LOW CARBON LIVING CRC

Beyond White Gum Valley Precinct Guide:

The Energy Village Concept

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Balance
Engine Room of the Energy Revolution

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- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

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Acronyms

ARENA - Australian Renewable Energy Agency

BESS - Battery Energy Storage System

BWGV - Beyond White Gum Valley

CUSP - Curtin University Sustainability Policy Institute

DER - Distributed energy resources

DERMS - Distributed Energy Resources Management Systems

DES - Distributed energy systems

EN - Embedded Network

ENO - Embedded Network Operator

kWh - Kilowatt Hour

LCOE – Levelised Cost of Energy

P2P - Peer-to-Peer

PV - Photovoltaic system

ROI – Return on Investment

SEN - Smart Embedded Network

VPP - Virtual Power Plant

WGV - White Gum Valley

WP - Western Power

Executive Summary

The 'Beyond White Gum Valley Precincts Guide: The Energy Village Concept' objective is to assist design teams and planning assessment officers on 'innovative' and achievable options for implementing a precinct distributed energy system (DES). Balance's starting point is that the objective for the precinct's embedded electricity system is to minimise utility grid import and reduce external dependency while increasing residents' energy savings and incorporating community energy sharing potential.

A precinct-scale DES can be ultimately designed as a 'smart embedded network' (SEN). The SEN is a grid-tied microgrid with additional ability to integrate, monitor and optimise (and potentially peer-to-peer trade) distributed energy, storage, load and demand while maintaining interaction with the main grid.

Integrating battery energy storage with solar PV within the embedded network, either behind the customer meter (rooftop solar PV and household storage) or in front of the customer meter (embedded generation and central shared storage) means the embedded network's community can make full use of solar electricity surpluses, before drawing from the main grid.

For greenfield and brownfield restoration developments, the precinct would benefit from being managed with a Virtual Power Plant (VPP) platform, and the network fitted (where possible) with a Distributed Energy Resources Management Systems (DERMS). This will optimise the use of on-site renewable energy assets by allowing more PV to be installed and fed in, and further reduce PV curtailment. These benefits enhance the return on investment (ROI) of PV and storage investments on the precinct, and, we believe, will, in turn, increase the value of - and the appeal for - the precinct and provide positive impacts on reduced GHG emissions.

We have introduced the concept and vision for the precinct-scale SEN as an '*Energy Village'*. This begins with defining the concept of a 'village' as a community gathered in the same geographic area that shares interests, infrastructures, local resources, and which are often managed by specific rules.

The energy producers and consumers interconnected to the village's SEN are considered 'villagers'' and the village is governed by agreed specific energy rules, The success of a village relies on achieving a workable balance of power between the villagers and the village; individual interest vs community interest. Its goal is to create and share a set of efficient, effective and affordable energy resources which benefit the individuals within the village and the village as a whole.

To ensure an effective implementation of this innovative energy network paradigm shift, the facilitating infrastructure and the rules behind the Energy Village should enable every villager to have access to reliable and affordable energy supply which can be expanded as required to run their operations (including electric vehicle charging) and allow investment in on-site generation and in particular renewable generation.

This report takes a relatively high-level look into precinct-scale DES, including energy modelling, and introducing the Energy Village concept, delivering advice and guidance.

1. Introduction

Balance Utility Solutions (Balance) is pleased to provide this report to Curtin University Sustainability Policy Institute (CUSP) for the Beyond White Gum Valley (BWGV) Precincts Guide.

Our understanding is that the Precinct Guide is to assist design teams and planning assessment officers with best practices and to advise (realistic) design options for implementing a precinct DES. Balance is under the assumption that the precinct's embedded electricity system is to be designed for utility grid import minimisation and reduced dependency, while reducing the precinct's carbon footprint, increasing residents' energy savings, and incorporating community energy sharing potential via Peer-to-Peer (P2P) trading.

This report draws on Balance's expertise and knowledge of renewable energy systems and integration, notably WGV solar and battery projects and Western Power's (WP) Perenjori edge-of-grid town Battery Energy Storage System (BESS). Relevantly, we have recently submitted a tender for the Power Ledger Knutsford BESS embedded network (grid-tied microgrid) proposal.

2. Distributed Energy & Embedded Network

2.1 Why?

Using the Western Australia context, under the standard model of build development (referred to as build and transfer), residents are limited into purchasing energy from the retail market at the regulated (Synergy A1) retail rate, exposed to a fixed daily supply charge to each Lot of $1 per day and $0.28 per unit (kWh) of electricity. Household electricity costs have increased annually by more than 10% in four years, with recent increases caused by the near doubling of the fixed supply charge, plus further increases recently in 2018.

Energy costs can have a significant impact on the family budget, especially for those on low incomes. Household expenditure on energy can rise beyond 30% of total spending for those families in the lowest 10% of the income distribution. Energy cost shares have been increasing over time, especially for single-parent families, as over 25% are experiencing electricity poverty.

Adding on-site generation options such as solar PV to reduce the electricity cost (and greenhouse gas emissions), is proven to provide a positive return on the capital investment within a 6-year period, with an ROI of 18%. There is an option to finance the capital at a current loan rate of 4-5% to keep the asset owner's finances positive. An average household with 3kW of PV would potentially reduce its carbon footprint by approximately 124 Tonnes of CO_2 emissions pa, depending on if it was exporting the energy generated or not.

