is to install solar PV on its own. The size depends on which metric is preferred as illustrated by Figure 33 NPV is highest at around 80kw whilst IRR is highest at smaller system sizes.

Figure 33: Solar PV, NPV, IRR



5.3 **Site Results: Overall Findings**

Considering the sites as a group, the key findings were:

- The pilots confirmed a range of demand flexibility opportunities exist on-site in addition to battery storage, including cold tanks, phase-change materials, boiler pre-heat, electric vehicles
- The on-site thermal storage options are generally cheaper than battery storage (and from the pilot sites cold storage applications are the technology with greatest potential) and deliver positive returns but generally beyond standard commercial benchmarks. The costs for non-battery storage applications were sometimes not easily available and in general less transparent than for battery storage.
- At most sites, increased load flexibility increased the value of solar PV and capacity to install higher levels of solar PV.
- Of the sites examined, only two sites had limited opportunity for REALM. Both were high-efficiency sites with large solar arrays (Woolworths) but this site had identified opportunities for network and wholesale energy bidding that could not be implemented due to coordination challenges and the absence of suitable offerings from networks.
- A further site (nbn) had limited on-site REALM opportunities due to a large, flat load with large UPS and back-up generation but potentially a large opportunity for DR energy market services subject to the development of business case for upgraded batteries.
- Tariffs are poorly aligned with network and wholesale peaks. Re-designed tariffs which were better focussed on emerging wholesale peaks (later afternoon) or critical network peaks (instead of monthly) with incentives to use power at other times would significantly improve the business case.
- At all sites, even those with on-going energy efficiency programs, there was significant potential for additional energy efficiency to reduce overall consumption and demand peaks;

6 BARRIERS TO REALM: UNLOCKING DEMAND-SIDE FLEXIBILITY

There is agreement amongst Australia's energy market institutions that there is significant untapped potential to improve the efficiency, security and reliability of our energy system by making greater use of load flexibility (see AEMO 2017; AEMC 2018; CSIRO; Commonwealth of Australia 2017).

> *To maintain system reliability at an efficient price, the full range of resources available need to be valued for the characteristics they can bring to the market. The current arrangements do not fully optimise the value that could be delivered by some resources, particularly price-responsive demand and fast responding storage. To deliver improved market outcomes, flexible resources should, for example, be rewarded for their ability to shift demand to the low load periods and to follow the ramp more effectively and efficiently. The current market design does not support these capabilities, and no single participant has sufficient system-wide situational awareness which AEMO, through a well-designed market, could provide to value this capability (AEMO, p10)*

However, this is now changing; every part of the value stack is either now open to businesses or the focus of reform processes to create new opportunities for price-responsive demand flexibility. The AEMC has released three models for demand-side participation in the wholesale energy market for stakeholder comment, a rule change has been lodged by the AEMO to improve access to demand response for the RERT and the DMIS has now commenced which opens up funds for businesses to provide network services where it is cheaper than new capital expenditure.[6]

The Australian Energy Market Commission has observed there is a 'lack of transparency' about how much wholesale market demand response is being utilised, its efficiency and the potential. This study has underlined the potential for low-cost demand flexibility but also that barriers will need to be addressed to unlock its potential.

6.1 Supply Agreements and Tariffs

The primary mechanism for unlocking load flexibility should be energy tariffs that deliver a price signal reflecting the energy market value of consumption. To get business willing to modify normal operations, the value delivered by doing so has to demonstrably and unequivocally significantly exceed the cost of acting. In addition, business energy users generally will not volunteer to do anything which results in increased operational complexity, diverts management attention, involves investment of time (and sometimes capital), and most importantly risks interfering with production or with a customer experience.

Current retail energy tariffs and network tariffs generally provide very blunt price signals, and often these do not reflect the actual costs of operation of the electricity supply system. This is a major limitation for achieving the type of load flexibility the system needs from its customers to most cost

[6] The Australian Energy Market Commission (2018: 35-36) previously rejected a rule change for demand-side participation in the wholesale market but has recently stated: 'Historically, a "reliable" power system invariably meant back-up generation … however, the emergence of new technologies and ensuing regulatory developments have meant that reliability is no longer the exclusive domain of "supply-side" solutions: Rather, the demand-side … now has a potentially important role to play in delivering a reliable power system at the lowest possible cost … it is abundantly clear that the demand-side will continue to be a key factor in driving the transformation of the energy sector … In the long-term, the Commission considers that the role of demand side in the wholesale market will be much stronger, resulting in a genuine two-sided market.'

effectively deliver energy services to the customer base, particularly in the light of increasingly volatile supply from renewable sources.

In country areas, there can be large subsidies for supply, so that when avoided government subsidies, network subsidies, societal benefit of avoided network infrastructure, reduced maintenance costs, etc are all considered, a much stronger case for major change can exist. In Western Australia and Queensland, recognition of these costs is influencing governments and energy agencies to promote storage and off-grid solutions.

