ARENA Knowledge Sharing Plan – Residential Solar and Storage Program Interim Report

28.02.18
This page intentionally blank
## Contents

1. Introduction .................................................................................................................. 6
   1.1 United Energy .......................................................................................................... 6
   1.2 Demand Planning ...................................................................................................... 6
   1.3 The Changing Environment ..................................................................................... 6
   1.4 ARENA and UE Residential Solar and Storage Systems (Project) ....................... 7

2. Substation Identification ............................................................................................... 8

3. Installation and Operation of Solar Storage Systems ................................................ 10
   3.1 Technology Selection .............................................................................................. 10
   3.2 Customer Identification .......................................................................................... 10
   3.3 Installation and Operation ....................................................................................... 10
   3.4 Transition to Business-AS-Usual .......................................................................... 11

4. Benefits ....................................................................................................................... 12

5. Economic Values ......................................................................................................... 14
   5.1 Network Value ........................................................................................................ 14
   5.2 Customer Value ...................................................................................................... 14
   5.3 Plans and Business Systems to Integrate the Solar and Storage Systems into BAU 15

6. Lessons Learnt ............................................................................................................. 16
   6.1 Marketing ............................................................................................................... 16
   6.2 Planning and Installation ........................................................................................ 16
   6.3 Operation ............................................................................................................... 17
   6.4 Customer Lessons .................................................................................................. 18

7. Control Strategy .......................................................................................................... 19
   7.1 Temperature Less than 35°C .................................................................................. 19
   7.2 Temperature Greater than or Equal to 35°C ............................................................ 19

8. Network Peak Demand Reduction ........................................................................... 21
   8.1 Multiple Solar and Storage Systems ....................................................................... 21
   8.2 Single Solar and Storage System .......................................................................... 25

9. Installation Requirements ............................................................................................ 28

10. Operational Requirements ......................................................................................... 30
    10.1 Customer Control ................................................................................................. 30
    10.2 Model Rollout ....................................................................................................... 30

11. Final Report ............................................................................................................... 31

12. Glossary of Terms ...................................................................................................... 32

13. References .................................................................................................................. 33
List of Tables

Table 1: Constrained Substations and Target Customers ......................................................... 8
Table 2: Constrained Substations and Actual Customers .......................................................... 9
Table 3: Offset Demand Strategy Deployed in UE Solar Storage Systems ............................. 19
Table 4: Demand Response Strategy Deployed in UE Solar Storage Systems ..................... 19
Table of Figures

Figure 1 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Hot Day – 6 January 2018 .......................................................... 21
Figure 2 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Normal Day – 7 January 2018 .......................................................... 22
Figure 3 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Normal Day – 17 January 2018 .......................................................... 23
Figure 4 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Hot Day – 18 January 2018 .......................................................... 24
Figure 5 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Hot Day – 19 January 2018 .......................................................... 24
Figure 6 Constrained Substation Demand with and without Single Solar and Storage System on a Normal Day – 17 January 2018 .......................................................... 25
Figure 7 Constrained Substation Demand with and without Single Solar and Storage System on a Hot Day – 18 January 2018 .......................................................... 26
Figure 8 Constrained Substation Demand with and without Single Solar and Storage System on a Hot Day – 19 January 2018 .......................................................... 26
1. Introduction

1.1 United Energy

United Energy (UE) is an electricity distribution business that supplies electricity to more than 660,000 customers across Melbourne’s eastern suburbs, south eastern suburbs and the Mornington Peninsula via 13,000 kilometres of wires, 209,000 poles, 78 sub transmission lines and 47 zone substations.

UE has an obligation to provide Distribution Services at the lowest cost consistent with the National Electricity Objective, as set out in the National Electricity Law. As such, this project allows UE to explore the viability of using developing Solar Storage technology as an alternative way to support the delivery of Distribution Services through the deferral of traditional network augmentation.

1.2 Demand Planning

UE designs and operates its network to facilitate there being sufficient capacity available on the network to meet customers’ peak electricity demand requirements. Electricity demand of residential customers on the UE network typically peaks in the evening period over the summer months on the hottest days of the year. Economic (including customer number) growth and the installation of sizable load appliances (such as air conditioners) has historically caused peak demand on the UE network to grow resulting in electricity distribution network infrastructure assets needing augmentation to avoid becoming overloaded [or ‘constrained’] over time. This is known as ‘traditional network augmentation’. Traditional augmentation solutions are capital intensive and are typically only available in large capacity increments. Therefore, when traditional augmentation projects are undertaken by UE they are often sized with additional spare capacity to cater for potential future growth in demand.

1.3 The Changing Environment

UE recognises that options of providing electricity supply services to customers is changing. A number of factors such as increased customer engagement in energy decision making, changing demographics, government policy and technology advances (such as energy efficiency and the installation of roof top solar photovoltaic (PV) systems) is causing growth in peak demand to slow in parts of the UE distribution network. The uncertainty this introduces into future demand forecasts may result in sub-optimal investment decisions being made when adding new capacity to the UE distribution network, potentially resulting in stranded and underutilised assets, if alternative options are not considered. In a world, where future peak demand on a constrained part of the network is uncertain, it has become increasingly difficult to plan under all credible growth scenarios for lump sum capacity upgrades using the traditional approach to demand planning.

Solar Storage is a technology that provides an opportunity to deliver a more incremental capacity approach to network planning. Technological advancements and ongoing price reductions in solar and storage technologies present an opportunity for UE to utilise the technology as an alternative to traditional network infrastructure for meeting peak demand. Recently, a number of studies have concluded, that Li-Ion battery prices are forecast to fall dramatically within the next few years. This is driven primarily by economies of scale achieved through an increase in manufacturing capacity (partly driven by the increased production of electric vehicles) as well as technological improvements in the energy density of batteries.