2.2 Distributed Energy

Distributed energy systems (DES) can incorporate a diverse array of distributed energy resources (DER) for generation, storage and energy monitoring and control solutions. DER can include:

- Rooftop or ground-mounted solar PV
- Wind turbines
- Biomass generators
- Geothermal
- Solar thermal
- Fuel cells (Hydrogen)
- Natural gas turbines (incl. Microturbines)
- Tri-generation units
- Battery storage
- Electric vehicles chargers
- Demand response applications

These separate elements work together to form distributed generation resources. This source of decentralised, community-generated energy and, in the case of embedded networks, is a two-way flow of power transforming the grid.

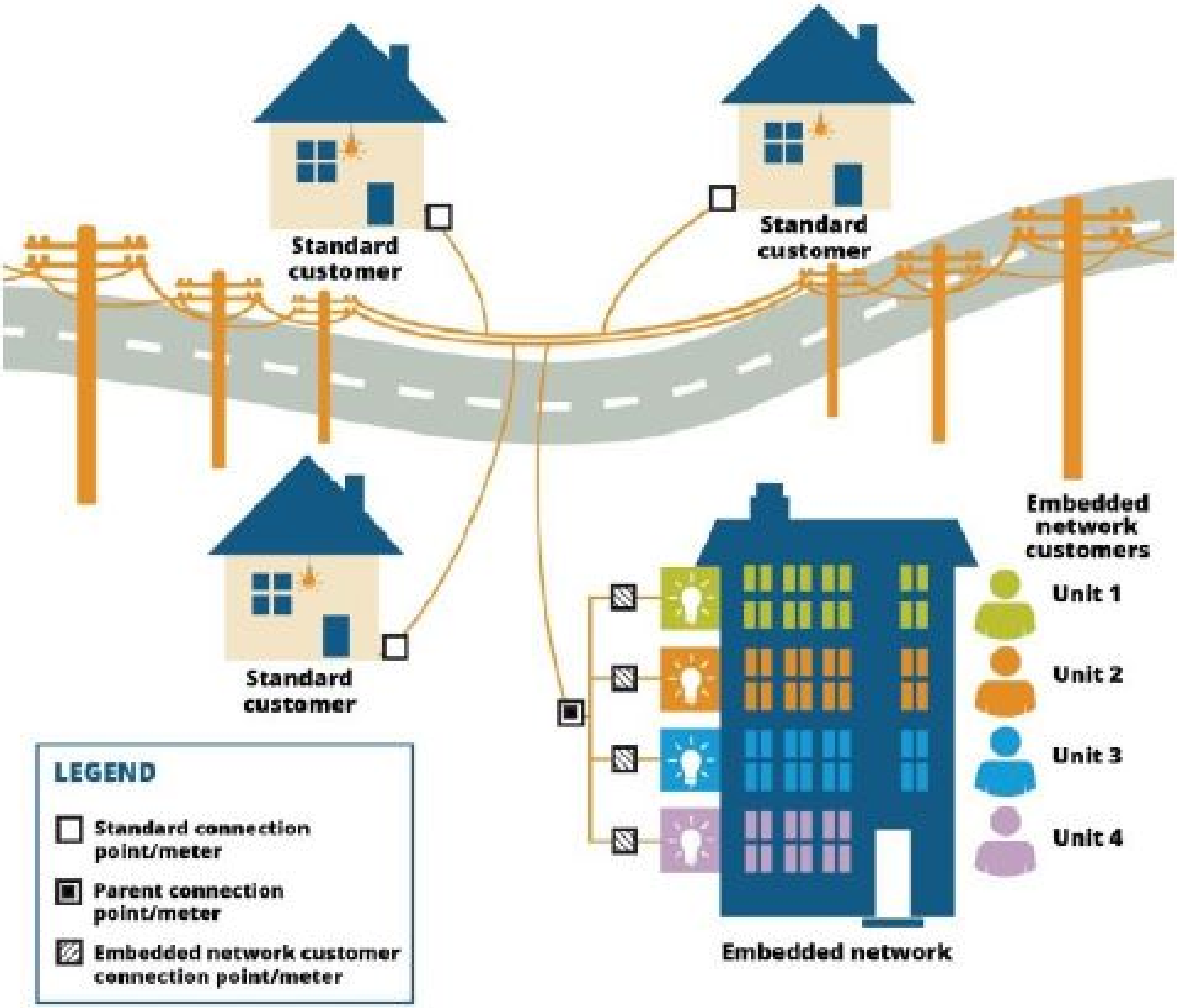
The DES can be designed to specifically desired requirements and users' applications including cost reductions, energy efficiency, security of supply and carbon reduction.

A precinct-scale DES can be ultimately designed as a (standalone) microgrid, an embedded network or a virtual power plant.

2.3 Embedded Network

An embedded network (EN) is a privately owned, operated or controlled energy network, connected at a parent (main) connection point to a distribution or transmission system tethered to the main centralised (public utility) grid. It is important to note that these are defined differently depending on the entity(s) understanding. For the purpose of this report, Balance will use the term 'embedded network' for a grid-tied microgrid.

Figure 1 Embedded network connection points (AEMC)



An embedded network operator (ENO) controls an embedded network's infrastructure to enable reliable, affordable and unconstrained energy supply. The ENO should be able to operate independently, but it may take on the commercial platforms (including retailing) too. Otherwise, this can be a third party. In some cases, the ENO is also the owner of the distribution infrastructure, therefore having a natural monopoly of this part of the energy supply chain.