If energy suppliers/regulators want to have energy users become a valuable and consistent part of their networks, offering load flexibility and other network services, there has to be an adequate financial reward, that it is easily accessed. The elements of an offer that impact on customer willingness to participate include the number of load changes required, the duration, the depth of load reduction, the flexibility in response allowable.

The characteristics of supply agreements that will appeal to customers are:

- Very clear and differentiated pricing for changes in load.
- Contracted clear benefits in bill savings and credibility of agency offering the arrangement. The price signal should be an incentive as many businesses would not have the flexibility to respond (and therefore just acts as a price increase)
- Ability to control loads by themselves (not remotely implemented), and have some flexibility about how much load to reduce, if there are operational issues at the time of a control signal
- Clear terms including the number, size and duration of load management required. Note that businesses generally deal with shorter duration events better than longer duration, which may require alternative/additional strategies and control, and investments, and thus higher payments.
- Continuity – once they have set up, including in some cases the business has invested funds to implement the control strategy, they would like the agreement to be in place for an extended period to ensure it will pay off and no chopping and changing the deal.
- Design the arrangement to facilitate automation of the control measures but with customer override capacity.
- Companies would also like to see that their efforts contribute in some way to the improved operation of the system

It is very clear from the case examples that current supply agreements do not provide price signals that meet client needs for a scheme that they would happily respond to - nor do they provide a good indication of the costs of operation of the electricity supply system. All the sites that participated in REALM agreed that tariffs provide little to no signal for load shaping which does not shape their investment decisions. In the case of the greenfield site, V&C food, there was no tariff agreement; the business case for REALM by using a tariff structure negotiated by a larger retail outlet that is unlikely to be achievable for them.

For energy efficiency measures, our inability to credibly identify the value of savings on an hourly 'real time' basis makes it difficult to incorporate them into 'energy market thinking' and to allow comparison with other options that manage demand. Work by groups like OpenEE in the USA may change this but, in the meantime, this acts as a barrier to energy networks and retailers sending price signals to energy consumers.

While supply agreements and tariffs are very important, they do not address a number of other issues discussed here, such as application of high discount rates and high IRR hurdles that affect valuation of future savings, revenue and increased flexibility in future business strategy. Also, while long term agreements can provide certainty, penalties or restrictions can undermine scope to capture benefits from changes through innovation.

6.2 The Capacity of Sites to Implement Change

The REALM project undertook feasibility assessments at sites within seven organisations, generally large corporates. The organisations were selected because they are progressive in their approach to energy management and interested in learning more and applying REALM principles within their organisations or sites.

However, even within these organisations, we found significant barriers to optimising load flexibility. Some of the key issues we found were:

- **Data quality data and data management systems**: a consistent feature across most sites was the quality of the data and its management. Variously, there were faulty building management systems, data was sometimes deleted after a certain time period preventing longer-term analysis, and on several sites the data available did not net out the impact of rooftop solar, creating challenges to understand their native energy load.
- Even on a site with a sophisticated BMS with self-learning capacity and sub-metering, there was substantial opportunity for improvement. Revisions could include improved through data storage protocols (e.g. to avoid deleting data after 1-year or even a few days) and real time), benchmarking of performance to better use the data. Potential developments could include upgrading the BMS to use predictive modelling to optimise solar and storage utilisation, and improvement in the communication of 'actionable advice' instead of raw data. There was a lack of information on the fundamental energy requirements of services and processes and real time equipment or process-specific energy use – so it was difficult to calculate equipment energy efficiency and, in turn, potential savings. This made preparation of a credible business case difficult.

  Emerging advanced data analytics, machine learning, improved access to data from BMS and utilities, cheaper sensors, and access to skilled data analysts and communicators will be important in addressing these issues.
- **Building management systems**: as Building Management Systems are often proprietary software, site personnel also sometimes had problems getting access to their energy data and it acted as a barrier to developing expertise in optimal equipment management and operating equipment efficiently.
- **Access to specialist expertise**: in-house and independent specialist expertise in demand-side solutions is limited. This limits corporate confidence and leads to higher perceived risk. It also adds to the challenges of delivering quality outcomes.
- **Demand control technology**: Our review of demand control software has also found further technological development will be needed to fully enable sites to deliver wider energy market services. For example, our understanding is that there is not currently a software package that could optimise multiple loads in response to external price signals (e.g. FCAS, wholesale, networks). Woolworths had investigated the opportunity to participate in the RERT scheme but were unable to aggregate sufficient load across its stores through automation.
- **Challenges at existing sites**: design and installation of measures at existing sites can be more expensive and potentially disruptive to production and organisational arrangements, adding to costs and increasing perceived risk and concern regarding the impacts on employment of individuals, need for retraining,
- **Energy knowledge and expertise:** the level of understanding of site energy profiles and opportunities for REALM is uneven. In particular:

- Understanding of site energy profiles and load flexibility;
- Understanding of existing on-site storage opportunities, especially in cooling applications
- Understanding of how rooftop solar interacts with demand charges and therefore the returns from investments.