Residential rooftop solar PV systems alone do little to reduce peak demand for network assets in these residential customer areas because of the difference in time between the solar PV generation peak and the residential demand peak. However, solar PV coupled with controllable energy storage technology provides UE with the ability to incrementally add capacity (by reducing customer grid consumption) to the network, as required, by better aligning in time, supply and demand. If solar coupled with storage can be delivered at a lower cost in the future, Solar and Storage can be progressively installed on the network to delay a capital investment in augmentation until a clear trend in peak demand growth is evident and it is established that network augmentation is required to support customer load. Where peak demand continues to grow, Solar and Storage can be incrementally added to provide capacity where it is cost effective in relation to traditional augmentation. Where peak demand growth is not rapid enough to justify network augmentation, additional energy storage units can be added as required to maintain the
network asset within its rating. In regions of the network where growth ceases, energy Storage can be stopped until growth resumes.

Should battery prices fall in the future as forecast, Solar PV coupled with Storage will become economically feasible relative to traditional distribution substation augmentation at a number of locations on the UE distribution network. UE has estimated that by 2025, Storage could be a cost effective solution for distribution substation and low-voltage circuit upgrades on the UE network.

1.4 ARENA and UE Residential Solar and Storage Systems (Project)

UE seeks, as a deliverable of this ARENA-funded project, to undertake a targeted deployment of solar PV and storage at customers’ premises that are connected to constrained (or overloaded) distribution substations of the UE distribution network. The Project aligns with multiple ARENA priority areas for new investments including “Integrating renewables and grids” and “fringe-of-grid and network constrained areas” [1].

UE will demonstrate through the Project that multiple Solar Storage units installed on a constrained distribution substation can be controlled in concert to defer investment in substation augmentation projects.

Solar PV and storage based systems are an emerging technology for both electricity customers and electricity distribution networks. Solar PV installers and energy retailers are offering solar PV systems coupled with storage as prices become increasingly competitive with grid-connected energy. The residential solar PV and storage based system market is developing rapidly and maturing.

The key objectives of this Project are:

- Validate the ability of solar PV and storage technology to defer or eliminate the requirement for traditional network augmentation. This will be undertaken by controlling and scheduling the residential Solar and Storage systems during the hotter summer months to reduce summer peak demand across constrained substations thus deferring network augmentation.
- Evaluate and report on the commercial and operational viability of the solar PV and storage technology and its ability to be integrated into business-as-usual network operations.
- Quantify the magnitude of the different benefits generated through the installation of solar PV and storage for utilities and customers.
- Demonstrate and provide data on the success of operation of the solar and storage systems and associated control algorithms.

“Successful demonstration will provide UE and other network service providers with confidence to replicate similar solutions to increase efficiency and reduce network costs.”

Recognising the potential opportunities of residential energy storage, UE along with ARENA initiated the Project in mid-2017. The trial was aimed primarily to investigate the potential of residential battery storage to:

- Demonstrate capability of Solar and Storage systems as an alternative to traditional augmentation;
- Flatten residential customer demand profiles;
- Manage the peaks in network demand that are driven by residential customers;
- Improve the integration of residential solar PV generation into the distribution network; and
- Assess the financial benefits of battery storage to the network and customers.
2. Substation Identification

Aggregated smart meter data over the 2016/17 summer was analysed to identify substation assets which were constrained (or overloaded). Subsequently, UE identified traditional augmentation projects to alleviate constraints on the substations identified. UE compared the cost of these augmentation projects with the cost of Solar Storage solutions (subsidised by ARENA and by customer contributions). Table 1 shows these substations where the use of Solar Storage was more economically viable than the traditional augmentation solution. Analysis revealed a requirement to have a total of 42 Solar Storage systems installed to bring the substations to their design rating to be effectively equivalent to a network augmentation. Progressive recruitment of customers will allow some level of augmentation deferral.

Table 1: Constrained Substations and Target Customers

<table>
<thead>
<tr>
<th>No</th>
<th>Substation</th>
<th>Suburb</th>
<th>Total Customers</th>
<th>Target Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACHERON KOETONG</td>
<td>Mount Eliza</td>
<td>107</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>ENTRANCE NEPEAN</td>
<td>Seaford</td>
<td>73</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>FLORENCE-GERALD</td>
<td>Blackburn Nunawading</td>
<td>82</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>HYPERNO LAYTON</td>
<td>Mount Martha</td>
<td>141</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>KARRAKATTA-BLUFF</td>
<td>Black Rock</td>
<td>99</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>MILLGROVE GEORGE</td>
<td>Scoresby</td>
<td>104</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>PRINCETON STANFORD</td>
<td>Keysborough</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>TRENTBRIDGE MANCHESTER</td>
<td>Mulgrave</td>
<td>86</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>WINDSOR-ST JAMES</td>
<td>Bentleigh</td>
<td>167</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>AMETHYST DIAMOND</td>
<td>Glen Waverley</td>
<td>133</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>BRIGGS CHLORIS</td>
<td>Caulfield</td>
<td>73</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>CASTLEWOOD MARLBOROUGH</td>
<td>Bentleigh East</td>
<td>156</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>WARATAH WARRIGAL</td>
<td>Bentleigh East and Oakleigh South</td>
<td>93</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>MT PLEASANT LORIKEET</td>
<td>Nunawading</td>
<td>98</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>–</td>
<td>–</td>
<td>1496</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 2 shows the actual customers recruited across the constrained substations as of end of February 2018.
Table 2: Constrained Substations and Actual Customers