Instead of individual consumers in the embedded network buying energy from an authorised retailer, the EN retailer (who can also be the ENO), service provider or third party exempt seller purchases all the energy at a commercial rate from an authorised contestable retailer (typically at a lower cost than would be available to individual small consumers) and then on-sells this energy to the individual downstream consumers within the embedded network. The savings become revenue to the embedded network operator, whether it be the owner council, Strata, a subsidiary of the precinct developer or a third-party. This is referred to as a 'simple embedded network'.

A 'smart embedded network' (SEN) has additional ability to integrate, monitor, and optimise (and potentially peer-to-peer trade) distributed energy, storage, load and demand, while maintaining interaction with the main grid.

Integrating battery energy storage with solar PV within the embedded network, either behind the customer meter (rooftop solar PV and household storage) or in front of the customer meter (embedded generation and central shared storage) means the embedded network's community can maximise full use of solar electricity surpluses before drawing from the main grid.

The SEN will provide advanced platforms that enable customer and network benefits through individual system management, efficient usage and access innovative energy retail products. These benefits are attracting momentum to restore and evolve existing brownfield embedded networks and plan advanced greenfield developments.

The growth in this market segment has the potential to provide opportunities for innovative new service offerings while supporting renewable energy and sustainable living.

It would be possible to eventually integrate multiple SENs, into a cluster of connected ‘cellular’ networks that enable a large-scale network. Each SEN would default to its specific locality when required.

2.4 Virtual Power Plant & Distributed Energy Resources Management Systems

A Virtual Power Plant (VPP) is a network of distributed energy resources and generations (i.e. DES), including energy storage, as well as flexible power consumers (i.e. households), to give reliable overall power supply. The interconnected systems are dispatched through the central control room of the VPP but nonetheless remain independent in their operation and ownership.

Introducing precinct-scale SENs will require advancements to the business-as-usual methods used by the Australian Energy Market Energy Operator (AEMO). For a precinct-scale ENO to ensure and protect the stability and reliability of a precinct distributed energy supply, a VPP platform will act on:

1. Control the load via demand response management; and
2. Control the supply via PV curtailment and battery energy system discharge.

The VPP incorporates a central IT control system that can monitor, forecast, and dispatch the networked generation.

The objective of a VPP is to relieve the load on the grid by distributing the electricity generated by the individual units during periods of peak load. Additionally, the combined energy generation and energy consumption of the networked units in the VPP could trade or sell energy to the market.

Distributed Energy Resources Management Systems DERMS use the same controls but are location-specific. They are more capital intensive but, on top of network stability, can perform network protection by manipulating power flows through individual feeders in accordance to the “live” capacity of each equipment on that section of the network.

Ideally, (for greenfield and brownfield restoration EN developments) the entire precinct would benefit from being managed with a VPP platform, and the network fitted (where possible) with a DERMS. This will optimise the use of on-site renewable energy assets by allowing more PV to be installed and fed in, and further reduce PV curtailment. This will optimise the ROI of PV and storage investments on the precinct which in turn will increase the value of - and the appeal for - the precinct.

3. Energy Village

3.1 Concept & Principles

Conceptualising the smart embedded network option as an 'Energy Village' is important for understanding the Energy Village Model and Principles that follow.