- **Competition for scarce capital**: whilst there are good opportunities for investment in load flexibility, they are competing for capital against both energy and non-energy projects. Opportunities for energy efficiency and renewable energy are better understood at all levels of the business. Competition from more attractive investment opportunities in other areas can also limit the capital and resources for energy investment. On the upside, energy investments are relatively low-risk (relative to say a marketing initiative).
- **Managing complexity:** the integration and optimisation of loads, renewable energy and storage potentially involves collecting, analysing and monitoring complex data. As part of REALM, a model that incorporates different types of loads and their properties has been developed – but obviously that is not a viable solution for each site. Developing more standard tools and solutions delivered through service providers will be essential for unlocking load flexibility.

6.3 Accessing energy market revenue streams

The development of rules, capacity and relationships with customers by energy market organisations will also be essential to build demand-side flexibility. With some exceptions, Australian energy retailers and networks have not sought to contract for load flexibility amongst their customers. ISF analysis has previously demonstrated the biases against demand management in energy rules (Dunstan et. al. 2017).

In relation to the wholesale market, the Australian Energy Market Commission has noted in its current reliability review the key factors that impede the development of wholesale demand response:

- difficulties for non-retailer service providers or aggregators to access the wholesale market;
- barriers for retailers: lack of expertise, up-front costs and risk of not realising investments due to term of retailer contracts which are insufficient duration;
- Retailers have alternative means to manage wholesale exposure through generation assets and financial instruments.
- Lack of competition for demand management services

Various issues observed during the REALM project and by participating sites were:

- High uncertainty on future revenues and costs (in part related to policy uncertainty);
- Transaction costs: developing knowledge and expertise in a new area, accessing the market;
- Low competition: retailers charge a high margin to access the wholesale market through demand management;
- Demand control technology: for example, the technology to aggregate loads across 10's of sites to provide energy market services does not currently exist in the Australian market;

- Limited transparency on network projects (e.g. one of the pilot participants noted they had investigated the scope to participate in network projects but not found anything that matched their circumstances);
- Notice periods and terms of participation (e.g. firmness of commitment).

The Demand Management Incentive Scheme has responded by offering up to $1 billion in matched funding for cost-effective non-network solutions. However, informal discussions by ISF has found networks are struggling to identify projects up to the value of available funding, reflecting limited knowledge on the implementation of demand-side projects; identifying opportunities, the consumer relationships and cost.

Simply changing the rules will not be enough. Certainly, if the rule change is well-drafted, it will encourage new market entrants, aggregators and retailers and networks to establish new business units to pursue market opportunities. However, developing REALM will also require demonstrating its effectiveness to retailers and networks and building relationships with customers.

7 CONCLUSION: NEXT STEPS

Deploying REALM pilots, which test the boundaries of both technology and the market, will give Australia a first-mover advantage in business-led renewable energy. Australia is already leading the world in residential deployment of renewable energy and is forecast to have one of most decentralised energy systems globally in coming years. Australia now has the opportunity to do the same for the commercial sector - capitalising on the rapid changes in our energy market, new technologies and emergence of innovative local energy businesses. International organisations such as IRENA have identified the opportunity for the integration of renewable energy and load management (through energy efficiency, demand management and other energy productivity measures) but no-one has yet globally demonstrated this in practice with a set of meaningful coordinated projects that deliver workable knowledge for the sector.

> *“Well considered load management increases the value and capacity to install on-site renewable energy by optimising it with flexible loads”*

Demonstrating REALM systems can remove a key barrier to renewable energy uptake: under-sizing systems to avoid low value grid export. This study showed that, across most sites, there is scope to configure a REALM project that would increase the value and installed capacity of renewable energy on-site (Table 10). If these projects can be shown to deliver these benefits in real case studies, more businesses will seek to unlock this value and expand their renewable energy deployments by using flexible loads.

Table 10: REALM and Increased On-site Renewable Energy

Site	Does REALM facilitate higher on-site renewable energy?	Quantum
nbn	No. 100kw system is a small portion of load and no load-shaping is required for additional solar.	n/a: nbn is assessing an opportunity for additional pv irrespective.
Ikea	Yes	250kW (existing 990kw system)
Teys	Yes	250kW (existing 300kw system)
Goodman fielder	Yes	450kW
Woolworths	No	n/a: 100kw system already on-site
V&C foods	No	n/a: optimum solution is 80kW of solar without storage
Schneider Electric	Neutral	Returns for 900kw PV with and without storage are very similar – but storage offers option value likely to earn higher returns over time

Again, it is important to note that this is under existing tariffs and excluding revenue from energy market services.

