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Inquiry into Microgrids and Associated Technologies in WA

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Sustainable Energy Now (SEN) is a voluntary group of some 200 members and associates, many of whom are professionals in the engineering, science, educational, business and IT fields. Its goal is to promote renewable energy in Western Australia.	Contact details: PO Box 341 West Perth, WA 6872 contact@sen.asn.au www.sen.asn.au

About SEN

SEN (Sustainable Energy Now Inc.) is a non-profit association advocating for the utilization of sustainable energy sources within Western Australia (WA). SEN brings together a mix of multidisciplinary knowledge and capability, providing independent advice on renewable energy.

SEN's working teams consist of volunteers whose professional backgrounds include engineering/science, business, education and the environment. The teams have committed thousands of hours to developing evidence-based solutions toward transitioning WA's energy use from fossil fuels to renewables for the good of humanity, the economy and the environment, as a way for WA to play its part in the global transition to a more sustainable future.

Executive Summary

This submission focusses on areas within SEN's strengths and technical/commercial expertise. It therefore primarily addresses Terms of Reference a), c) and d). The submission commences with an overview of the need for this Inquiry, and suggests some improvements in the working definition of a Microgrid. It then discusses the potential of Microgrids both in the urban (behind-the-meter batteries and front-of-meter, utility-scale or utility-controlled storage); and regional contexts. Enablers and barriers are then discussed, with a consideration of broader issues which arise from the potential uses of Microgrids and associated technologies.

Record numbers of WA consumers already have rooftop solar systems, and on-going adoption is increasing in pace. However, limits are increasingly imposed on how much grid-connected solar PV individual households can install (without battery storage), to match the power that can be accommodated by the distribution network.

The Inquiry's working definition was analysed in the context of the arguments SEN intended to present in this submission, and three improvements in the definition are suggested:

Recommendation 1*: Three improvements in the definition are suggested:*

- *The definition should explicitly include smart-grid battery storage and enabling technologies, so that it becomes a forward-looking definition.*
- *The definition should be looser with respect to 'connect and disconnect', to enable communities to disconnect from the grid when it is economically sensible to do so, while still being defined as Microgrids.*
- *The Inquiry should adopt a more nuanced definition of 'Microgrids' that encompasses the diversity of application of the technology. This might include the use of the terms minigrid, microgrid and nanogrid to indicate the varying scales and characteristics of application.*

In terms of potential, SEN argues that, in most circumstances, Microgrids should remain connected to the SWIS grid. The SWIS will remain an important conduit between load and generation sources, although transmission volumes are likely to decrease with more localised generation capacity.

The economics of smaller microgrids and nanogrids mean that the costs of going off-grid are less than the costs of staying connected. There is therefore potential to some 11kV feeder lines, along with the low voltage connector lines and transformers to be decommissioned, with significant maintenance and replacement cost savings

Three inter-related factors characterise the potential benefits of Microgrids:

- Renewable energy technologies, which provide a distributed source of generation;
- Battery technologies, which enable electricity to be stored for use at another time or another place;
- Smart-grid control technologies (Energy Management Systems), which control, manage and monitor the use and storage of electricity.

SEN's modelling has shown that renewable energy technologies, particularly Wind and Solar PV, can cost-effectively meet more than 85% of WA's electricity needs by 2030, reducing carbon emissions more than 90%. This will also be cheaper than building new fossil-fuelled generation facilities. Government action will be required to manage the transition of the entire SWIS grid, and Microgrids will play an important part in this.

With time-of-use tariffs, smart meters, smart inverters and smart devices, end users can minimise their power bills. They can be paid to reduce power consumption during high demand periods – household demand-side-management. Peer-to-peer trading (e.g. Power Ledger) will enable end users on Microgrids to trade between each other to meet load within the Microgrid.

Recommendation 2*: That Government accelerate the modernization of the main electricity grids and integration of Microgrids by instructing agencies to commence:*

- *implementing a compulsory roll out of smart meters across the state*
- *implementing requirements for PV inverter functionality, including wireless control and ability to turn down power exported to the grid*
- *implementing a broad rollout of 'time of use' tariffs*
- *developing incentives to encourage consumers to purchase behind-the-meter Microgrid technologies*
- *developing incentives to purchase smart appliances, to provide household demand-side-management*

By storing excess energy and discharging it into the grid at a steadier rate and at peak demand periods, Microgrids can assist network operators to manage technical issues associated with intermittency, voltage rise, voltage variability and peak demand, including unscheduled peak events. They can also mitigate the need for network upgrades, both at distribution and transmission levels.

Behind-the-meter batteries are predicted become economically viable for households by 2020. Appropriate planning by the government in the next two years will enable the State to be prepared for the advantages of batteries as soon as they become financially attractive for consumers.

At a larger scale, a compelling argument exists for installation of utility-scale batteries at electricity sub-stations and/or behind-the-meter, centrally-controlled batteries in urban areas. This will enable electricity time-shifting to smooth out the daily load profile, and also contribute to grid stability and frequency control.

Grid-controlled batteries can assist in the transition to renewables from WA's aging coal-fired generators, and can provide the Government with more time to implement a planned transition to renewables.

In regional areas, Microgrids provide significant opportunities at fringe areas of the SWIS, where long feeder lines result in expensive voltage losses and lead to frequent outages. A very large, but unknown proportion of WP's operational expenditure budget is spent in maintaining supply on 11kV feeder lines to remote areas that could be most effectively provided for by Microgrids. SEN suggests that Western Power assess all 11kV feeder lines, with a view to replacing some of them with Microgrids. Potential benefits are reduced government expenditure, reduced risk of power outages, reduced risk of fire hazard risk and increased political good will in regional areas.