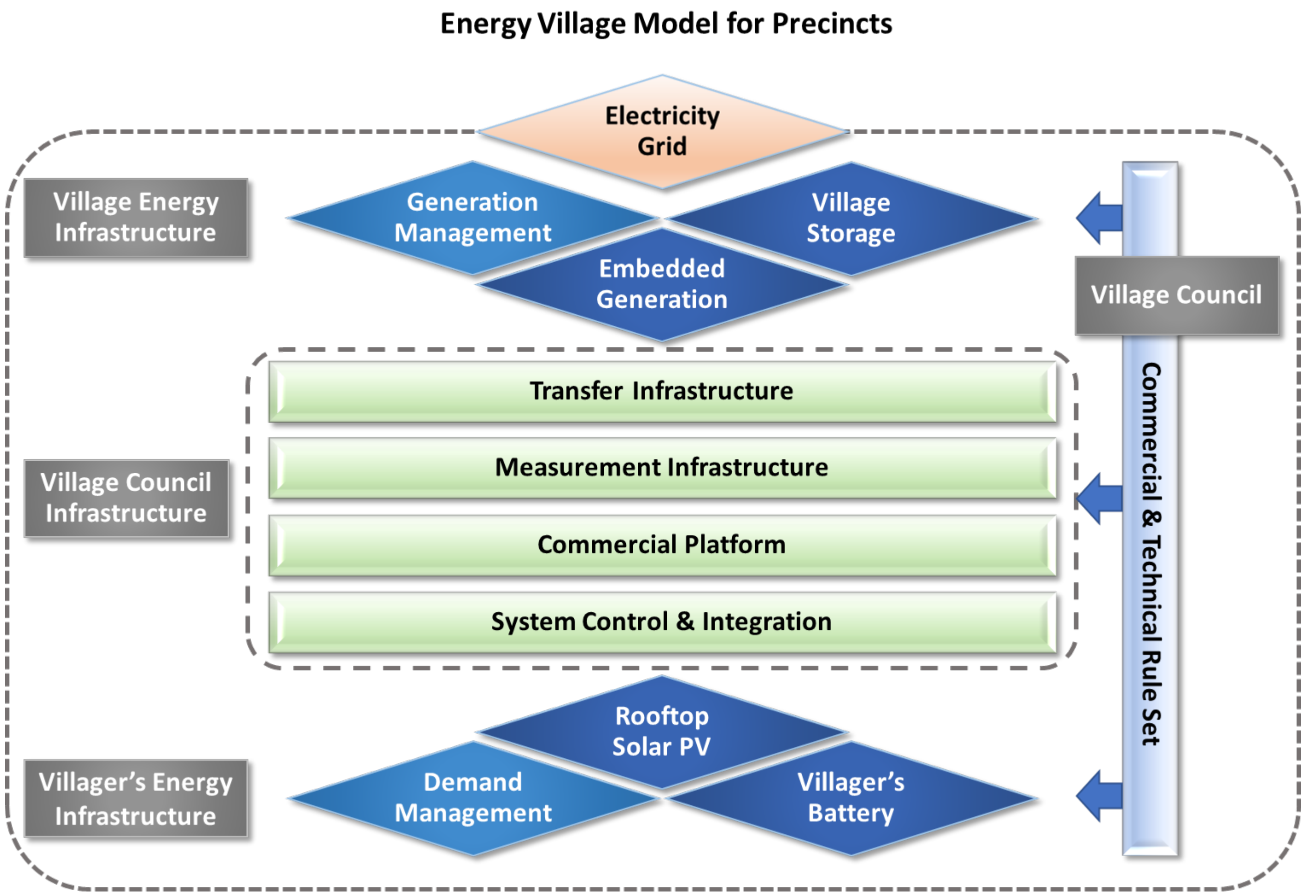
This vision for the precinct-scale SEN as an Energy Village begins with defining the concept of a 'village' as a community gathered in the same geographic area that share interests, infrastructures and local resources. A village encourages collaboration between its villagers and is often managed by specific rules.

An Energy Village has energy as its common business/shared interest, the SEN as the shared infrastructure and on-site (renewable) distributed energy as the shared resource. All the energy producers and consumers interconnected to the village's SEN are considered as 'villagers', and the village is governed by specific energy rules and a 'Village Council'. The success of a village relies on the balance of power between the villagers and individual interest vs community interest. Its goal is to create and share a set of efficient, effective and affordable energy resources which benefit the individuals within the village and the village as a whole.

The infrastructure and the rules behind the Energy Village enable every villager to have access to reliable, affordable and unconstrained energy supply to run their operations (including charge their electric vehicles), and enable them to invest in on-site renewables.

3.2 Energy Village Model

Figure 2 Energy Village Model



To develop an Energy Village – Smart Embedded Network – the framework and infrastructure need to be established first. The four grey boxes in Figure 2 represent the fundamental pillars that hold together and enable the Energy Village. Out of each grey box are the components that developers need to focus on and understand to ensure a fully functional and 'future-ready' SEN.

3.2.1 Energy Village Council Infrastructure

3.2.1.1 Transfer Infrastructure
Provision, maintenance and operation of the core distribution assets such as poles, wires, transformers, switch-rooms, and connection to the main grid. This is regulated, as it's a common user platform. Reducing transfer infrastructure cost could be achieved by the power capacity (kVA) size per lot, based on a predicted lower net import maximum demand (kVA).

This initiative has been demonstrated by the Australian Renewable Energy Agency (ARENA) and the Curtin University Sustainability Policy (CUSP) Institute at the WGV housing precinct - a 110 dwelling residential housing located in White Gum Valley, Fremantle.

Figure 3 WGV

WGV Project partners included LandCorp, Western Power, Balance Utility Solutions, Synergy, Yolk, Contempo and the City of Fremantle.

3.2.1.2 Measurement Infrastructure
Introducing distributed renewable energy and storage into the interconnected (grid-tied) Energy Village means addressing the expectation and complexity of bi-directional energy flow. This requires putting in place smart bi-directional meters in the network to enable sharing between villagers and the potential to use a VPP platform and create an 'energy internet'.

3.2.1.3 Commercial Platform
The commercial platform sets the energy pricing structure, retailer (can be an independent platform due to potential contestability), P2P trading system and investment incentives.

Network electricity charges can be calculated in many ways by:

- Ensuring the cost of the network (asset) is covered to ensure the services are stable and reliable;
- Fair to customers for their use of the network. Giving price signals representing what drives the costs of the network; and
- Future-proof to increase in on-site distributed generation and storage to incentivise customers to remain on the network.

For a commercially mature Energy Village to exist, costs related to the network must be fair and equitable. Customers should be charged based on the demand profile pressure they put on the network while offered the ability to reduce this pressure and be rewarded for it. Reducing the peak demand could be achieved via demand-side management or increased on-site generation and storage.

3.2.1.4 System Control & Integration
The ability to install and run a range of renewable generation and electricity storage systems in an integrated manner is a particularly exciting prospect, albeit complex. The precinct Energy Village requires expert engineering and design for smooth integration of systems.

For high penetration of on-site renewables generation within the Energy Village, the ENO enabled by the Village Council Infrastructure will have to be given control over all on-site generation and storage assets. In the context of the SWIS for example, export to the public main grid currently not permitted by Western Power at this point, therefore demand will need to be controlled.