This study demonstrated that at 5 out of 7 sites, there was significant scope for increased demand flexibility or energy market services. In half the sites it was also evident that load flexibility increased the potential for viable on-site renewable generation. The proposed interventions to achieve this ranged from installing demand controllers and more generally from investing in additional capacity, to leveraging energy storage to deliver new market services. As the costs of new load management technologies (such as batteries and advanced controls) fall, greater sources of demand-side flexibility and associated revenues will become available. Piloting options for demand-side flexibility across several sectors will facilitate greater system hosting capacity for renewable energy across Australia.

The majority of businesses need to see successful projects before they engage deeply with the management of their energy. While the cost of energy is of rising concern, it is still not the core focus of most companies. Seeing successful REALM pilots that deliver tangible value for a company (particularly a competitor!) will raise the profile, and the likelihood of uptake, of both renewable energy and load management.

To transition REALM from demonstration pilots to broader industry application requires preparation from multiple industry stakeholders, including suppliers, businesses and regulators:

- Businesses need to be prepared with well logged and thorough data on operations and energy use in order to mount the case for renewable energy and load management capital upgrades;
- Suppliers and aggregators need to communicate the value proposition and support pilot projects that demonstrate the value and operationalisation of REALM systems for businesses, energy networks and retailers. Suppliers and aggregators also have a role in developing business and market capacity and relationships and the commercialisation of demand-side technologies;
- Regulators need to consider market reform to open up the energy market revenue streams for load flexibility that can be delivered more cheaply than supply-side options to participating businesses, without onerous market registrations and risks;
- Networks in the transition to cost reflective pricing need to innovate electricity supply agreements and tariffs to provide genuine, focussed incentives for consumers that unlock value for networks.

Australia has an opportunity to manage energy cost and risk with new technology and new markets. As pilot projects develop, business, regulators and suppliers all need to be conscious of developing and positioning their activities in preparation to take advantage of the changing energy landscape.

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APPENDIX A: CASE STUDIES - SITES

1. Gardena Manufacturing Plant load management system

Example: The Gardena Manufacturing facility which produces 500 million plastic parts a year in southern Germany is a prime example of peak load management. This facility, on average, requires 2 to 2.3 MW of energy. However, when the machinery is restarted in unison after a short break, the power demand suddenly rises to 3.2 MW. In order to manage this power spike, nine Seimens Sentron PAC 3200 monitoring devices to measure voltage, current and power were installed. Their measurements are fed into a Simantic S7-400 controller, which monitors the average power use of the facility every fifteen minutes (which is the time span over which the utility company monitors the average used power) and caps it to a maximum of 2.86 MW. This is achieved with the use of a controller that scales back the power demand gradually in 200 kW stages. The installed load management system has paid for itself within a year.

Reference: https://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/efficient-energy-use-the-energy-efficiency-bonus.html

2. Resource and Energy Efficient Manufacturing (REEMAIN) project, Europe

Project running since 2013, combining cutting edge knowledge and experience from production processes, energy simulation software tools, energy and resource planning and renewable energy and storage to develop and demonstrate a methodology and platform to boost the efficiency of both energy and material resources.

Three demonstration factories representing energy-intensive sectors of the European manufacturing industry are part of the project:

- Food: Gullón, cookie producer, Spain;
- Iron and steel: SCM Group Spa – Fonderie, iron castings producer, Italy; and,
- Textiles: Bossa, fabrics and sportswear producer, Turkey.

Energy generation: Concentrated solar thermal collector prototype developed and tested at demonstration factory sites. Waste energy is recovered for reuse e.g. capturing waste heat from baking oven chimneys to preheat ovens.

Storage: Lithium ion battery storage systems - data is collected from sites to evaluate performance, cycle life and cost. The project is also investigating the use of soil as a seasonal store of thermal energy.

Energy efficiency/demand management/load flexibility: A decision making tool developed to support factory owners in the complex task of analysing and planning the best strategies to drive their factories towards the goal of zero-carbon manufacturing. The tool creates a detailed factory model in which different technical solutions are virtually tested and assessed. The tool evaluates and quantifies energy available from a range of sources and energy demand from a set of processes and the factory building services, in order to perform demand response and tariff analysis of the factory environment.

Reference: http://www.reemain.eu/

3. Smart ZAE industrial park, France

Smart grid industrial park in Toulouse designed to optimise energy management and reduce energy consumption of industries located in the park, while also being more compatible with the needs of the distribution grid.

Energy generation: Six wind turbines (60kW), roof mounted solar panels (200kWc) and two solar canopies (100kWc) connected to electric vehicle recharging terminals and electrical storage infrastructure.

Storage: Electrical storage infrastructure consists of 100kWh flywheel and 100kWh Li-ion batteries.