Recommendation 3*: That the Inquiry obtains information from Western Power about the amount of operational expenditure that can be saved by rolling back the most remote 11kV feeder lines.*

Recommendation 4*: that Western Power assess all 11kV feeder lines, and the requirements of the communities serviced by them, with a view to replacing some of these 11kV lines with Microgrids. Suggested criteria for replacement would include: reducing the risk of power outages, and reducing risk of fire hazard risk.*

Microgrids have benefits in various contexts:

- They smooth out demand on central generation facilities
- They reduce load (and losses) on power distribution lines, reducing the need for distribution and transmission line upgrades
- Lower maximum operating temperatures for lines, transformers and switchgear, thus increasing their longevity and reducing fire risk
- Enhancing grid stability, maintaining the 50hz grid frequency within a narrow threshold

Microgrids are enablers for a transition to renewable electricity, and potentially reduce costs to utilities into the future. The State stands to benefit in a range of ways, by:

- Reducing operational expenditure on the ‘fringe of grid’
- Reduced need for capital expenditure on grid upgrades
- Reduce liability for fires caused by failure on remote transmission lines
- Reduce carbon emissions and contribute to the national Paris Agreement target

Despite the benefits of Microgrids and associated technologies, there are currently legislative and regulatory barriers to their implementation. For example, 3 significant issues are:

- Western Power is not able to install storage to resolve grid issues, because storage is viewed as ‘generation’, and hence Synergy’s responsibility.
- Synergy is required to pay Western Power for the use of its network, regardless of whether transmission is used or not.
- Horizon Power’s responsibility is with all governmental power generation off the SWIS. If a load on the network is replaced with a stand-alone system, then these become Horizon's responsibility under current rules – an inefficient outcome.

Recommendation 5*: The Inquiry should address how the separation of power utility responsibilities should be best managed to enable uptake of Microgrids*

SEN considers that extensive planning and regulatory changes are required before Microgrids can be effectively implemented. Planning and regulatory development is a relatively inexpensive component of the total implementation budget.

Recommendation 6*: The Government should require agencies to undertake comprehensive planning and regulatory development to effectively implement Microgrids.*

Finally, promotion of the benefits of Microgrids, in all their forms, can be presented to the public as a good news story by the Government and power utilities. An argument can be made that power prices will reduce over time, if the transition is accompanied by careful planning.

Introduction

While the transformation of the electricity network in WA is already upon us, further adoption and uptake of new technologies and appropriate regulatory frameworks are necessary. Years of environmental advocacy, rapid technological advances and shifts in consumer demand are driving an unprecedented shake up of our century-old supply network. With this change come opportunities (and some risks) to harness the value of renewable energy across the grid as we drive towards zero emissions. SEN therefore welcomes this Inquiry.

Traditionally, WA's electricity network was largely built and controlled by the state government, and operated as a centralised power supply system managed with two policy imperatives in mind: security of supply and equity of pricing between country and city customers.

The emerging distributed energy generation and storage disruption is placing unprecedented financial and technical challenges on this system, but also presenting great opportunities.

A large part of the shift to date is 'behind-the-meter' photovoltaic (PV) systems, where there is a clear economic case for householders and businesses to invest in solar PV to reduce the impact of the cost of conventional energy supply. Yet establishing value 'in front of the meter'– e.g. enabling trading of locally-generated energy across the grid – has not yet been achieved.

Australia has one of the the highest per-capita rates of rooftop solar uptake internationally, at 20% of households in 2016[1]. This trend is expected to continue increasing size of PV installations[2], falling costs of storage and the advance of Electric Vehicles (EVs).

The increasing uptake of solar PV has led to questions about how much solar power can be accommodated by the power network. This is particularly relevant in Australia because electricity networks were designed to facilitate power flowing in one direction – from centralised power station locations to consumers. If too much distributed solar power is fed back into the grid at any one time, typically midday, it can cause technical problems, and grid operators have resolved this issue by capping the amount of solar PV that can be installed. Properly designed Microgrids can mitigate and alleviate this problem. Pooling solar PV generation and storage across a number of households or a community using a neighbourhood Microgrid could sidestep current caps on grid-connected residential solar and allow residential customers to generate, store and use more of their own solar PV.

New technologies and business models offer opportunities to reduce costs and improve service to all customers. Microgrids and virtual power plants are starting to demonstrate that sharing solar PV generation and battery storage across the grid can provide financial benefits to consumers, and mitigate the security risks that are inherent in the nation's changing electricity sector.

Customers are already benefitting from lower electricity prices, and, in rural areas in particular, the greater reliability provided by Microgrids. For networks, local control and load management can reduce costs, particularly if the models can reduce peak demand and avoid the need for network infrastructure augmentation. For rural areas, there are also economic benefits that flow from local generation.

To be of value, a successful Microgrid, or local energy-sharing system, must also be able to reduce total costs to consumers and/or reduce or avoid infrastructure costs to utilities when compared with the current, business-as-usual approach.

It is understood by the authors that supply of power to rural communities comprise a major portion of Western Power's annual operational budget. We address and highlight the cost saving benefits of providing Microgrids where appropriate as a means of improving network power quality, security and provision of reliable rural power.

However, it should not be construed that the main SWIS electricity grid can ever be replaced by an aggregation of Microgrids. Over 80% of load in the SWIS is concentrated in the Perth Metropolitan area. Most of the remainder is in large mining and industrial sites and three regional towns. SEN's modelling shows that the most cost effective and reliable way to supply these areas with electricity is with the existing distribution and transmission network, with some extension and modernisation.

[1] https://www.cleanenergycouncil.org.au/dam/cec/policy-and-advocacy/reports/2017/clean-energy-australia-report-2016/CEC_AR_2016_FA_WEB_RES.pdf
[2] http://apvi.org.au/wp-content/uploads/2017/08/PV-In-Australia_AU.1.1.pdf

SEN's submission

SEN's submission to this Inquiry addresses the issue of Microgrids across the whole state of Western Australia:

- The South-West region, supplied by the South West interconnected System (SWIS), operated by Western Power (WP), with generation and retailing for households and businesses provided by Synergy
- The rest of the state, mainly the smaller grids (which are too large to be termed Microgrids) supplying the Pilbara and Esperance, and Microgrids supplying isolated towns and communities, which are serviced by Horizon Power (HP).
- Microgrids supplying isolated Mines outside the SWIS and Horizon grids

This submission focusses on areas within SEN's strengths and technical/commercial expertise. It therefore primarily addresses Terms of Reference a), c) and d).

Definitions

The Inquiry has adopted a working definition of the term Microgrid from the US Department of Energy Microgrid Exchange Group:

> *A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid-connected or islanded mode.*

SEN finds this definition problematic in three ways.

Firstly, it refers broadly to 'distributed energy resources'. As such, it includes legacy, fossil-fuel-powered installations (such as at wind/diesel Hopetoun and Bremer Bay). The solar/diesel installations at Nullagine and Marble Bar could also be seen as Microgrids, although they are not connected to a grid.

While there will remain a role for fossil-fuelled generation in Microgrids, SEN argues that the definition should explicitly include smart-grid battery storage and enabling technologies, so that it becomes a forward-looking definition. The benefits, discussed below, which may be gained from Microgrids all rely on innovative use of renewable technologies, and the definition should reflect this.