The Village Council Infrastructure must protect the stability and reliability of the energy supply by controlling the:

- Balance between demand and supply
- Management of demand response with respect to supply capacity
- Frequency regulation
- Operational reserves management
- Peak demand management

Successfully managing the balance between demand and supply – making the most of on-site DER –results in deferring new infrastructure investments such as upgrades to the capacity of the connection to the main grid.

3.2.2 Energy Village Council

Commercial and technical rule sets are needed to support the principles of an Energy Village, as defined in section 3.1, particularly sharing energy resources for the benefit of individuals within the village as well as for the village. Therefore, to ensure effective implementation of this innovative energy network paradigm shift, the Energy Village will have to be governed by a set of rules protecting its principles.

A precinct-scale Energy Village governance framework will provide legal, commercial and technical information needed to implement, and govern DER (i.e. solar PV and battery storage) in developments under built- and survey-strata, and community title. Integrating a successful governance framework will also overcome the barriers of integrating Electric Vehicle (EV) shared charging equipment and prepare for the future of P2P electricity trading over the regulated electricity market.

The governance framework would outline the revenue incentive of positioning the Village Council as the private utility, and act as a tool identifying the shared benefits, risks and costs between developers, owners, villagers, strata bodies and the public utility.

The governance framework model can be presented as an information packet detailing energy system infrastructure, commercial modelling, billing structure, and legal addendums for dwelling purchasers and leases, for any development under strata or community title, for example, within the Energy Village.

Regulation of the supply of electricity through an embedded network is currently focused on two key elements: the network component and the electricity retailing component. However, to ensure the advancement of battery storage, integrated renewable embedded generation, and smart control systems are fully utilised, it is important for the regulatory design to embrace the integrated system concept.

3.2.3 Energy Infrastructure

The Village Energy Infrastructure is divided into two parts, the 'village' and 'villagers'.

'*Village generation assets*; can be, for example, PV and shared village battery storage connected in front of the customer meter. It will necessitate generation management (i.e. PV curtailment) to control excess generation supply. This village generation is driven by commercial models and LCOE. Where there is a need to balance the demand and supply with the Energy Village, the in-front-of-the-meter connection can be a safe option, given the infrastructure and rules facilitate it.

'*Villagers decentralised generation*' can be, for example, rooftop PV and villager's battery behind the customer meter. This requires demand-side management to facilitate the embedded network's overall system demand control. This behind the meter generation investment is driven by a healthy ROI and government incentives.

3.3 Maturity Table

Table 1 Maturity Table

Current Maturity Level		
Aspect	**Technical**	**Regulatory**
Transfer Infrastructure	High	Medium
Measurement Infrastructure	Medium	Low
System Control & Integration	High	Medium
Commercial Platform	Medium	Low
Governance Framework	Medium	Medium
Energy Infrastructure	High	Medium

There are no real technical barriers to implementing and operating renewable energy distributed systems in an Energy Village Model for a precinct. The solar and storage energy systems, for example, are technically proven, with high maturity for PV and rapidly growing for battery systems (notably Lithium Ion).

System control and integration are, from Balance's point of view, mature. The barriers currently posing the most challenges are in the governance and commercial platforms. This is due to their relatively low maturity levels due to their low exposure to the changing energy landscape.

Overall, the embedded network roles and significance in the energy landscape is maturing. It is at the leading edge of network development, a barometer for our success to implement a suitable regulatory regime.