<table>
<thead>
<tr>
<th>No</th>
<th>Substation</th>
<th>Suburb</th>
<th>Total Customers</th>
<th>Target Customers</th>
<th>Actual Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACHERON KOETONG</td>
<td>Mount Eliza</td>
<td>107</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>ENTRANCE NEPEAN</td>
<td>Seaford</td>
<td>73</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>FLORENCE-GERALD</td>
<td>Blackburn Nunawading</td>
<td>82</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>HYPERNO LAYTON</td>
<td>Mount Martha</td>
<td>141</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>KARRAKATTA-BLUFF</td>
<td>Black Rock</td>
<td>99</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>MILLGROVE GEORGE</td>
<td>Scoresby</td>
<td>104</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>PRINCETON STANFORD</td>
<td>Keysborough</td>
<td>84</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>TRENTBRIDGE MANCHESTER</td>
<td>Mulgrave</td>
<td>86</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>WINDSOR-ST JAMES</td>
<td>Bentleigh</td>
<td>167</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>AMETHYST DIAMOND</td>
<td>Glen Waverley</td>
<td>133</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>BRIGGS CHLORIS</td>
<td>Caulfield</td>
<td>73</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>CASTLEWOOD MARLBOROUGH</td>
<td>Bentleigh East</td>
<td>156</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>WARATAH WARRIGAL</td>
<td>Bentleigh East and Oakleigh South</td>
<td>93</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>MT PLEASANT LORIKEET</td>
<td>Nunawading</td>
<td>98</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>–</td>
<td>1496</td>
<td>42</td>
<td>31</td>
</tr>
</tbody>
</table>

The target customers are expected to be recruited by June 2018.
3. Installation and Operation of Solar Storage Systems

3.1 Technology Selection

UE undertook a comprehensive investigation to identify and understand the state of technology that would be suitable for this Project. The following hardware was recommended for procurement and installation as the least-cost lifecycle option for the Project:

- Solar PV system with optimisers (15 Jinko Solar Panels × 270W = 4kW)
- LGChem RESU10 battery (9.8kWh)
- Sungrow SH5k (5kW) inverter
- Reposit Power control

3.2 Customer Identification

With suitable substations for the Project identified by UE, the next phase of the project was to identify appropriate customers on the substation to target for the installation. Solar PV and storage may not be economic to install for the customers at all these sites. UE seeks to install solar PV and storage at customers that provide good value for the network but also good economic return for their investment (customers fund the solar PV component of the system). In order to identify and target these 'high value' customers along an overloaded substation, UE used a combination of smart meter data, demographic profiling and market research to assist in the analysis and selection of suitable customers on each substation subsequent to customers registering. Customers that provided the best network benefits were strategically targeted by UE for having the Solar and Storage systems installed.

3.3 Installation and Operation

A marketing plan was developed for the Project and deployed to recruit potential customers supplied by the nominated distribution substations. UE undertook marketing to approximately 1,400 customers targeted across the identified constrained substations. 140 customers registered with 69 proposals prepared and submitted to customers. 27 Solar and Storage systems were installed by 15 December 2017, ready for dispatch during the 2017/2018 summer.

Site visits were undertaken to customer premises and included technical representatives to ensure the customer fully understood the product technology and how it will be controlled by UE, as well as a sales representative that communicated the benefit of the offer being presented to the customer via marketing collateral. Once a customer agreed to participate in the project, the customer was required to enter into a legal agreement with UE.

UE controlled the multiple solar PV and storage units on a substation as an aggregated fleet for network benefits (i.e. shaving the customers demand and exporting to the network) on peak demand days when the ambient temperature exceeded 35°C. All other times, UE controlled the solar PV and energy storage units for the financial benefit of the customer (i.e. to maximise their self-consumption of solar).

After commissioning, UE is testing and demonstrating the operation of the systems over the 2017/2018 and 2018/2019 summers. UE is remotely monitoring the performance of the customers’ solar PV and storage units and providing all maintenance and repair services required for customers in the event of a fault or mal-operation with the systems. UE will also make any necessary adjustments to the control algorithms (if required) in order to optimise the systems operation.
3.4 Transition to Business-AS-Usual

Testing has been undertaken over summer 2017/18 for 27 systems and will be undertaken over summer 2018/2019 for 42 systems. This report will be updated for ARENA and released to the public in June 2019 with the full set of results and analysis.

An important part of this project will be to establish the appropriate plans and business systems in order to integrate the systems installed as part of this project into business-as-usual (BAU) processes. This will include the development of asset management plans as well as the establishment of procedures for ongoing customer support of the units.

Once the units have been integrated into business as usual, UE will perform project closeout. This will include the provision of this knowledge sharing report to ARENA to communicate the project outcomes and learnings.
4. Benefits

The main benefit arising out of this Project is the confirmation that residential Solar and Storage systems can be an economic network augmentation alternative, in certain instances. Networks can potentially procure these solutions to achieve prudency of investment and reduce network costs for customers. Once confirmed, the use of this technology could also be scaled to achieve peak demand reduction to economically defer many larger network augmentation projects for greater network infrastructure cost savings. In addition, as battery storage costs reduce over time and more customers take up solar PV and/or storage systems, networks could utilise these systems at very low cost. This would increase the available applications and reduce costs across its network for the benefit of all customers.

However, it is not just peak demand reduction benefits that this technology could offer. Coordinated Solar Storage control could also act to improve power quality, in particular through voltage regulation. This could solve many network power quality issues and may also allow a higher penetration of solar PV systems to be installed on low-voltage networks. Installation of these systems could also improve the reliability of supply for customers by acting as back-up which can supply the customer load islanded for a period of time in the event of a network outage.

This Project has begun to familiarise participants with the technology and help to spread knowledge of the benefits of combining both Solar and Storage systems to all customers. This will lead to increased customer adoption of Solar and Storage in the market and will also allow greater customer recruitment for these types of projects in the future. This Project will also highlight the value of renewable energy and storage systems to regulators and policy makers to enable them to establish appropriate frameworks to encourage increased customer take-up.

The Project will also have significant benefits for the participating customers. Given the peaky nature of residential load, systems are typically, only required to operate as a network tool, to reduce demand on only the hottest days of the year. On non-peak demand days, the Solar and Storage systems will operate to maximise the customers own economic benefits from significantly lower grid consumption with savings realised through electricity bills.