Secondly, SEN feels that the defined ability to 'connect and disconnect' to the grid can artificially restrict the breadth of discussion. For example, an isolated installation at Marble Bar, powered by solar/ battery, with diesel only as a backup, will probably remain isolated from a main grid but, apart from that, would share all other characteristics of a Microgrid. Indeed, the discussion below highlights several instances where Microgrid technologies could result in regional communities being taken off the grid for economic and service quality reasons. If this would mean that they were no longer Microgrids, then the Inquiry would not be able to discuss the full impact of Microgrids. SEN believes that the definition should be looser with respect to grid connectivity.

Finally, SEN feels that the definition does not encompass the diversity of application of Microgrids, and this may inhibit thinking around the application of this technology. The following paragraphs propose three definitions of 'Microgrid', differentiated by size.

A relatively large town, such as Kalbarri, would qualify as a Microgrid under this definition once the current 5MW Western Power[3] wind and solar project is completed. Most generation and storage would occur within the town boundaries, but a grid connect exists for import of electricity during weather lulls, and for export of excess electricity. Utility-scale battery storage, e.g. a large battery bank located at an electricity sub-station, is appropriate in such a scenario. The scale of this installation leads it to be called a *minigrid*, as shown in Table 1.

Smaller towns on the edge of the SWIS grid could also benefit from Microgrid approaches (for example in the wheatbelt and coastal communities), because they are prone to grid outages and maintaining a secure, reliable power supply is more expensive than close to major population centres. Storage can be provided by either utility scale storage or individual batteries 'behind-the-meter' in

[3] https://westernpower.com.au/energy-solutions/projects-and-trials/kalbarri-microgrid

households. The term *microgrid* is appropriate for this scale, and it can also be applied to self-contained suburban contexts, such as in the trial Alkimos site[4].

At an even smaller scale, Microgrids are also attractive for small communities, e.g. farms at the edge of the grid, apartment complexes. Localised generation and storage is very attractive for such communities, typically behind the meter. The term *nanogrid* is preferred in this context (see Table 1).

SEN asserts that the Committee should adopt a more nuanced definition of 'Microgrids' that encompasses the diversity of application discussed above. This will be expanded upon in the body of this submission.

Table 1. Suggested terminology based on grid connectivity and scale.

Term	Application	Context	Example
Minigrid	Relatively large suburb or regional town	2-20 MW Utility-scale batteries Predominantly connected to the main grid	Kalbarri
Microgrid	Small town at edge of grid Self-contained suburban context	200 kW – 2 MW Small utility-scale batteries and/or aggregated behind-the-meter batteries Predominantly islanded from grid	Alkimos
Nanogrid	Individual farm or dwelling Small community Apartment complex	Up to 200 kW Behind-the-meter batteries Typically disconnected from the grid	White Gum Valley

Requirements of a modern electricity system

To conclude this introduction, SEN offers this explanation of two key concepts that are referred to frequently in the body of this submission.

A modern electricity system is required to provide secure and stable power when needed. This means the electricity grid must be able to:

- Provide sufficient power to meet the power demand at all times of the day, regardless of renewable energy source (*grid security*).
- Respond to fluctuations in alternating current frequency (frequency control) caused by unexpected outages or demand changes (*grid stability*).
- Accommodate distributed energy through smart-grid[5] technologies

The Potential for Microgrids

This section addresses the provision of affordable, secure, reliable and sustainable energy supply, in Western Australia. Microgrids, in all their forms, can contribute to achieving these criteria.

SEN argues that, in most circumstances, minigrids and larger microgrids should remain connected to the main grid. The SWIS will remain an important conduit between load and generation sources, although transmission volumes are likely to decrease with more localised generation capacity. SWIS connection of these Microgrids will be important as uptake of electric cars, trucks and tractors increases the need for reliable fuelled backup, which is more cost effectively provided by large gas turbines located at urban and industrial load centres with access to gas pipelines. EV's will comprise a major part of the grid load along regional 'electric highways.

The economics of smaller microgrids and nanogrids may mean that the costs of going off-grid are less than the costs of staying connected, and they could function more effectively off-grid.

[4] https://www.synergy.net.au/Our-energy/Store/Energy-Storage-Trial-at-Alkimos-Beach
[5] See, for example, http://cdn.intechopen.com/pdfs/17061/InTech-Smart_grid_and_dynamic_power_management.pdf and https://www.nist.gov/sites/default/files/documents/public_affairs/releases/smartgrid_interoperability_final.pdf

Three inter-related factors characterise the potential benefits of Microgrids:

- Renewable energy technologies, which provide a distributed source of generation;
- Battery technologies, which enable electricity to be stored for use at another time or another place[6];
- Smart-grid control technologies (Energy Management Systems), which control, manage and monitor the use and storage of electricity.

SEN's own modelling[7] has shown that renewable energy technologies, particularly Wind and Solar PV, can meet 85% of WA's electricity needs by 2030, reducing carbon emissions more than 90%. This will also be cheaper than building new fossil-fuelled generation facilities. Government action will be required to manage the transition, and Microgrids will play an important part in this.

Battery storage in Microgrids, and the larger grid, is being used around the world, including trials in WA. Battery prices are falling steeply. For example, the Tesla Powerwall price fell by 50% in 12 months and prices are predicted to decrease further over the next decade.

Energy Management Systems, together with innovative technologies and business models, enable the potential of Microgrids. For example:

- Smart meters and smart inverters can be used with behind-the-meter batteries (BMB) to smooth out network demand peaks. As well as using their stored energy for personal loads, end users can export power to meet evening demand, and re-charge their batteries in periods of low demand/price.
- With smart meters and smart appliances, end users can choose to utilize the benefits of time-of-use tariffs and household demand-side-management, and make cash savings by reducing or even curtailing their power consumption during high demand periods.
- Peer-to-peer trading (e.g. Power Ledger) enables end users on Microgrids to trade between each other to supply a large portion of their demand within the Microgrid. This reduces demand on the centralised network.

In summary, renewable and battery-based Microgrids can contribute to an affordable, secure, reliable and sustainable energy supply, in Western Australia.

Microgrids in Metropolitan WA

The previous section outlines factors which are particularly relevant in an urban context. Urban Microgrids are being trialled or developed in WA, as shown in Table 2.