4. How Will It Look: Energy Village On-Site Generation Options

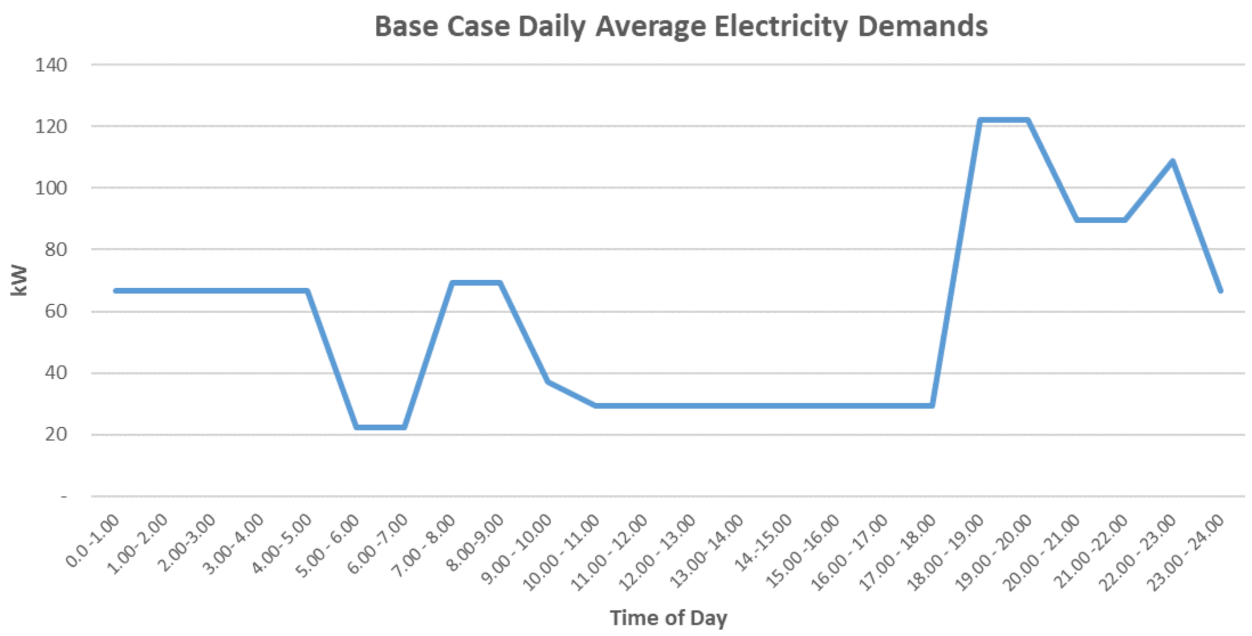
4.1 Precinct Energy Demand Profile

An expected electricity demand profile was created based on the WGV precinct. The basis of the demand profile is assuming mixed housing density with very energy efficient households. This base case daily average electricity demand profile was based on previous research from Lio Hebert and Josh Byrne's proposed dwelling load predictions, using state of the art efficient housing designs.

Assumptions:

- 89 households (39 single dwellings and 50 apartments) with an average daily energy consumption of 15.58kWh per household,
- No gas connection,
- Overnight EV charging – creating the greater than usual overnight demand (beginning at 10 pm)

Figure 4 Base case electricity demand for the 89 dwelling embedded network



4.2 Different methods of ownership

The governance framework should accommodate different methods of asset ownership: Internal ownership (residents owned), Hybrid ownership (residents and external party), and External ownership.

1) Internal ownership model: Where the residents (owner occupiers/investors) jointly own the shared solar PV and battery storage. The council of owners (body corporate or strata body) agrees on an internal electricity price for the solar electricity (usually equal or less than grid-sourced electricity). The strata management company is used as the vehicle to receive payments for all electricity consumed from the battery and the main grid. The portion of this payment for electricity consumed from the battery to the strata can then be deducted from the strata levy. This arrangement benefits both the owner-occupiers and the tenants (renters).

2) Hybrid ownership: Where the residents (owner occupiers/investors) jointly own a percentage of the solar PV and battery storage, the remaining percentage is owned by an external party. The asset owners negotiate on an internal electricity price for solar electricity (which is usually equal to or less than grid-sourced electricity). The strata management company is used as the vehicle to receive payments for all electricity consumed from the battery and the mains-grid. The revenue is also distributed accordingly.

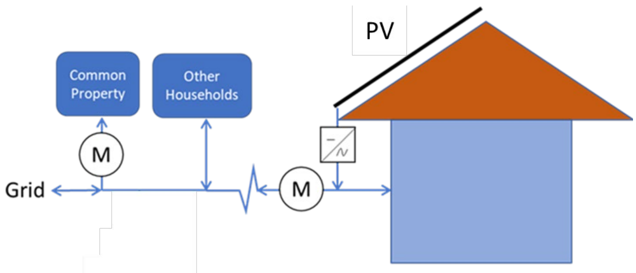
3) External ownership: The external method of ownership enables a third party to be the sole owner of the solar and battery system. In this case, the owner of the asset may also become the local energy retailer to keep everything "in-

house". The asset owner pays rent to the owners (body corporate) for the use of the roof, network, and access to the client base.

4.3 Behind the Customer Meter

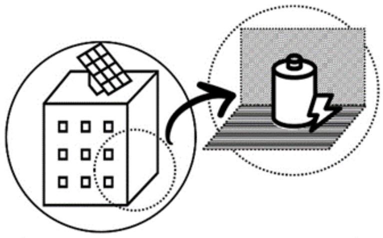
Precinct on-site distributed energy (solar PV and/or battery) connected behind the customer meter (figure 5) benefits the occupants (villagers) directly. However, there is less ability for the Village Council (ENO) to control the electricity prices. For example, occupants that use a substantial portion of their electricity in the evening will potentially still be exposed to the (commercial) peak charges, while occupants who use most of their electricity during the day time still see the biggest savings. The electricity (PV) generated that is not consumed behind the customer meter is exported and shared to the Village (embedded network), of that, a portion of the energy exported is on-sold to other residents on the embedded network and the remainder is exported to the main grid. Depending on whether the Feed-in Tariff applies, the ENO will receive the benefit and choose to pass it down depending on the governing rules set. Alternatively, adding a central battery will allow a greater portion of the excess energy generated to be on-sold to the residents within the precinct.

Figure 5 Owner owned PV system with connection behind the customer meter (blue lines showing energy flow)



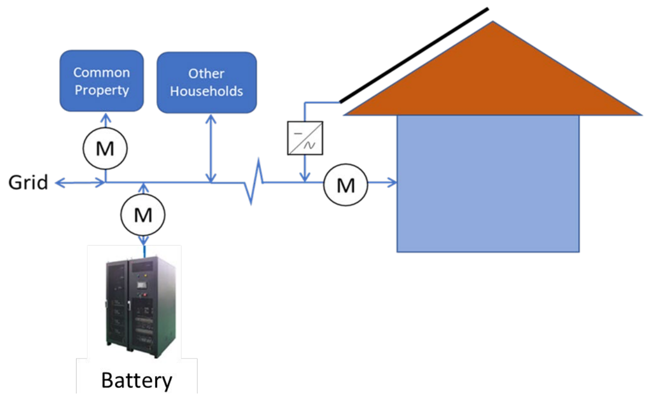
4.4 Front of the Customer Meter

Connecting solar PV and/or central battery in front of the customer meter will allow the ENO or third-party owner/asset manager (operating under the Energy Village rules and governance framework) to essentially allocate the share of PV energy and subsequent storage to each customer, thus controlling the benefits. A proportion could also be set aside for powering the common areas. In the strata context, a shared central battery and solar PV array (in front of the meter) are deemed common property and managed by strata management. In the Energy Village concept, the village council infrastructure is the enabler of this DES setup and functional capacity.