By undertaking this project with ARENA, UE has been able to share its key learnings which will be invaluable for the industry for implementation of similar projects moving forward.

This Project aligns with multiple ARENA priority areas for new investments including “integrating renewables and grids” and “fringe-of-grid and network constrained areas”. This project has demonstrated the value that renewable energy systems when combined with storage can play in alleviating network constraints.

In relation to ARENA’s Advancing Renewables Programme objectives this Project will:

**Increase the Value delivered by Renewable Energy Sources**

Despite the rapid uptake of rooftop solar PV systems over the last few years there has been a relatively small impact on peak demand. Particularly in residential areas, network peak demand tends to occur in the evening as people arrive home from work, when the generation of solar PV systems is quickly subsiding. Hence, residential solar PV systems alone do not necessarily reduce peak demand.

Residential solar PV systems have low network value as the same level of network infrastructure is still required to meet peak demand for just a few days of the year. Batteries alone can reduce peak demand, but are expensive and rely on charging from the grid.

Energy storage coupled with solar PV systems could work together to solve this problem and has the potential to play a key role in supporting future energy infrastructure. Solar PV paired with batteries is a more optimal solution to supply power in times of peak demand rather than solar PV or batteries alone as solar energy helps fill the first part of the residential peak period (typically 4:00 - 5.30 pm) and batteries can be used for the remaining part of the peak (5.30 – 7:00 pm).

This Project aims to demonstrate to the industry, the capability and value of the role that renewable energy systems with storage can increasingly play as a potential economic alternative to traditional network augmentation. In the future, as costs reduce and more customers take up solar PV and/or storage systems, networks could potentially procure and utilise Solar and Storage systems at very low cost across its network delivering benefits for all users.

**Reduce the Barriers to Renewable Energy Sources Uptake**

This Project will allow investors, the industry and the regulator to understand the value that renewable energy systems combined with energy storage can play in the future, enabling them to establish appropriate conditions...
and frameworks for entry into the market. Successful demonstration of economics and technology provides a stepping stone for investment in solar and storage.

1. Increase skills, capacity and knowledge relevant to renewable energy sources

This Project will help broaden the knowledge base and capability for many stakeholders including distributors, equipment suppliers, retailers and customers. Key learnings from this Project for the industry include:

- Introduction of a new commercial model to the market that can facilitate investment in Solar and Storage by utilities.
- Technical ability of Solar and Storage to be collectively controlled to shave peak demand and add capacity to the network during high temperature days.
- Value streams that can be generated through the installation of the technology will be quantified including augmentation deferral for the network and increased self-utilisation of solar PV for the customer.
- Customer behaviour will be explored including response to technology, ownership, installation and operation by the distributor.

2. Reducing the cost of renewable energy sources

Successful demonstration of the Project may enable the reduction in cost of renewable energy technologies as below:

- Investment in Solar and Storage is presently uneconomic for the majority of customers due to the high capital costs of battery technology. The business model UE has developed will allow customers to tap into the network benefits (augmentation deferral) value stream and improve the economics of the technology for early adopters.
- The business model is also scalable to larger augmentation deferral projects thereby increasing the number of locations and applications for which renewable energy systems could be used.
- A market for the installation of Solar and Storage at residential customer’s premises is developing facilitated by initiatives like this. It is expected that additional competition, supply chain efficiencies, etc. will develop and lead to a reduction in cost of renewable energy for customers.
- Demonstrating the value that renewable energy and storage systems can have in reducing network costs will allow regulators and policy makers to establish appropriate frameworks to encourage customer take up.

Network Benefits

The network cost reduction benefits would be as below:

- The network upgrade solution could be deferred for a number of years depending on the growth rate being experienced. In areas of very high demand growth, it may not be possible to defer an upgrade for very long due to the large numbers of storage systems that must be deployed. Storage viability and requirements need to be assessed and implemented according to the demand growth in the area.
- The network upgrade solution for a constraint could be high-cost in some cases. In practice, this can be the case for long rural power lines where an upgrade would require the replacement of many kilometres of line, or where capacity is limited by underground cables that are expensive to replace. In other cases however, a low-cost network solution may exist which would reduce the attractiveness of the battery storage option. Storage viability and requirements need to be assessed and implemented according to the comparative costs of the traditional network solution.
- The Solar and Storage systems installed across constrained substations were successfully controlled to act in concert on days of peak demand. The financial value of voltage-rise management through reducing solar exports was assessed to be small in most cases given that low-cost alternative responses such as transformer tap changing can often alleviate the issues. As solar PV penetration increases over time, traditional responses such as this may be less effective, and the relative value of alternative approaches such as battery storage may increase. Options to adjust power factor settings on solar PV inverters may provide a transitional solution until storage take-up increases.
5. Economic Values

This section will be updated progressively over 2018/2019 and will include an analysis of the economic value to the UE network business of utilising Solar and Storage systems as opposed to traditional augmentation, including the cost and benefit of using non-network solutions. Included in this section will be a comparison of the costs and benefits of augmentation versus Solar and Storage systems.

5.1 Network Value

For UE, residential Solar and Storage systems has the potential to help reduce network costs by reducing peaks in demand, and managing the impact on the network from standalone solar PV systems. Reducing customers’ use of electricity at peak times or shifting the usage to off-peak times is desirable because it reduces the risk of the network becoming overloaded with the associated asset risks. In the long term, this can reduce or defer the need for networks to invest in new capacity that may only rarely be used (i.e. during periods of peak demand), and that would be paid for by customers through their electricity bills.

By storing excess solar PV generation that would otherwise be exported to the grid, storage systems help mitigate the technical issues for the network such as voltage rise that can be caused by high penetration levels of solar PV generation. In this way, storage systems will help facilitate a higher uptake of solar power whilst maintaining network power quality and reliability for all customers.