Table 2. Urban Microgrids under trial or development

Site	Size	Status
Alkimos [4]	1.1 MW	Synergy Trial using utility-scale storage
White Gum Valley[8]	9 kW	Landcorp trial using Powerledger technology
Fremantle solar city[9]	4.9 MW	Proposed minigrid
Broome: Waranyjarri Estate[10]	~50kW	LandCorp/ Horizon Power trial using BMB on individual houses

[6] See, for example, https://rmi.org/insights/reports/economics-battery-energy-storage/

[7] https://d3n8a8pro7vhmx.cloudfront.net/sen/pages/185/attachments/original/1488077878/Briefing_Note_Economics_2017_V1d.pdf?1488077878

[8] https://www.landcorp.com.au/innovation/wgv/initiatives/energy/

[9] https://www.fremantle.wa.gov.au/solarfarm

[10] http://www.landcorp.com.au/smartsun

If these trials prove to be cost-effective, there is significant potential for new urban developments and re-development projects to deploy Microgrids that integrate renewable generation and storage facilities[11].

Alternative Technology Association (ATA) research[12] from 2014 found that *"Regional towns and new housing estates could function viably and economically off the electricity grid".*

Further Alternative Technology Association research[13] in 2015 identified that behind-the-meter batteries will be economically viable by 2020. Appropriate planning by the government in the next two years will enable the State to be prepared for the advantages of BMB as soon as it becomes financially attractive for consumers.

There are numerous opportunities for suburban Microgrids to be developed, with appropriate government policy settings. See, for example, Issues 137 (pp. 30-35) and 138 (pp. 22-23) of Renew Magazine. These include:

- Geographically localised dwellings, such as caravan parks and apartment blocks, where connection to the grid is through a parent meter, with sub-meters at premises.
- Virtual Power Plants (VPPs) where software is used to control generation and consumption between non-neighbouring buildings. A particular example is the SA government's proposed Virtual Power Plant project[14], which will install subsidised solar PV and batteries on social housing, and use the aggregated battery storage to dynamically respond to load and frequency fluctuations[15].
- Other applications of VPP's would be in the vicinity of light industrial areas, commercial precincts and carparks with EV charging facilities, where demand would be high during the middle of the day when solar PV generation is highest.

Utility-scale storage at sub-stations

There is compelling argument for installation of utility-scale batteries at electricity sub-stations and/or behind-the-meter, centrally-controlled batteries in urban areas. In addition to previous discussion about battery storage contributing to grid stability and frequency control, this can also assist in the transition to renewables from WA's aging coal-fired generators.

The historical electricity generation system is based on a constant level of generation to meet minimum demand at night, while variations in load are met by more flexible gas generation. The minimum daily demand (so called 'base-load' generation) has historically been met by coal-fired plants. Coal-fired plants, especially old ones, are not designed to vary their output up and down (so-called 'ramping).

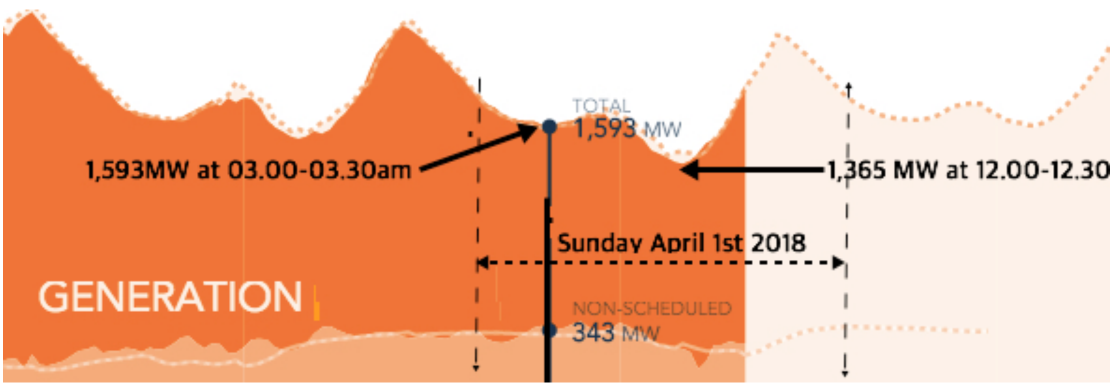

Figure 1. SWIS generation on 1 April 2018, showing solar PV reducing load below the overnight baseload at around midday. Source: AEMO, 01 April 2018.

[11] https://www.theurbandeveloper.com/micro-grids-give-new-meaning-community-empowerment
[12] http://www.ata.org.au/ata-research/towns-and-estates-could-unplug-from-the-grid-report
[13] http://www.ata.org.au/wp-content/projects/ATA%20Household%20Battery%20Study.pdf
[14] http://ourenergyplan.sa.gov.au/virtual-power-plant
[15] A further benefit of this approach is that it addresses the current inequity in solar PV uptake. Currently, people on low incomes, who can least afford to pay their power bills, cannot afford to purchase solar PV to reduce their power bills.

SEN has recently been closely monitoring the power generation statistics provided by AEMO, and on several recent occasions, solar generation during the day has resulted in the daytime load being less than the overnight base load. Figure 1 shows this for the 1st of April 2018, where minimum daytime load fell below the overnight minimum by over 220MW. This clearly shows that solar PV is already at times decreasing the amount of coal required. As renewable energy increases, this situation will occur more frequently.

During periods of high solar energy (middle of sunny days), or high wind energy, renewable generation will increase, and coal-fired generation will need to ramp down or shut off, then ramp up within hours or even minutes to provide power as demand increases when the sun sets or wind drops. When coal-fired power units within stations are operated in load following mode in this way, with frequent large ramps (over 30% of capacity), or alternatively shut down, maintenance costs increase steeply and the risks of failure escalates. This is exacerbated when the units in question are ageing, as is the case with the Muja C-D power station. Coal units are therefore becoming increasingly vulnerable to unplanned outages, potentially involving dangerous and costly catastrophic failure, e.g. boiler explosions. This poses an increasing threat to grid security.

Alternatively, the coal units may, under some circumstances, be kept running when renewable energy is available at zero marginal cost, causing increasing amounts of fuel 'wastage'. As solar PV uptake by consumers increases further and the midday network load falls in equal proportion, coal units will be forced to operate inefficiently at low load while 'free' RE is wasted, for increasingly frequent and longer periods. Either way, forced ramping or wasted generation means increased energy costs. In either case, government inaction will lead to increased costs to the state, and ultimately consumers.

In the medium term, installation of utility-scale batteries at sub-stations, or other suitable locations, will enable electricity time-shifting. That is, some excess rooftop solar PV generation can be stored during the day ready to supply demand during the evening, thereby smoothing out the load profile and reducing the immediate risk of coal outages.