Energy efficiency/demand management/load flexibility: Prediction, monitoring and optimisation of the balance of renewable energy production and consumption. The sites uses Smart'eo smart metering and has software to forecast electricity consumption and production using weather data inputs. Demand management control on site and the benefit of economic flexibility with use of energy storage. This is achieved through a smart management algorithm that optimises the business park's consumption profile according to economic and energy input data. This directly results in reduced demand on the electricity grid during peak demand periods and lower electricity bills for the business park users.

Reference: http://www.scle-sfe.fr/en/Nos-ressources/Des-demonstrateurs/

4. Smart Green Tower, Germany

The Smart Green Tower, which will commence construction in 2017, will be a 16,000 square metre mixed-use residential and commercial building in Freiburg, Germany.

Energy generation: The tower will have a sheath made of glass photovoltaic modules with high performance PERC cells. Excess electricity generated will be fed back into the grid.

Storage: The building design includes approximately 0.5 MWh of storage in the form of a lithium-ion battery, with vanadium redox flow batteries to help link the building with future energy producers in the district.

Energy efficiency/demand management/load flexibility: Grid peak load control and energy monitoring are to be incorporated with the aim of reducing energy costs and carbon emissions without sacrificing occupants' comfort. The building management systems will use a direct current intermediate circuit rather than the standard alternating current transmission and distribution of electrical energy to reduce losses.

Reference: http://www.freyarchitekten.com/en/projects/smart-green-tower/

5. University of Genoa microgrid, Italy

The University of Genoa is implementing the "Energia 2020" project, which involves the development of a microgrid at its Savona Campus.

Energy generation: Energy is generated on site using three concentrated solar power (CSP) parabolic reflectors, gas micro-turbines and PV installations. The parabolic reflectors produce three kW of electrical energy and nine KW of thermal energy, the PV facility has a maximum output of 80kW and the gas turbines have 250 kW of electrical output and 300 kW of thermal output. The microgrid enables the University of Genoa to self-generate approximately half of its annual energy needs of one GWh.

Storage: Load demand is managed using two heat storage devices, two electric vehicle charging stations and sodium nickel batteries with a capacity of 100 kWh that can supply the campus with electricity for three hours, for example, when insufficient renewable energy supply is available and gas prices are high.

Energy efficiency/demand management/load flexibility: Absorption refrigerators are used for heating and cooling. The microgrid has an intelligent energy management system, Siemens Decentralized Energy Management System (DEMS), which uses smart meters to monitor all energy flows in real-time and ensure optimal operation of all energy generation units. It also forecasts energy demand and power produced from renewable sources using historical data and current information to deliver cost savings. The DEMS is linked to the SICAM PAS SCADA solution using the SICAM Microgrid Manager.

Reference: https://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/smart-grids-and-energy-storage-smart-grid-in-italy.html

6. Monash University microgrid, Australia

Monash University has recently begun work on a microgrid at its Clayton Campus as part of its aim to become powered with 100 per cent renewable electricity and carbon neutral by 2030.

Energy generation: 1 MW of rooftop solar PV has already been installed and another 3 MW of rooftop PV will be added by the end of 2018. The campus has a 500kW solar thermal hot water system, an ultra-efficient Greenland Systems Orange Series with advanced evacuated tube modules that can produce at temperatures up to 200°C. The solar thermal hot water system will eventually be extended to 1 MW to support the existing natural gas-powered district heating system. By the end of 2020 the university will be generating 7 GWh of energy and is in the process of securing renewable energy power purchase agreements so it is eventually 100 per cent renewable powered.

Storage: Installation of a 1 MWh battery is planned by mid 2018. The battery will be a vanadium flow/lithium hybrid energy storage system from UK-based redT energy. The battery system will be used to demonstrate the use of "energy storage" flow machines (suited to high-energy applications over many hours, like solar firming, which involve heavy daily cycling) integrated with "power storage" lithium batteries. Combined, the flow machine does approximately 80 per cent of the work each day, while the lithium element can be used infrequently to provide about 20 per cent of power requirements.

Energy efficiency/demand management/load flexibility: The project will explore the role of batteries in providing stability in the campus network, given high renewables penetration, and the potential for load shifting. The flow machine will be used to shape the building load profile to minimise costs on a daily basis, while the lithium component will be used to assist with the connection of the building to a highly intermittent and sustainable embedded generation network.

Reference: https://onestepoffthegrid.com.au/monash-uni-begins-solar-battery-storage-microgrid-road-100-renewables/?utm_source=RE+Daily+Newsletter&utm_campaign=e5132fbdf7-EMAIL_CAMPAIGN_2017_10_09&utm_medium=email&utm_term=0_46a1943223-e5132fbdf7-18471861

http://www.scle-sfe.fr/en/Nos-ressources/Des-demonstrateurs/

7. Renewable Energy Integration Demonstrator (REIDS) Project, Singapore

Semakau Island, Singapore is a landfill waste facility with an off-grid microgrid. It is the site of the REIDS project which seeks to research and test microgrid platforms suitable for deployment in tropical Southeast Asia.