5.2 Customer Value

For customers, solar PV and storage systems offer a potential means to reduce electricity bills and to better utilise their solar PV generation. Storage can also be used to provide a backup power supply during times of network outage, however backup functionality was not part of this Project.

There are three primary ways a customer can lower their energy costs using a storage system.

1. **Time-of-use tariff arbitrage:** When a customer’s tariff includes different rates for different times of the day (time-of-use pricing), the customer can charge the storage system during off-peak times when the cost is lower and discharge during peak times, when the cost is higher.

2. **Feed-in tariff arbitrage:** When a customer’s solar PV generation exports excess energy to the grid at a feed-in-tariff rate lower than the import tariff, the customer can use a storage system to store the excess energy for re-use later when customer energy demand exceeds supply from the customer’s solar PV system. This is the default offset control algorithm implemented across all the Solar and Storage systems.

3. **Demand charge minimisation:** When a customer’s tariff includes a charge for the maximum customer demand, the customer can operate the storage system so as to minimise the maximum electricity demand from the network. The demand charge is typically calculated during peak periods only.

An important finding was the importance of storage capacity for use in demand management. While peak demand periods can vary across a range of networks, a solution which provides a short-term reduction in the peak demand on a network asset should ideally have the potential to provide 3 to 5 hours of demand reduction. The storage systems were discharged across 3 hours. Where a solution is only capable of shorter dispatch periods, networks would typically combine demand reductions from multiple sources staged in time windows to achieve the required reduction.

The energy storage capacity can be optimised by using automated battery management functions which better utilise the available storage capacity by only discharging at partial power output to maintain network demand to a pre-set threshold. The use of remote measurement devices along with smart control algorithms should be investigated.
5.3 Plans and Business Systems to Integrate the Solar and Storage Systems into BAU

In the current Project, the following applies:

- The installer provides initial support until the system is operational and commissioned.
- The Solar and Storage systems will be regularly monitored by UE. If an issue is encountered, UE will request the installer to investigate and resolve the issue.
- Equipment is covered under warranty.
- Cleaning of panels is to be undertaken by the customer at their expense.
- Customers have been advised to ensure the Solar and Storage systems are covered under their Home and Contents Insurance policy.
6. Lessons Learnt

The lessons learnt are detailed below under the respective headings of marketing, planning/installation, operations and customers.

6.1 Marketing

- Customers were enrolled for the Program using a combination of direct mail-outs, web-based promotion and outbound calling. Customers registering interest were screened to assess site suitability.
- The initial round of marketing included a brochure detailing the offer of the Solar and Storage system by UE, customer contribution, benefits the customers would receive and a high level overview of the Solar and Storage system.
- Due to the slow rate of uptake, the marketing material was revised in future marketing campaigns to include the above and details on benefits of renewable energy sources, environmental benefits and cost savings.
- In addition, existing customers who had installations undertaken were contacted to determine whether they would be willing to provide testimonials and become a point of reference for new customers deciding to sign onto the Project.

6.2 Planning and Installation

- During implementation, a site visit was undertaken to every customer who sought to participate, to confirm their suitability of their site, considering criteria such as space, surface types and potential hazards.
- Insufficient roof space and shading are the two most common criteria resulting in elimination of ineligible sites. The evaluation process was streamlined by undertaking assessments using Google Maps data.
- Installers needed to assess types of roof tiling and the need to source spare roof tiles (roof tiles being cracked as part of the installation is common). UE ensured installers prearranged supply of tiles prior to commencing installation.
- Wi-Fi connectivity at some sites has posed issues. During site visits, details on Wi-Fi connections were gathered to ensure installation proceeds smoothly.
- Initial installations took 2 days to complete with subsequent installations undertaken in a day as the installers became more familiar with equipment and installation requirements. The plan was to utilise existing installers to complete additional installations.
- Some installations required installation of concrete slabs which increased the installation time. Installers were advised of this immediately after the site visit to fast track installation.
- Ideal sites were those with a West or North facing roof with no shading from surrounding trees. The evaluation ensured the roof was clear of flu pipes, antennas or satellite dishes on the face where panels are to be installed. Such aspects were assessed during the site visit.
- The batteries were installed close to the switchboard and solar PV panels to minimise the length of the Alternating Current (AC) and Direct Current (DC) cable runs.
- The evaluation ensured the switchboard had sufficient spare terminals to accommodate the critical load and Voltage Transformer (VT) / Current Transformer (CT) reference Master Control Circuit Breakers (MCCBs).
- Other technical risks were mitigated by a rigorous product selection process and using initial installations to identify potential installation, integration and telecommunications issues and develop mitigations.
6.3 Operation

- Preliminary results have shown Solar and Storage systems can be a viable solution to managing network demand once the product matures along with lower energy storage prices.

- Reducing the peak demand on an asset can enable significant savings for networks by facilitating the avoidance or deferral of network investments to build additional network assets. These savings are ultimately passed on to customers in the form of lower bills.

- Batteries were discharging as expected.

- This Project has involved recruiting a large base of customers across a number of constrained sub-stations to reduce constraints on the selected constrained sub-stations. This has allowed UE to halt growth in demand and defer network augmentation across the selected constrained substations.

- Ideally, battery installations should be undertaken in an incremental manner to relieve constraints on selected constrained sub-stations to defer the required network augmentation. Such an approach will be more prudent, cost effective and efficient allowing incremental deferral of network augmentation.

- The control strategy implemented included customer benefit self-maximisation for days when temperature was less than 35°C. On days, when temperature was forecast to exceed 35°C, the network support control algorithm ensured the battery was charged prior to the 35°C exceedance day. On the 35°C exceedance day, battery was discharged between a selected duration (for example, 5:00 – 8:00 pm or 4:00 – 7:00 pm) with due consideration to limits on battery State of Charge (SOC).