However, SEN is aware that legislative and regulatory impediments prevent this technical solution from being implemented at present (see Regulatory Barriers below). SEN is aware that the grid operator, AEMO, is also concerned about these regulatory barriers.

Grid-controlled batteries can provide the government with more time to implement a planned transition to renewables, but this is just one of several approaches needed to provide an affordable, secure, reliable and sustainable energy supply in Western Australia.

SEN asserts that a planned, rapid transition of the entire SWIS grid to wind and solar PV generation, with new utility scale RE power stations connected by new HVAC transmission lines, combined with energy storage, is the lowest cost and most secure and cleanest trajectory for electricity generation in WA. The more rapidly the coal generators are replaced by renewable generators, the shorter the period of time they will be exposed to costly ramping and/ or fuel wastage. Further discussion of this strategy for the SWIS is beyond the scope of this Inquiry, but SEN are happy to continue to engage with Government on it.

Microgrids in Regional WA

In addition to the application discussed above, Microgrids of various sizes also provide significant opportunities at fringe areas of the SWIS. Long feeder lines result in expensive voltage losses and lead to frequent outages in towns. Excessive load on the distribution network can result in high operating temperatures for lines, transformers and switchgear, increasing risk of failure and fires. Microgrids can alleviate these occurrences, and lead to better services for regional customers.

SEN concurs with ATA research [13] that

> *"Regional towns … could function viably and economically off the electricity grid."* and
>
> *"The stand-alone approach would give electricity network companies the opportunity to sell assets that they can no longer afford to maintain, and creates the potential to unwind cross-subsidies from urban to regional consumers"*

Various Microgrids already exist in isolated towns at the far reaches of the SWIS. For example, Bremer Bay and Hopetoun have had hybrid wind/ diesel Microgrids for many years. SEN is aware that Synergy is proposing an upgrade to the Bremer Bay facility to include rooftop solar and batteries. A small utility-scale battery would be able to decrease the time of an outage from seconds to milliseconds and support town load whilst diesel generators start. Installation of additional renewable generation and battery storage could provide virtual power plant functionality, and enable the power line to Albany to be decommissioned.

A second example under development is the 5MW Kalbarri minigrid [3],which will combine the existing windfarm with solar PV and utility-scale battery storage to achieve improved grid security and stability.

These approaches can be extended to other localities near the edge of the grid, e.g. Seabird (less than 100kms from Perth, but at the end of a feeder line), and Walpole (serviced by a 120km radial line out from Albany substation).

A solution for Walpole and similar communities would be to create an isolated microgrid, powered by local wind and PV generation and batteries with fuelled backup generators. SEN has costed this generation mix as being competitive with the existing SWIS coal- and gas-based mix. Electricity retailing and metering could potentially still be administered by Synergy, but neighbours could use Microgrid functionality to import and export to each other. SEN has estimated that transmission cost from Albany to Walpole is approximately 1.5c/kWh ($15/MWh) for residential customers. In addition, transmission losses are 9.9% for Albany, so an additional 1c /kWh may be saved This type of Microgrid would reduce, and may even eliminate, the current 'Tariff Adjustment Payments' paid to Synergy to subsidise the energy bills of country customers.

SEN is aware, following conversations with Western Power representatives, that a very large proportion of WP's operational expenditure (OPEX) budget is spent in maintaining supply on 11kV feeder lines to remote areas that could be most effectively provided for by Microgrids. Western Power has an economic incentive to roll-out microgrid and nanogrid technology at the fringe of the grid, and with appropriate governmental direction, it could redirect some of its OPEX budget to subsidise them. SEN is unaware of the exact amount of this funding, and suggests that the Inquiry obtains this information from WP, and considers ways in which reducing dependence on 11kV feeder lines could be funded – such as bulk purchasing by Western Power of Microgrid technology components and rapid roll out of Microgrids using competitive tenders.

SEN suggests that the best way forward is to start with 'low-hanging fruit'. One option is the communities at the far end of the grid, as discussed above. A second option is to replace feeder lines to farming properties with localised nanogrids. Subsidised solar PV and battery installations on farms most distant from town-based substation will reduce transmission and operational costs. The rollout can progressively target farms closer to the town, and other users will benefit from the most distant load not being as far as before.

As Microgrid technologies become cheaper, a decision might be made to progressively close selected 11kV lines to communities that have been assessed as being serviceable by 'stand-alone' Microgrids. Cost/benefit judgements will need to be made about a balance point between how much to transmit over what distance. There are benefits to grid security of retaining interconnectors between Microgrids, but the costs of the interconnectors may be more than providing energy security through backup generation.

On the other hand, where significant generation capacity is installed in minigrids (e.g. Kalbarri, Denmark), energy security can be provided by upgrading to 3 phase 22kV or 33kV lines.

In summary, SEN suggests that the Inquiry recommend that Western Power assess all 11kV feeder lines, and the requirements of the communities serviced by them, with a view to replacing some of these 11kV lines with Microgrids. Potential benefits are reduced government expenditure, reduced risk of power outages, reduced risk of fire hazard risk and increased political good will in regional areas.

To reinforce this point, the global market for Microgrids shows that rural/remote installations comprise the largest share of Microgrid opportunities as indicated in Fig. 2.

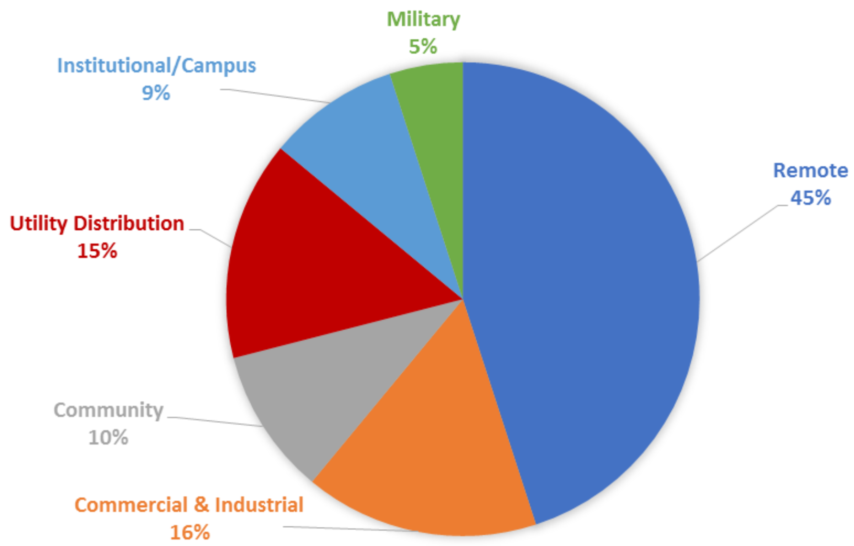

Figure 2. International market share in Microgrid applications. From http://energymarketintel.com/whats-next-microgrid-industry.