In the case where a third-party asset owner connects the PV system in front of the individual household (and business) meters, and the BESS behind a separate meter, as shown in Figure 6, there can be varying benefits. While there are less apparent benefits to the customers, as their energy use shown in the meter will be the same, the savings are estimated to be similar to the average household, and more independent of individual household variation in load. For example, occupants who don't use much energy during the day, but more in the evening and night will save as much as the occupant that uses more energy during the day.

Figure 6 Third-party assets ownership with PV systems & shared BESS connected in front of the meter (blue lines showing energy flow)

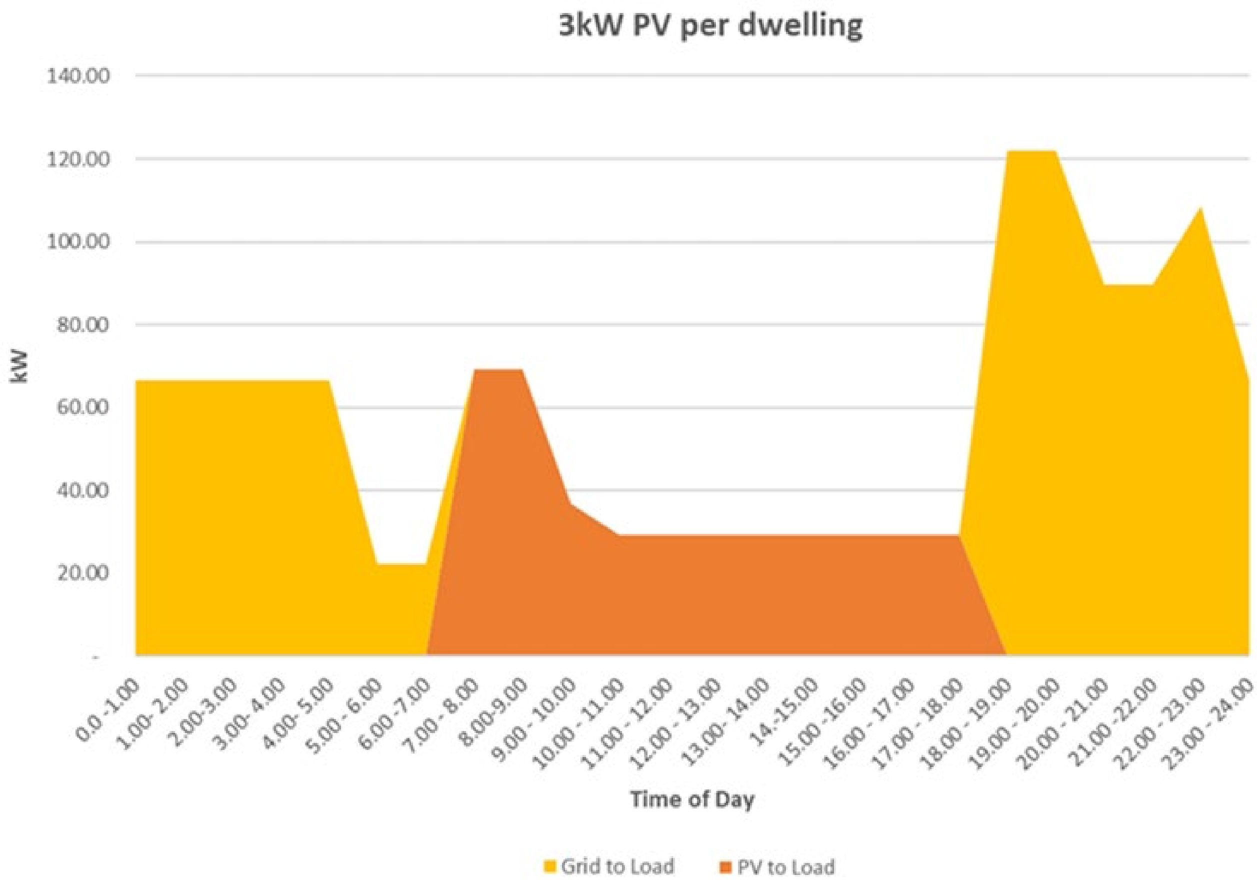


4.5 Precinct Energy Demand with Solar PV & Battery Storage

To help understand the daily energy profile in a future precinct (based on the earlier WGV modelling), two scenarios of introducing DER are shown below.