- The network support control algorithm, discharges a set output for the specified time, and guarantees a set reduction during that time. One of the considerations for using this type of operation is that the battery only has a certain amount of storage capacity at full power output. For this battery, there was only a nominal 3 hours of storage capacity at full power output, so the peak load would need to be predicted within a 3-hour window to reduce the peak by the full power output of the battery. Alternatively, a bigger time window could be specified at a reduced rate of power output.

- When considering the value to networks of using battery storage systems for peak reduction, the limit of stored energy is a significant consideration as a battery may exhaust stored energy during a peak reduction event, if it is not sized appropriately. The two main battery storage system specifications to consider when selecting the size of the battery for this application are the usable energy storage capacity (kWh) and peak power output (kW). By sizing a larger battery storage capacity for a given power output, any limitation would be alleviated, but the battery system cost is likely to increase for a given power output as the majority of battery system costs are currently related to the battery costs. As battery prices continue to decrease, this may make larger battery systems more affordable such that this concern may be less of an issue.

- When considering the potential application of using a battery system as a demand management solution to defer a network augmentation, other solutions should also be considered. Such other solutions may include customer demand response (load shedding or generation) and can be viable to meet network needs.

- Although battery storage systems are currently more expensive than other similar demand management solutions, this technology does offer other environmental advantages over other solutions, including noise and exhaust emissions. As battery costs decline, this technology will offer a cost effective alternative to other forms of demand management such as demand response.

- The Project has shown that centralised control of batteries can provide network support without materially reducing the primary customer benefit of bill reduction through solar PV shifting.

- In the longer term, the Project has also shown the potential for residential batteries to mitigate emerging system-wide challenges in maintaining network reliability, quality and security of supply as the penetration of rooftop solar PV continues to increase.
6.4 Customer Lessons

- This Program has involved recruiting a large base of customers across a number of constrained sub-stations to reduce constraints on the selected constrained sub-stations. This has allowed us to halt growth and defer network augmentation across the selected constrained substations.

- Customer Lessons:
  
  - **Duration of Contract:** The contract offered to the customers was for a period of 10 years and many customers were deterred to sign up to the Program. In future, a potential model should be considered to offer customers a short duration contract such as for 3 or 5 years.
  
  - **Ownership of the system:** The ownership of the system was also a concern expressed by many customers. The 10-year contract in effect binds the customer to provide ownership to UE.
  
  - **Unfamiliarity with technology:** Many customers were unable to appreciate the way the Solar and Storage System would operate and benefit them. In subsequent rounds of marketing, UE modified the marketing material to present the benefits to customers in a simple manner.
  
  - **Upfront payment:** Many customers were deterred to pay the upfront payment of $3,000 (ex GST). In future, flexible finance offerings should be considered for customers.
  
- Residential battery storage products have the potential to store and shift the usage of solar PV energy into the early evening, potentially flattening load profiles on the network and reducing network costs.

- The primary investment driver for customers was a reduction in their electricity bill. A desire for energy independence was also a key factor as well as having a source of back-up power.
7. Control Strategy

The following control strategy will be implemented for the duration of the Project across all Solar and Storage systems installed at the selected constrained substations.

7.1 Temperature Less than 35°C

For days when forecast maximum temperature is less than 35°C, the offset demand control strategy as demonstrated in Table 3 will be implemented across the selected constrained substations.

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Day</td>
<td>Offset Demand</td>
<td>Offset demand control is the typical customer mode which seeks to limit exports to the network and maximise self-consumption of solar PV systems. The batteries and solar PV systems will be used to firstly offset customer usage. The batteries will only charge from excess solar PV generation which is not used by the customer.</td>
</tr>
</tbody>
</table>

The default Reposit algorithm is the offset demand control strategy.

7.2 Temperature Greater than or Equal to 35°C

For days when forecast maximum temperature is greater than or equal to 35°C, the network support control strategy demonstrated in Table 4 will be implemented across the selected constrained substations.

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Day</td>
<td>Demand Response</td>
<td>Ensure battery is charged prior to the weather event condition. On the weather event condition day, ensure battery is discharged between a selected duration (5:00 – 8:00 pm or 4:00 – 7:00 pm) with due consideration to limits on battery SOC. For Solar PV systems, limit export to network and maximise self-consumption.</td>
</tr>
</tbody>
</table>

An event is set up in the Reposit Fleet to discharge the battery between a selected duration when the temperature is forecast to be greater than or equal to 35°C.

The current system utilises the Reposit Fleet software which can be deployed as follows:

1. Offset demand control is the typical customer mode which seeks to limit exports to the network and maximise self-consumption of solar PV systems. The batteries and solar PV systems will be used to firstly offset customer usage. The batteries will only charge from excess solar PV generation which is not used by the customer. This is the default control algorithm.

2. A manual discharge event can be scheduled for a selected day in the future. This also allows the flexibility of discharging the battery over a selected duration.

An option is to automate dispatch by programming a user specific dispatch control algorithm. For example, a 3, 5 or 7 day forward temperature forecast check would be performed. If the temperature is forecast to be greater than or equal to 35°C on a particular day, the network support control algorithm would ensure the battery is charged
prior to that day and available to discharge between selected hours on the greater than 35°C. UE is working with Reposit to implement such a dispatch algorithm.

The customer load profile which presents the best economic value for the network from a Solar Storage perspective is one which meets the following criteria:

- Is relatively consistent over a given peak period.
- Is not lumpy in nature.
8. Network Peak Demand Reduction

8.1 Multiple Solar and Storage Systems

This section presents the load profiles for Demand Response dispatch events executed on the Solar and Storage systems on 6 January 2018 (41°C), 18 January 2018 (40°C) and 19 January 2018 (40°C) for a constrained substation which had 5 Solar and Storage Systems installed. Comparative days are also shown to demonstrate operation in Offset Demand mode.