Enablers and Barriers

This section addresses key enablers, barriers and other factors affecting Microgrid development and electricity network operations in Western Australia.

Micro-grids can also enable self-generated electricity to be sold into the grid at peak prices, while charging the batteries during off peak periods, increasing the value to participating residences (arbitrage).

In addition, the ability to reduce peak demand through such a system could actively assist network utilities to manage challenging periods of variable power production and overall activity on the grid.

Enablers/ benefits

Previous sections have pointed out the benefits of Microgrids in various contexts. A more comprehensive list of benefits is that they:

- smooth out demand on central generation facilities
- reduce load (and losses) on power distribution lines, reducing the need for distribution and transmission line upgrades
- lower maximum operating temperatures for lines, transformers and switchgear, thus increasing their longevity and reducing fire risk
- enhance grid stability, maintaining the 50hz grid frequency within a narrow threshold
- can, during a utility grid disturbance, separate and isolate themselves from the utility with little or no disruption to the loads within the microgrid.
- prevent utility grid failure in peak load periods by reducing the overall load on the grid.
- provide significant environmental benefits made possible by the use of low or zero emission generators
- mitigate electricity costs to users by generating some individual electricity needs.

Microgrids have the potential to reduce the cost burden on consumers. Subsidised (Government or otherwise) virtual power plants for social housing reduce the cost burden on people on low incomes, with the added benefit of reducing demand on government hardship payments.

Microgrids are enablers for a transition to renewable electricity, and potentially reduce costs to utilities into the future. The State stands to benefit in a range of ways, by:

- Reducing operational expenditure on the 'fringe of grid'
- Reduced need for capital expenditure on grid upgrades

- Reduce liability for fires caused by failure on remote transmission lines
- Reduce carbon emissions and contribute to the national Paris Agreement target

Promotion of the benefits of Microgrids, in all their forms, can be presented to the public as a good news story by the Government and power utilities. An argument can be made that power prices will reduce in time, if the transition is accompanied by careful planning.

Barriers

Despite the benefits of Microgrids and associated technologies, they also present some technical challenges:

- Voltage, frequency and power quality are three main parameters that must be considered and controlled to acceptable standards whilst the power and energy balance is maintained.
- Electrical energy needs to be stored in battery banks or other storage media thus requiring more space and maintenance.
- Microgrid protection is one of the most important challenges facing the implementation of Microgrids.
- Issues such as standby charges and net metering may pose obstacles.
- Interconnection standards need to be developed to ensure consistency across the network.

More importantly to this Inquiry are the legislative and regulatory barriers to their implementation.

Separation of power utility responsibilities

The separation of responsibilities between generation, transmission and retailing, and between Synergy, Western Power and Horizon Power has led to a situation where these utilities cannot take best advantage of changes in technology. Urgent government action is needed to resolve these regulatory issues. For example:

- Western Power is not legally able to install storage to resolve grid issues, because storage is classed as ‘generation’, and hence Synergy’s responsibility, under the law as it stands.
- Synergy is required by current regulations to pay Western Power for the use of its network, regardless of whether transmission is used or not.
- Horizon Power’s responsibility is with all government-owned power generation off the SWIS. If Western Power decides to replace a load on the network with a stand-alone system (e.g. Bremer Bay and Walpole, as discussed here), then these become Horizon's responsibility under current rules. The Inquiry might consider how this division of responsibility should be best managed.

Planning and regulatory development

SEN argues that extensive planning and regulatory updates are required before Microgrids can be effectively implemented on a large scale, across the state and in a controlled manner that supports future development. However, SEN recognises that much of this work overlaps with that required for the broader transition to high levels of renewable electricity on the SWIS and the Horizon grids. SEN sees this Inquiry as contributing to the development of a Renewable Electricity Transition Plan which sets out the government’s *vision* and addresses the requirements for a just transition for affected communities. It also recognises the current tight budget situation. However, the early phase of solid planning and regulatory development is a relatively inexpensive component of the total implementation budget, and it also:

- delivers significant savings over the life of the project, when budget funding is available for roll-out of renewables;
- substantially reduces the state government’s risk profile, as the time needed to react to evolving markets and electricity generation and delivery outages is reduced. New generation can be delivered quickly and with budget confidence once the planning and regulatory framework is in place.

The following paragraphs outline planning components which will facilitate the implementation of Microgrids.

Any modernisation of the power system to enable renewables will require the use of smart meters. Government should require a compulsory roll out of smart meters across the state, as is currently being carried out by Horizon Power.

Similarly, the government should ensure that 'state of the art' inverter functionality is applied and standardised for use in Microgrids, to enable wireless control of inverters.

At the development planning level, the Inquiry might investigate requiring residential, commercial and industrial developments to undertake feasibility studies into deploying Microgrids as part of the planning process.

Consumer issues

Consumers also need incentives to buy into Microgrid initiatives. These include:

- Broad rollout of 'time of use' tariffs, to encourage consumers to use electricity at times of low demand or high supply. These should eventually evolve into real time tariffs to accurately reflect the true cost of generation at all times.
- Incentives to encourage consumers to purchase behind-the-meter battery and PV technologies
- Incentives to purchase smart appliances, to enable household demand-side-management

Where the greatest potential savings are available to government, e.g. in rural areas, the Inquiry should seriously consider universal subsidies for behind the meter battery system installations and related technologies, to speed the transition process.

Technical factors

Much of the preceding discussion has been about the benefits to users *within* a Microgrid, and many technical issues have been discussed. However, Microgrids also benefit the network as a whole. They smooth out demand on central generation facilities, and reduce load (and losses) on power distribution lines.

Grid stability

One major, system-wide benefit is in enhancing grid stability, maintaining the 50hz grid frequency within a narrow threshold. Traditionally, frequency control has been provided by spinning reserve, using standby turbines or diesels in 'hot standby duty'. These reserve generator sets are kept spinning without producing any energy, ready to deliver reserve power in opposition to any frequency change. In the case of gas turbines running in spinning reserve mode, the cost of operation is very high, often up to 65% of full load power consumption. Similarly coal units operating at low load for spinning reserve are very energy inefficient.