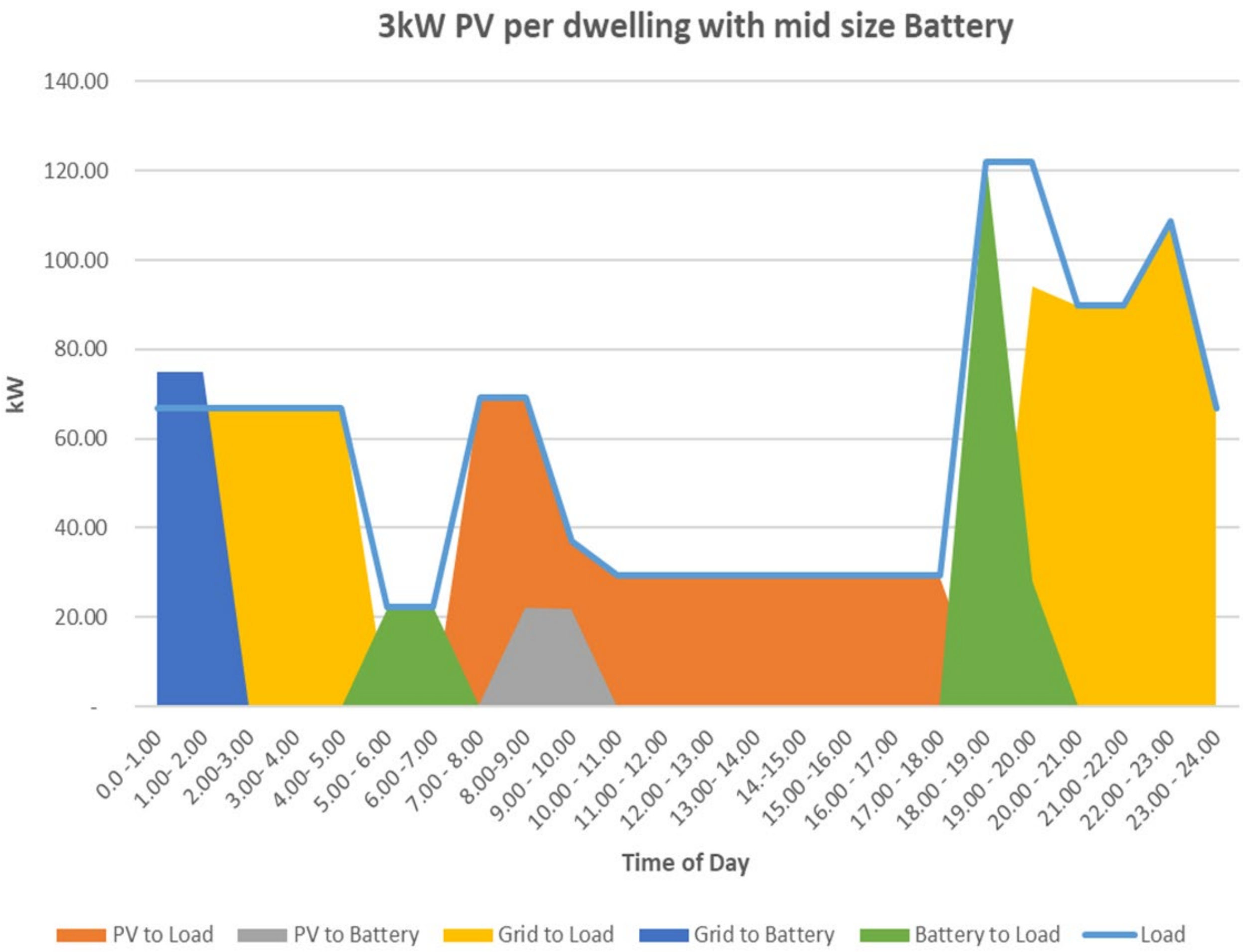
The energy model for the 3kW rooftop PV (behind the customer meter) per dwelling in the EN, with EV charging, is presented in Figure 7. The net PV from the dwellings meets the net demand of the precinct. The high overnight load is due to residents charging their EVs from the main grid, taking advantage of a (potential) low off-peak time-of-use tariff.

Figure 7 3kW solar PV per dwelling with EV charging



A scenario with a mid-sized centralised shared battery connected in front of the customers' meter, and customer-owned rooftop PV connected behind the customer meter, has been modelled (in Figure 8 below) to represent a potential energy profile. Each dwelling has 3kW rooftop PV that supplied the precincts load from 7 am to 5 pm, while the combined excess PV charges the shared central battery from 8 am to 11 am.

Figure 8 3kW solar PV per dwelling with mid-central battery



By 6 pm, as the sun goes down and the load begins its evening demand, the central battery discharges to meet the load until the end of the peak period (9 pm). However, around 7:30 pm, the battery needs help to meet all the load, so the SEN imports the required electricity from the main grid. The demand remains high at night and through to the early morning, due to residents taking advantage of a (potential) low off-peak time-of-use tariff to charge the EV. After midnight the grid is also used in this way to charge the central battery.

To offset the morning peak demand, the central battery (now charged) discharges to the SEN loads for 3 hours then seamlessly the PV increases its generation. In this scenario, the grid is only utilised during the night, mainly to charge EVs and the central battery.

5. Future research

This report takes a relatively high-level look into precinct-scale DES, delivering advice and guidance without going too specifically into solutions and technical depth.

Balance recommends further research and more time to be put into formulating a more comprehensive and in-depth suite of guidelines, information sets and governance framework on precinct-scale DES/energy village networks. We are open to the offer of future contributions in this space and are excited about moving forward.

Reference