Energy generation: Solar PV, wind, tidal, waste (from fish hatcheries located on the island) to energy, diesel genset, power to gas technologies.

Storage: Battery storage.

Energy efficiency/demand management/load flexibility: EcoStruxure Microgrid Operation software used to: increase resiliency, energy security and improve sustainability.

References: http://erian.ntu.edu.sg/REIDS/Pages/default.aspx and Schneider Electric https://www.schneider-electric.com.au/en/

8. Schneider Electric NAM HQ microgrid, USA

R&D centre microgrid located in Boston, with the ability to operate in island mode.

Energy generation: Solar PV and CHP.

Storage: Battery storage and EVs.

Energy efficiency/demand management/load flexibility: Utilises microgrid as a service model with Duke Energy delivering microgrid solutions with no upfront costs. EcoStruxure Microgrid Operation and Microgrid Advisor software used to : reduce exposure to volatile energy costs, increase resiliency, energy security and improve sustainability.

Reference: Information provided by Schneider Electric https://www.schneider-electric.com.au/en/

9. Montgomery County microgrid, USA

Correctional facility microgrid located in Maryland, USA, with the ability to operate in island mode.

Energy generation: Solar PV and gas engine.

Storage: Battery storage.

Energy efficiency/demand management/load flexibility: Utilises microgrid as a service model with Duke Energy delivering microgrid solutions with no upfront costs. EcoStruxure Microgrid Operation and Microgrid Advisor software used to : reduce exposure to volatile energy costs, increase resiliency, energy security and improve sustainability.

Reference: Information provided by Schneider Electric https://www.schneider-electric.com.au/en/

10. Synwater water desalination, Germany

Renewable energy powered water desalination by reverse osmosis, particularly for mines.

Energy generation: Solar PV and/or wind.

Storage: Surplus potable water produced during periods of high renewable energy production is stored in tanks to provide supply of potable water during periods of low renewable energy production.

Energy efficiency/demand management/load flexibility: Built in flexible ‘blocks’ or ‘containers’ of desalination, in 250 m^3/day units.

Can vary production based on renewable energy supply and flexible quantities of water storage (multi-day storage facilities for potable water) and can export power to grid during high demand periods if there are flexible tariffs.

Reference: http://synlift.de/

APPENDIX B: CASE STUDIES - NETWORKS

1. GreenLys smart grid demonstration project, France

Full-scale smart grid demonstration project in the French cities of Grenoble and Lyon involving 1,000 residential customers and 40 commercial buildings.

Energy generation: Decentralised energy generation based on renewables and natural gas.

Storage: Electric vehicles treated as a potential source of flexible storage capacity that can be reinjected into the grid when needed. On site energy storage systems at businesses.

Energy efficiency: Schneider Electric has developed the Wiser systems for residential customers, which monitors and controls all electrical equipment and can be programmed to energy-saving mode. Similar systems are also available for business customers.

Demand management/load flexibility: At the grid level new analysis tools, next generation substation automation equipment and smart meters at consumer locations. Cloud-based technologies to enable automated participation in demand response programs that offer financial incentives to residential and business customers for adjusting energy consumption when required. For example, cost savings of 16% were achieved by shifting heating load from peak to non-peak periods at the Schneider Electric 38TEC building in Grenoble. Actions are managed intelligently to maintain comfort and productivity.

Reference: https://download.schneider-electric.com/files?p_enDocType=Brochure&p_File_Id=485537211&p_File_Name=998-1242824_GMA-GB_Greenlys.pdf&p_Reference=998-1242824_GMA-GB

2. Nice smart solar district, France

Nice grid is the first smart solar district demonstration project in Europe, combining business and residential customers. The site was selected because there is a single 400 kV line that supplies the area and therefore there is significant risk of peak demand or voltage issues during summer. The Nice Grid can operate in 'island' mode, where the grid supply can be disconnected and the solar and battery systems continue to operate.

Energy generation and storage: 200 solar systems and 100 batteries with equivalent to 2 MWh of storage are included in the trial.

Energy efficiency/demand management/load flexibility: The network operator controls and optimises local energy generation in real time. Next-day forecasts of production and demand are taken and battery storage maintains voltage and frequency to offset intermittency in the supply of solar energy. This is achieved using GE software, called distributed energy resource management system.

Incentives for residential and industrial customers helps lower demand and demand response can be achieved with load and supply management (algorithms compute the optimal schedule considering demand-response and storage). For example, the distributed energy resource management system allowed the operators to offer a subsidy via text message to a local coffee roaster if the company fired up its ovens when neighbours' solar panels were generating excess electricity.