While the current SWIS relies heavily on traditional spinning reserve, it is not the only option for managing grid stability. Utility-scale batteries and/or behind-the-meter, grid-controlled batteries can reduce the need for traditional, fossil-fuel driven spinning reserve and respond more rapidly. Indeed, they can significantly outperform spinning reserve. Current AEMO guidelines for frequency control ancillary services require them to provide response in less than 6 seconds[16]. However, batteries can respond in tens to hundreds of milliseconds.

An example of this occurred on 14 December 2017, when the 560MW Loy Yang A 3 coal generator in Victoria tripped suddenly. The 100MW Tesla battery in SA responded in milliseconds[17], maintaining frequency until the contracted spinning reserve started to react.

Modern grid stability requires multiple technologies, including spinning reserve, but including mature technologies such as flywheels and 'isochronous spinning reserve'. However, battery technology will play an increasing role in providing frequency control functionality, and can speed the transition away from fossil-fuelled generation.

[16] https://reneweconomy.com.au/yes-tesla-battery-massive-can-much-beside-54815/
[17] https://reneweconomy.com.au/tesla-big-battery-outsmarts-lumbering-coal-units-after-loy-yang-trips-70003

Workforce planning and development and Social factors

While SEN has no specific data about the employment associated with Microgrids, it has modelled the jobs created through a transition to renewables across the SWIS as a whole[18].

Our 2016 work estimated that the transition would result in 37,000 job-years in construction and 6,000 job-years in manufacturing over 5 years, plus 2000 ongoing Operations and Maintenance jobs – 1400 more than the existing 650 jobs in coal-fired electricity.

This work was expanded in 2017, to map the jobs created across a 15 year transition to 85% of energy generated by renewables. This is shown in Figure 3, and it indicates that there are approximately 4,500 jobs over ten years in construction and manufacturing, and, by 2030, over 2,000 permanent jobs in operations and maintenance.

SEN's Jobs Revolution Briefing Note also presented ideas about how to achieve a just transition for the Collie community. This work claimed that Collie can grow and prosper if some of the new renewable energy generation is directed to the region, in a carefully planned way, to minimise disruption to that community. This can be achieved through, for example:

- Installing 1,000 MW of wind farms, 200 MW of utility scale solar PV east and west of Collie, and 400 MW of biomass generation
- Creating permanent renewable electricity jobs for the community, plus initial construction and other supporting jobs
- Establishing local manufacturing industry for wind turbine towers and blades, and solar panel support structures, etc.

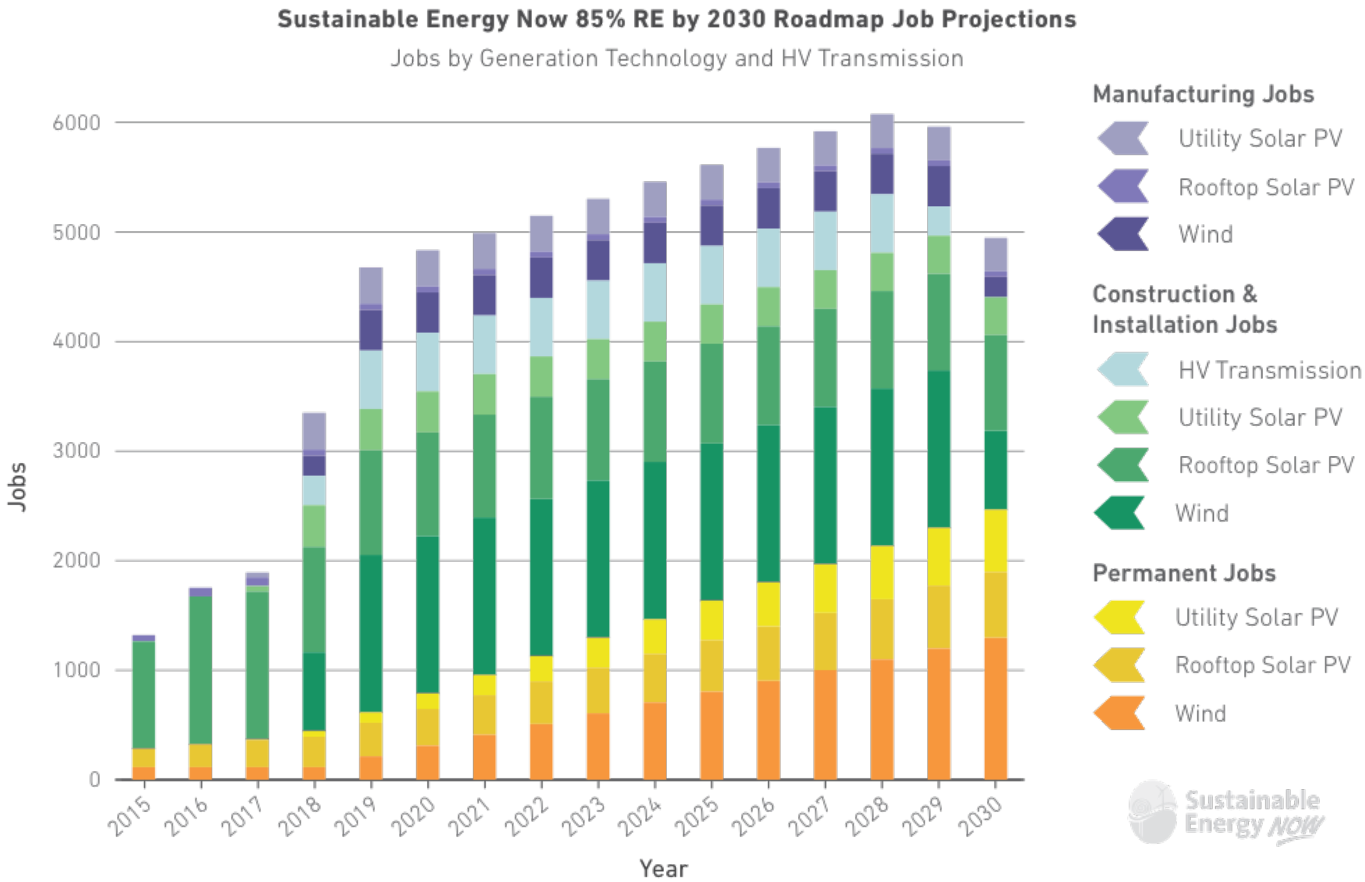

Figure 3. Types of jobs created through a 15 year transition to renewable electricity in the SWIS

18 https://d3n8a8pro7vhmx.cloudfront.net/sen/pages/185/attachments/original/1488077885/Briefing_Note_Jobs_Revolution_2017_V1d.pdf?1488077885

Electric Vehicles

The uptake of electric vehicles (EVs) will inevitably increase, despite Australia lagging behind many other countries in the policy arena. World-wide demand is increasing rapidly and prices will fall.

