

Lessons from the fringes: Australian fringe-of-grid projects in ARENA's portfolio

JUNE 2018

Ekistica

Prepared by Ekistica on behalf of ARENA



Australian Government
Australian Renewable
Energy Agency

ARENA

EXECUTIVE SUMMARY

Fringe-of-grid (FOG) areas of Australia's National Electricity Market (NEM) and South West Interconnected System (SWIS) are parts of the grid that are remote, far from the main load and population centres along the country's coastline. Electricity supply to these areas is characterised by more frequent reliability and quality issues and greater electrical losses, reaching 35% or above in some areas. Cost of supply is significantly higher, requiring government support or subsidisation to improve the viability of delivering this essential service.

ARENA's funding portfolio includes projects in FOG areas whose experiences, development to construction, commissioning and operation, provide insight into the ability of decentralised renewable energy to serve these areas. A number of ARENA projects provide such experiences, and three, specifically, within the Regional Australia's Renewables (RAR) portfolio were funded with the objectives to (1) demonstrate a portfolio of renewable energy solutions in FOG areas; (2) ensure knowledge is created and disseminated on deploying renewable energy solutions in FOG areas; and (3) remove the roadblocks to deploying renewable energy solutions in FOG areas. This paper examines insights from these projects to broaden and deepen Australia's understanding of FOG systems.

INTRODUCTION

Australia is home to some of the world's longest interconnected power systems, the largest being the National Electricity Market (NEM). Serving 9 million customers, the NEM spans over 5,000 kilometres from Port Douglas in Queensland to Port Lincoln in South Australia, and across the Bass Strait to Tasmania. Grid-connected customers located in remote areas are called fringe-of-grid (FOG) customers as defined in Figure 1, left. FOG electricity supply is a growing area of interest, as reflected in Energeia's *Cutting the Cord* report which identified 'fringe-of-grid towns' as one of the four key segments for potential growth in Australia. Energeia states that 'these customers are being driven to reject, or defect from, the grid by, for example, high connection costs, high fixed charges, the desire for increased reliability and the falling cost of energy storage and solar PV' [1].

FOG areas are more likely to experience supply reliability and quality issues, including susceptibility to more frequent outages, higher transmission losses and increased electricity prices due to higher capital costs per unit of delivered energy. Since most of Australia's generation is located along its coastline, decentralised renewable generation in FOG areas has the potential to improve energy supply to many Australian users because the systems can be deployed close to the point of demand.

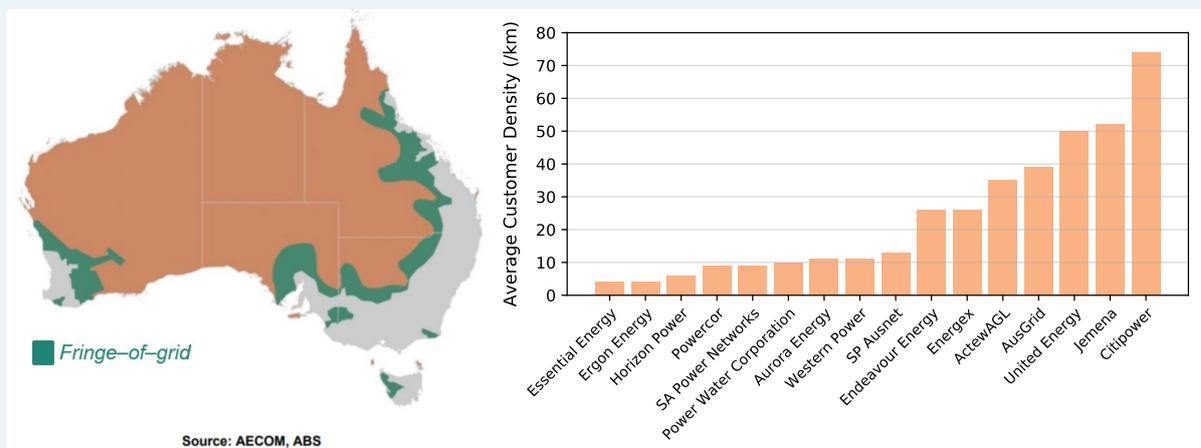


Figure 1. (left) Fringe-of-grid locations around Australia (AECOM, ABS); (right) Average network customer density (customers per kilometre) of Australian network service providers (NSPs) (AER 2013, Western Power 2014, Horizon Power 2014, Power and Water Corporation 2013)

Network service providers (NSPs) have several options to address supply issues in FOG areas, including network augmentation, demand management and distributed generation. Of the distributed generation options, the forms range from renewable energy to more traditional fossil fuel-based generation, where historically, renewable energy has not been widely adopted to address network-related issues due to concerns about reliability and network security. Technology costs and the regulatory environment have also been barriers.