Figure 1 (DSS – Distribution substation demand, DSS w/o BESS – Distribution substation demand without Battery Energy Storage System and BESS – Battery Energy Storage System demand profile) shows the demand on a selected constrained substation on 6 January 2018 (41°C) along with the impact of the multiple Solar and Storage Systems.

The key observations to note from Figure 1 are:

- Given Network Demand is growing at less than 1% growth rate, dispatch on 6 January 2018 achieved a 7% reduction in demand which in effect will defer augmentation by 7 years.
- Advantage of Solar and Storage systems is the ability to incrementally add to the network to continue achieving deferral of augmentation.
- For Network support mode, battery pre-charges overnight to allow solar PV energy to support network during the day.
- Battery exports full capacity in the early evening during peak demand when solar output reduces.
- Dispatch event on 6 January 2018 demonstrated that Solar and Storage systems can address network constraints.
Figure 2 shows the demand on a selected constrained substation on 7 January 2018 with the multiple Solar and Storage Systems in operation on a normal day.

![Figure 2 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Normal Day – 7 January 2018](image_url)

The key observations to note from Figure 2 are:

- The impact of Solar PV systems should be noted during the middle of the day.
- When Solar PV generation is high, demand is reduced and excess solar generation is used to charge the battery.
- When demand increases in the evening, battery commences discharging to support the increased demand maximising customer benefits.
- For energy arbitrage mode, battery charges from solar PV energy during the middle of the day.

Figure 3 shows the demand on a selected constrained substation on 17 January 2018 (30°C) with the multiple Solar and Storage System in operation on a normal day.
The key observations to note from the Figure 3 are:

- The impact of Solar PV systems should be noted during the middle of the day.
- When Solar PV generation is high, demand is reduced and excess solar PV generation is used to charge the battery.
- When demand increases in the evening, battery commences discharging to support the increased demand maximising customer benefits.
- For energy arbitrage mode, battery charges from solar energy during the middle of the day.

Figure 4 shows the demand on a selected constrained substation on 18 January 2018 (40°C) along with the impact of the multiple Solar and Storage Systems.
Figure 4 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Hot Day – 18 January 2018

Figure 5 shows the demand on a selected constrained substation on 19 January 2018 (40°C) along with the impact of the multiple Solar and Storage Systems.

Figure 5 Constrained Substation Demand with and without Multiple Solar and Storage Systems on a Hot Day – 19 January 2018
The key observations to note from Figure 4 and Figure 5 are:

- Dispatch on 18 and 19 January 2018 achieved a 7% to 8% reduction in demand which in effect will defer augmentation by 7 to 8 years if demand continued to grow at the rate of 1% per annum.
- Advantage of Solar and Storage system is the ability to incrementally add to the network to continue achieving deferral of augmentation.
- For Network support mode, battery pre-charges overnight to allow solar PV energy to support network during the day.
- Battery exports full capacity in the early evening during peak demand when solar PV output reduces.
- Dispatch events on 18 and 19 January 2018 demonstrated that Solar and Storage systems can address network constraints.

### 8.2 Single Solar and Storage System

This section presents the load profiles for dispatch events executed on a single Solar and Storage system on 17 January 2018 (30°C), 18 January 2018 (40°C) and 19 January 2018 (40°C) for a constrained substation which had 5 Solar and Storage Systems installed.

Figure 6 shows the demand on a selected constrained substation on 17 January 2018 (30°C) along with the impact of the single Solar and Storage System.

Figure 6 Constrained Substation Demand with and without Single Solar and Storage System on a Normal Day – 17 January 2018

Figure 7 shows the demand on a selected constrained substation on 18 January 2018 (40°C) along with the impact of a single Solar and Storage System.
Figure 7 Constrained Substation Demand with and without Single Solar and Storage System on a Hot Day – 18 January 2018

Figure 8 shows the demand on a selected constrained substation on 19 January 2018 (40°C) along with the impact of a single Solar and Storage System.

Figure 8 Constrained Substation Demand with and without Single Solar and Storage System on a Hot Day – 19 January 2018
The key observations to note from the Figures 6 to 8 are:

- Dispatch events on 18 and 19 January 2018 achieved a 4% reduction in demand which in effect will defer augmentation by 4 years if demand continued to grow at the rate of 1% per annum.

- The two main battery storage system specifications to consider when selecting the size of the battery for this application are the usable energy storage capacity (kWh) and peak power output (kW). The system needs to be sized appropriately to achieve the desired deferral of network augmentation.

- Advantage of Solar and Storage system is the ability to incrementally add to the network to continue achieving deferral of augmentation.

- For Network support mode, battery pre-charges overnight to allow solar PV energy to support network during the day.

- Battery exports full capacity in the early evening during peak demand when solar output reduces.

- Dispatch events on 18 and 19 January 2018 demonstrated that Solar and Storage systems can address network constraints.
9. **Installation Requirements**

For the installation of all systems, UE ensured our Service Provider met the following requirements:

- Ensure its personnel installing the solar PV and energy storage unit had the required licences, certifications and qualifications required to perform installations, including a certificate as an A-Grade Registered Electrical contractor and Clean Energy Council (CEC) accreditation for the design and installation of solar PV systems. A copy of the relevant licences, certifications and qualifications were to be provided to UE on request.

- Install the solar PV and energy storage system in accordance with relevant Australian Standards and Regulatory codes and standards, including but not limited to the CEC guidelines and requirements and other reasonable directions by UE.

- Comply with HS&E (Health, Safety and Environmental) requirements of the site and manage site safety as required. The Service Provider prepared Job Safety Assessment (JSA) before commencing the installation.

- Install the solar PV and energy storage system in line with installation guidelines and requirements from the manufacturer.

- Install the solar PV and energy storage system in a presentable and aesthetically pleasing manner where possible.