References:

- http://www.gegridsolutions.com/alstomenergy/grid/Global/CleanGrid/Resources/Documents/NiceGridat%20a%20glance.pdf
- http://www.grid4eu.eu/project-demonstrators/demonstrators/demo-6.aspx

- https://www.ge.com/reports/thats-so-nice-electricitys-digital-future-has-dawned-on-the-french-riviera/
- https://docbox.etsi.org/Workshop/2014/201412_M2MWORKSHOP/S03_SMARTandSUSTAINABLE_CITIES/ERDF_ARNOULT.pdf.

3. Issygrid smart district, France

The city of Issy les Moulineaux is a smart district in the inner suburbs of Paris created to demonstrate management of energy produced and shared locally. The project commenced in 2012 and was fully operation in 2016. Buildings included in the smart grid include around 1,000 homes, four office buildings and the Paris Law School, plus a portion the urban street lighting. An extension of the Issygrid is planned.

Energy generation and storage: PV, batteries and EVs. The project aims to better integrate local renewable energy production by using storage.

Energy efficiency/demand management/load flexibility: Optimise and reduce energy use e.g using building management systems to shift HVAC loads. Tools include a solar power forecasting system, 14 interconnected information systems and an energy monitoring dashboard. IssyGrid receives hourly consumption data for lighting, heating, water and electric sockets on a building-by-building basis. Residents can find out their average electricity consumption throughout the day and be informed of the level of solar power generation available on an hourly basis, six hours in advance, which gives them the option to shift their electricity consumption.

References: http://issygrid.com/en/home/

4. Isle of Eigg microgrid, Scotland

Until 2008, small diesel generators and a few micro-hydroelectric generators supplied electricity on the Isle of Eigg in the Scottish Hebrides archipelago. Between 2004 and 2008 a new modular flexible microgrid was installed and has resulted in a reliable energy supply and reduced utility costs for residents.

Energy generation and storage: The microgrid incorporates wind, PV, hydro, batteries and diesel generators. Approximately 95% of energy generation is from renewable sources.

Energy efficiency/demand management/load flexibility: Better load management supported the introduction of renewable on-site energy sources. Energy monitors were installed in all properties, including visual “traffic light” energy monitors. A passive droop operating strategy manages the batteries, as well as heating public buildings when there is an excess of energy produced.

References:

- http://microgrid-symposiums.org/microgrid-examples-and-demonstrations/isle-of-eigg-microgrid/
- https://www.siemens.com/content/dam/webassetpool/mam/tag-siemens-com/smdb/regions/china/topic-areas/sustainable-energy/distributed-energy-systems/documents/des-white-paper-en.pdf

5. IREN2 research project, Germany

IREN2 is a three year European Union funded project that commenced in 2017 to test the technical and economic viability of distributed renewable energy systems. One of the goals of the project is to develop microgrids for low and medium voltages, with particular focus on control systems, improving resilience (including system black starts) and microgrid management.

Energy generation and storage: The project builds upon a predecessor project, IRENE, which was implemented in the Bavarian town of Wildpoldsried, where renewable generation is now five times higher than self consumption. Solar and wind are the primary sources of renewable energy generation. Five biogas plants also operate in Wildpoldsried, with surplus heat being fed into the district heating network. Storage includes batteries.

Energy efficiency/demand management/load flexibility: The project is investigating operational strategies to achieve grid control and system reliability. Renewables are providing ancillary services required for grid operation.

Reference: http://www.iren2.de/en/

6. Reforming the Energy Vision (REV) – 2015 NY State Energy Plan, USA

In the aftermath of Superstorm Sandy the New York Public Service Commission, the New York Energy Research and Development Authority, the New York Power Authority and the Long Island Power Authority developed a strategy for a clean, resilient and more affordable energy system, which also aims to spur energy innovation, bring new investments to the State and improve consumer choice.

Energy generation: The REV aims for 50% for New York State's electricity to be produced from renewables by 2030. Renewable energy sources include: biogas e.g. produced in anaerobic digesters; biomass; fuel cells; hydro (from small to large scale); solar PV; and, land-based and offshore wind.

Storage*:* State R&D support includes a focus on storage and other innovations such as smart grid technologies that facilitate and reduce the cost of New York's transition to a REV-based energy system. NY-BEST was established in 2009 with $25 million in seed funding through NYSERDA to position New York Sate as a leader in energy storage solutions. New York also committed $65 million to Brookhaven National Laboratory to allow commercial developers to test battery and storage research in real time.

Energy efficiency/demand management/load flexibility: see below for discussion of load management in New York State. Energy efficiency programs include BuildSmart NY, Energy Efficiency Measures in Affordable Housing and Combined Heat and Power.

Reference: https://energyplan.ny.gov/Plans/2015

7. Demand management in New York, USA

a) Non-utility companies supporting demand management programs

New York State Energy Research and Development Authority (NYSERDA)

NYSERDA has been New York's administrator of funding for energy efficiency and load management programs since 1998. The funding comes from a System Benefits Charge paid by Central Hudson, Con Edison, National Grid, New York State Electric and Gas, Orange & Rockland, and Rochester Gas and Electric. The organization offers a variety of incentives to promote grid efficiency, including the Performance Based Demand Response initiative, which provides financial support to energy producers that install the equipment necessary to participate in demand response programs.