While average transmission losses in Australia are estimated at around 5% [2], delivering electricity to remote regions in Australia can see transmission losses of 20-25%, in some places reaching 35%. Considering this and other factors such as the high capital (network) costs per customer, it is far more expensive for an NSP to have a customer base spread out over large areas (Figure 1, right). In order to ensure consumers in FOG regions pay comparable tariffs to those in more urban areas, State and Territory governments lend their support in a variety of ways including internalised cross-subsidy, such as used in SA, and a subsidy known as a Community Service Obligation (CSO) for NSPs to cover additional costs of delivering electricity to further locations. Ergon Energy, a government-owned NSP based in Queensland, has one of the least dense customer bases in Australia,¹ requiring it to transport electricity over extremely long distances; consequently, Ergon Energy will receive over \$460 million in CSO subsidies in 2018/19 to allow it to maintain its very long grid.

The staggeringly large numbers associated with transmission losses and CSO subsidies highlights the value of support from the Australian Renewable Energy Agency (ARENA) to assist early movers to determine the viability of renewable-based, distributed generation to address energy supply issues in FOG regions. Further, the scalability of renewable energy systems allows projects to be tailored to meet growing demand profiles and potentially, lower electricity costs in the short and longer term.

WHY FOG?

While the number of renewable energy generators connecting to the network continues to increase, so does the average distance between generators and respective regional reference nodes (RRNs). While at present, renewable energy fractions in FOG areas are relatively low, this is likely to rise considering current trends and the intended connections published by the Australian Energy Market Operator (AEMO) [3]. Renewable generators are now increasingly likely to consider network locations previously deemed too distant from major load centres. This is particularly true for PV in Queensland, as the nature of the technology has seen proponents chasing optimal solar resources in balance with proximity to transmission lines and population centres.

The swift transition from thermal to renewable energy highlights the importance for stakeholders to understand associated project risks on quality, timeframes, costs and performance before committing to a FOG investment. While the line between FOG/non-FOG categories is not clearly defined, many principles are transferable from case to case, and lessons learned from ARENA-funded projects within this space are extremely relevant as more of Australia's electricity is sourced from these regions. To date, several ARENA-funded projects are demonstrating renewable generators to be highly reliable in FOG regions. This reliability, coupled with modularity and scalability to meet changing demand, allows for a large uptake of renewables in these regions. Depending on the size of the plant relative to demand near this point of supply, the need for network augmentation may also be reduced, lowering electricity costs by virtue of avoiding that expensive exercise - although it should be noted that network augmentation may equally be called upon if these new plants require increased volumes to be transmitted to main load centres. Further, these projects are demonstrating the application of renewable energy in different system configurations which has not only suggested opportunities for renewables in FOG areas, but integrating renewables into grids more generally.

¹ Horizon Power has a similar customer base to Ergon Energy, which is approximately one customer every 53 square kilometres.

Figure 2 shows the growing number of installed renewable energy generators as well as transmission line distances between generators and respective RRNs, year-on-year. It does not include AEMO's intended connections which, if included, would likely continue the upward trend into 2020/21 as more remote systems are scheduled to be installed. It is also worth acknowledging that transmission line data is often incomplete for regional and remote generators, so while this underestimation of distances due to the missing data affects all years, it would certainly not undermine the discernible upward trend and, if anything, exacerbate it as the growing number of remote systems goes understated. In any case, the rise is clear, validating ARENA's investment in testing and demonstrating the viability of distributed renewable energy systems for solving issues that will be increasingly pertinent - namely, for alleviating the need for network augmentation, reducing losses, and increasing reliability in FOG areas.