- Install the solar PV and energy storage system without causing damage to the property.

- Install the solar PV and energy storage system in a manner in which it is secured from theft.

- Install all necessary safety and warning signs, and any additional signage as required to comply with standards.

- Provide all required tools, equipment, hardware and software required to successfully install the solar PV and energy storage system at the Customer Site.

- Review the structural capability of the wall to support the weight of the battery and inverter (even if the hardware is installed on a uni-strut).

- The solar PV and energy storage system (including solar optimisers, inverter and the energy storage units) was commissioned by the Service Provider in line with manufacturer’s requirement. The inverter and battery will come pre-programmed with default settings however, the default settings may need to be altered in line with the manufacturers commissioning requirements.

- For the purpose of the scope of works, it can be assumed that a standard installation includes:
  - The switchboard and customer modem are 40m away from the solar storage installation.
  - The switchboard has sufficient room to house peripheral hardware i.e. MCCB’s.
  - Battery and inverter are installed next to each other.
  - The installation is a standard install i.e. no tilt frames, single story, single array, no switchboard replacement required.

At the conclusion of the installation phase, the Service Provider prepared paperwork to be submitted to the retailer/UE (UE Inverter-Based Micro Embedded Generator Connection form, CEC installation and commissioning form, Electrical Works Request form, other CEC forms as required for residential PV installation, etc.).

The Service Provider ensured the following documents were submitted to UE at the completion of the installation:

- Job Safety Assessment at the customer’s site.

- UE Inverter-Based Micro Embedded Generator Connection form.

- Clean Energy Council’s installation and commissioning checklist.

- Array frame installation declaration.
- Electrical Works Request form.
- Pictures of installation.
- Written record of all assets installed i.e. serial numbers of solar PV, solar optimisers, DC disconnect switch, AC disconnect switch, check meter, inverter and battery.
- Prescribed Certificate of Electrical Safety.
- The Service Provider supplied a copy of maintenance manuals to the customer for all plant and equipment supplied and/or installed, together with manufacturers printed matter related to the component parts including drawings, illustrations, data sheets, photographs, hazard identification lists and manuals.
- As built mark-up of aerial drawing showing location of equipment on the customer’s premises.

The Service Provider organised for an independent Licenced Electrical Inspector to inspect the installation for defects post installation. The Service Provider ensured any defects identified by the Licenced Electrical Inspector were remedied by the installer. The Service Provider obtained a Certificate of Electrical Safety (CES) for the installation signed by Licenced Electrical Inspector for submission to UE.
10. Operational Requirements

10.1 Customer Control

In this section, documented are the findings of the extent to which customers were willing to give over control of the Solar and Storage systems to the UE network.

Initially, there was hesitation by customers to provide control of the Solar and Storage systems to UE. However, customers were briefed on the following:

- UE would be deploying the Solar and Storage Systems for provision of network support on peak demand days.
- Network support on peak demand days would be required only when temperatures exceeded 35°C and such events would be limited to between 4 and 5 per year.
- Customers would be reimbursed when the batteries were charged from the grid to provide network support on peak demand days.

The briefing above assisted in customers feeling at ease with allowing UE to control the assets for network support.

10.2 Model Rollout

The model employed in the Project can now be formalised for application to other locations in the UE network. The process to be followed is as below:

- Identify the constrained substation.
- Determine the volume of network support required to alleviate the constraint.
- Calculate the costs of alleviating the constraint using traditional augmentation and Solar and Storage Systems.
- Assess the costs and benefits of traditional augmentation versus Solar and Storage Systems.
- Recommend traditional augmentation or Solar and Storage Systems.
11. Final Report

The Residential Solar and Storage Project so far has been successful in demonstrating a reduction in peak demand as an alternative solution for deferring network augmentation. Additional aspects UE will continue to investigate during 2017/2018 and 2018/2019 are as below:

- Development of operating modes for the system including automated control algorithms.
- Investigation of business models that could facilitate the deployment of storage to address network issues.
- The outcomes from the dispatch events will be complemented by ongoing market research in order to facilitate the provision of non-network solutions to system planners where network constraints are identified, and to feed into ongoing asset strategy development regarding the application of energy storage in a network context.

Performance of the systems will be monitored over the 2017/2018 and 2018/2019 summer and this Knowledge Sharing Plan will be updated and submitted to ARENA as the Final and Public Report by 30 June 2019.
12. Glossary of Terms

The following terms are referenced within this document:

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARENA</td>
<td>Australian Renewable Energy Agency</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>BAU</td>
<td>Business As Usual</td>
</tr>
<tr>
<td>CEC</td>
<td>Clean Energy Council</td>
</tr>
<tr>
<td>CES</td>
<td>Certificate of Electrical Safety</td>
</tr>
<tr>
<td>CT</td>
<td>Current Transformer</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>MCCBs</td>
<td>Master Control Circuit Breakers</td>
</tr>
<tr>
<td>SOC</td>
<td>State of Charge</td>
</tr>
<tr>
<td>UE</td>
<td>United Energy</td>
</tr>
<tr>
<td>VT</td>
<td>Voltage Transformer</td>
</tr>
</tbody>
</table>
13. References

1. Australian Renewable Energy Agency, Advancing Renewables Programme Funding Agreement Number G00904.
2. AS/NZS 3000 Electrical Installation Wiring Rules.
4. AS/NZS 5033 Installation of Photovoltaic (PV) Arrays.
5. AS1170.2 Part 2 Wind Loads.
6. AS/NZS 3008 Selection of Cables.
7. AS2050 Installation of Roof Tiles.
8. AS1768 Lightning protection.
10. AS4777.2 Grid Connection of Energy Systems via Inverters (Inverter requirements).
11. AS4777.3 Grid Connection of Energy Systems via Inverters (Grid protection requirements).
12. Clean Energy Council installation requirements.