In addition, NYSERDA has also demonstrated a commitment to increasing solar energy production by providing cash incentives and/or financing for the installation of new grid-connected PV systems at residential and commercial sites.

Reference: https://energy.gov/eere/femp/federal-energy-management-program

New York Independent System Operator (NYISO)

NYISO offers reliability-based and economic-based demand response programs that pay participants for decreasing their electricity usage during peak periods. The first category comprises the Installed Capacity – Special Case Resource program and the Emergency Demand Response

Program, while the latter consists of the Day-Ahead Demand Response Program and the Demand Side Ancillary Services Program.

Reference: http://www.nyiso.com/public/index.jsp

b) Demand management programs at New York utilities

Central Hudson

Serves 300,000 electric customers and 79,000 natural gas customers in a defined service territory of New York State's Mid-Hudson River Valley.

Central Hudson offers two commercial demand response programs: the Targeted Demand Response Program and the Commercial System Relief Program. The first is only available to customers in particular areas, and it requires participants to commit to reduce electrical demand by at least 50 kW upon request. The latter is available throughout Central Hudson's service area, and it also asks participants to decrease electricity upon request. Both programs provide financial incentives that vary depending on how much load is reduced.

Reference: https://www.cenhud.com/energyefficiency/energy-efficiency-and-conservation

Con Edison

Serves 10 million people who live in New York City and Westchester County; one of the world's largest energy delivery systems.

Con Edison offers financial incentives to reduce peak energy demand via its Demand Management Program. The program is targeted at large customers that propose projects resulting in a peak reduction of at least 50 kW from their current demand baseline, and it supports the implementation of advanced control systems and battery storage.

Brooklyn Queens Demand Management Program - Con Edison is investing $200 million in energy efficiency, demand response and thermal energy storage, renewable energy and CHP systems to defer a $1.2 billion substation upgrade required to meet an additional 69MW of peak demand forecast for 2018 in Brooklyn and Queens.

References:

- https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-commercial-industrial-buildings-customers/demand-management-incentives
- http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BEA551051-F5C8-4E51-9B83-F77017F0ED0D%7D

National Grid

Serves Massachusetts, New York, and Rhode Island.

National Grid offers a variety of incentives to promote load optimization. Most notably, the ConnectedSolutions software synchs with Honeywell and ecobee smart thermostats to reduce energy demand during peak hours, and National Grid provides financial rewards to Massachusetts and New York businesses that utilize the tool. In New York, businesses receive $30 for signing up their already-purchased Honeywell or ecobee thermostat to ConnectedSolutions, or they can earn a $75 for purchasing one of the devices, plus the $30 sign-up bonus. Businesses also receive $20 per smart thermostat at the end of each calendar year when they participate in at least 80 percent of National Grid's "Peak Energy Events." In addition, National Grid offers Energy Saving Programs that provide rebates and incentives for other types of efficiency-boosting technology.

The company is working to decarbonize the grid, including by advocating for increased solar generation in the Northeast. National Grid is implementing its own solar program that currently includes six solar farms, which collectively produce nearly 5 MW of power. The next phase of the project will add more than 16 MW of additional solar generation.

References:

- https://www.nationalgridus.com/energy-saving-programs
- https://connectedsolutions.connectedsavings.com/Auth/Portal
- https://www.nationalgridus.com/new-energy-solutions/Renewables/Massachusetts/

NYSEG

Serves 881,000 electricity customers and 263,000 natural gas customers across more than 40 percent of upstate New York; subsidiary of AVANGRID.

NYSEG has a variety of demand response programs for residential, small business, and industrial customers. The CA$HBACK Programs, Commercial System Relief Program, and the Distribution Load Relief Program all provide financial incentives to reduce or shift electricity consumption during peak periods.

Reference: http://www.nyseg.com/YourBusiness/default.html

Orange & Rockland

Serves 745,000 people in six counties in New York and northern New Jersey.

Orange & Rockland pays customers to reduce electricity consumption during peak periods via its Smart Usage Rewards program. The program includes two different load management options: the Distribution Load Relief Program and the Commercial System Relief Program.

The company is also modernizing its grid to support integration of solar and wind energy and to increase efficiency. In its Monsey service area, Orange & Rockland is asking prospective business partners to provide proposals on how they can help the company's customers install solar panels, fuel cells, energy efficient equipment, batteries, and other distributed energy resources.

References:

- https://www.oru.com/en/save-money/rebates-incentives-credits/rebates-incentives-tax-credits-for-commercial-and-industrial-customers/choose-smart-usage-rewards
- https://www.oru.com/en/about-orange-rockland/media/news/2017082401/oru-eyeing-new-energy-savings-grid-suppor-opportunities