This may ultimately increase total grid load by over 20%. Households with nanogrids can meet much of their own demand for EV charging, thus reducing demand on the grid. Electric vehicles on an appropriately configured Microgrid may enhance grid security and balance demand, because their storage may be drawn on when needed, as a supplementary behind-the-meter battery.

Electric vehicles offer the potential to substantially replace Australia’s consumption of petroleum fuels, which is currently approaching 100% imported, with locally generated electricity. This will greatly increase transport fuel security, and shift the balance of trade in our favour by many billions of dollars per year. In the event of fuel supplies being cut off, Australia's total stockholding of oil and liquid fuel comprised two weeks of supply at sea, five to 12 days' supply at refineries, 10 days of refined stock at terminals and three days at service stations[19]. Powering transport with locally produced electricity will greatly improve our fuel security.

Electric buses are now commercially available and widely used in some countries, with successful trials of a unit manufactured in South Australia and also trials in ACT and Melbourne[20]. A policy decision by the state government to progressively migrate to electric buses (and reduce carbon emissions) could, perhaps counterintuitively, lead to economies of scale in implementing minigrids at sub-stations. The deep discharges on bus batteries means that they need to be replaced every four years. However, these batteries potentially have many years of future life in less onerous duty as energy storage for electricity supply (including in Microgrids). The state would then repurpose old bus batteries rather than purchasing new batteries, therefore reducing the price of a rollout of utility-scale batteries.

Initiatives in other jurisdictions

Many examples from other jurisdictions have been discussed above. Some other sources of information which are relevant for the Inquiry are listed below.

Enabling Better Utilisation of Distributed Generation with Distributed Storage

http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1013-enabling-better-utilisation-distributed

The economics of stand-alone power systems

http://www.ata.org.au/ata-research/the-economics-of-stand-alone-power-systems/

http://www.ata.org.au/wp-content/uploads/2013/09/Fringe-of-Grid-SAPS-Research-Summary-for-Policy-Makers-Final-160812-v4.0.pdf

The key finding of the research was the fact that it does not take large amounts of network capital investment to make SAPS a more economically attractive alternative.

http://www.abc.net.au/news/2018-04-07/people-power:-communities-funding-their-own-wind/9630150

Community Power Agency

http://cpagency.org.au/

[19] http://www.abc.net.au/news/2016-02-24/fuel-imports-a-risk-amid-south-china-sea-tensions-nrma-advisor/7149648

[20] https://www.businessinsider.com.au/south-australia-just-built-the-nations-first-electric-bus-2017-6

Conclusion

In this submission, SEN has attempted to provide an independent assessment of the emergence and impact of Microgrids and associated technologies in Western Australia. This assessment unequivocally finds that Microgrids, in all their forms, will contribute to a necessary modernisation of Western Australia's electricity system, ultimately reduce costs to consumers, and contribute to Australia's carbon pollution reduction goals.

SEN commends the Economics and Industry Standing Committee for carrying out this Inquiry. It has the potential to start a conversation between the Executive Arm and agencies and utilities about the best way to move forward in challenging times.

To meet the challenge of transitioning to renewable electricity, we will need to better coordinate variations in supply and demand across the grid with proper transition planning. Smart Microgrid technologies (whether behind-the-meter or front-of-meter) will be a significant enabler of an inevitable transition to renewable energy. It is clear that renewables are cheaper than fossil-fuel alternatives over their lifetime, but, for this to be implemented, appropriate policies and planning need to be in place.

SEN's assessment is that the relevant technologies for Microgrids exist, and are in use elsewhere, and are being trialled in WA. Their benefits are clear and are already being realized. While there may be some downsides (e.g. stranded assets), net economic benefits clearly outweigh these, in SEN's assessment.

SEN believes that the *most important next step* is for Government to set a *vision* and put a *policy framework* in place, to meet public expectations, and provide direction for Government agencies. This may commence with a follow-up inquiry of the Economics and Industry Standing Committee to consider the Western Australia's electricity system holistically. Ideally, it would be a policy statement from the Premier, and planning directives from the Minister for Energy, the Minister for Regional Development; Agriculture and Food and other relevant ministers, to pursue the McGowan Government's intention to work across departmental boundaries.

In addition to these broad aspirations, SEN summarises its submission with these specific recommendations.

Recommendations

***Recommendation 1**: Three improvements in the definition are suggested:*

- *The definition should explicitly include smart-grid battery storage and enabling technologies, so that it becomes a forward-looking definition.*
- *The definition should be looser with respect to 'connect and disconnect', to enable communities to disconnect from the grid when it is economically sensible to do so, while still being defined as Microgrids.*
- *The Inquiry should adopt a more nuanced definition of 'Microgrids' that encompasses the diversity of application of the technology. This might include the use of the terms minigrid, microgrid and nanogrid to indicate the varying scales and characteristics of application.*

***Recommendation 2**: That Government accelerate the modernization of the main electricity grids and integration of Microgrids by instructing agencies to commence:*

- *implementing a compulsory roll out of smart meters across the state*
- *implementing requirements for PV inverter functionality, including wireless control and ability to turn down power exported to the grid*
- *implementing a broad rollout of 'time of use' tariffs*
- *developing incentives to encourage consumers to purchase behind-the-meter Microgrid technologies*
- *developing incentives to purchase smart appliances, to provide household demand-side-management*

Recommendation 3: That the Inquiry obtains information from Western Power about the amount of operational expenditure that can be saved by rolling back the most remote 11kV feeder lines.

Recommendation 4: that Western Power assess all 11kV feeder lines, and the requirements of the communities serviced by them, with a view to replacing some of these 11kV lines with Microgrids. Suggested criteria for replacement would include: reducing the risk of power outages, and reducing risk of fire hazard risk.

Recommendation 5: The Inquiry should address how the separation of power utility responsibilities should be best managed to enable uptake of Microgrids

Recommendation 6: That the Government should direct agencies to undertake comprehensive planning and regulatory development to effectively implement Microgrids.