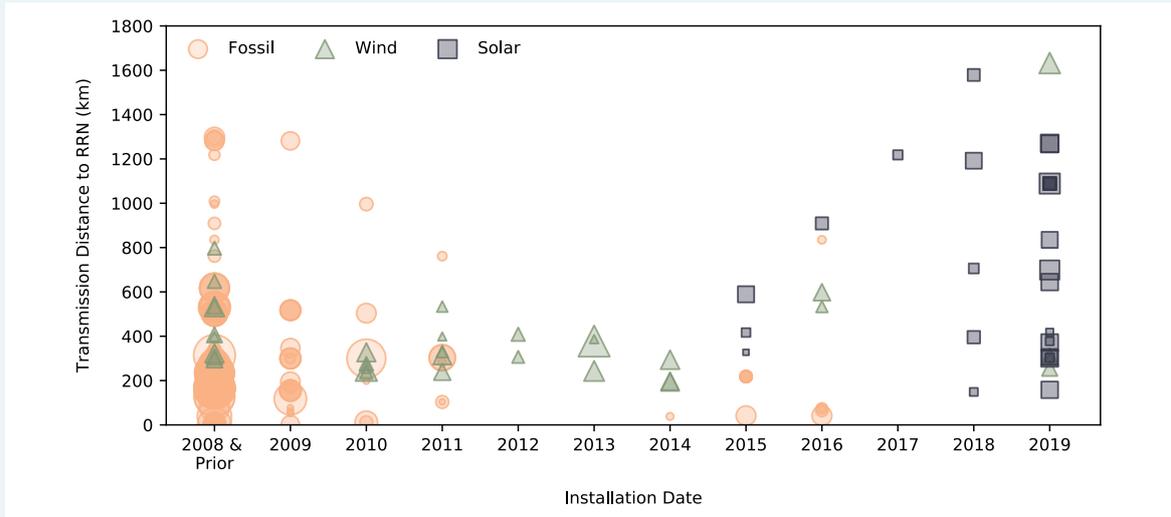


Figure 2. Transmission line distance between generators and respective regional reference nodes (data not including AEMO's intended connections, and transmission line data for some regional/remote generators not complete)

ARENA-FUNDED FOG PROJECTS

In 2013, ARENA launched the Regional Australia's Renewables (RAR) Program with two geographical focus areas, fringe-of-grid and off-grid, of which 28 among the 72 expressions of interest were considered to be 'FOG' as shown in Table 1 and eligible for funding consideration on this basis. Today, ARENA's FOG portfolio consists of three large-scale projects, all connected to the NEM in Queensland, which were funded to achieve the following objectives:

1. Demonstrate a portfolio of renewable energy solutions in FOG regions;
2. Create and disseminate knowledge about deploying solutions in FOG regions; and
3. Remove any existing roadblocks to delivering solutions in FOG regions.

Table 1. Expressions of interest for ARENA's Regional Australia's Renewables (RAR) Program

Sector	Expression of interest			Approved for funding	Committed for funding	Constructed or under construction
	Fringe-of-grid	Off-grid	Total applications			
Agriculture & Other	6	3	9	0	0	0
Community	10	8	18	9*	7*	6*
Community & Tourism	0	9	9	1	1	1
Grid-connected	10	0	10	5	5	4
Mining	2	24	26	5*	4*	1*
Total	28	44	72	18	17	12**

*One project services both mining and community loads and is counted under both categories

**Weipa stage 1 was constructed, Weipa stage 2 will not progress further

However, there are several other ARENA-funded projects located in FOG regions that, while not funded to report on FOG experiences, do deliver worthwhile FOG-related lessons. One is Karratha Airport in Western Australia, a hybrid grid stability system (GSS) on a PV and BESS station, connected to the North-West Interconnected System (NWIS) and also funded under the RAR Program. Another two come under ARENA's Large-scale Solar (LSS) portfolio, where grant funding was provided to 12 projects to stimulate utility-scale solar in Australia, including two projects - Kidston and Longreach - connected in FOG regions on the NEM in Queensland. The serendipitous as well as sought lessons learned from all ARENA-funded projects in FOG regions are adding their insights and affirming renewable-based distributed generation as a potentially viable solution in FOG regions.

Table 2. ARENA-funded projects located in FOG regions

Project	Program	Funding	Project Cost	Technology
Barcaldine	RAR	\$22.8m	\$69.0m	• 25 MW _{DC} / 20 MW _{AC} solar PV
Lakeland	RAR	\$17.4m	\$42.5m	• 13.3 MW _{DC} / 10.8 MW _{AC} solar PV • 1.4 MW / 5.3 MWh BESS
Normanton	RAR	\$8.4m	\$14.0m	• 5 MW _{DC} / 4.5 MW _{AC} solar PV
Karratha Airport	RAR	\$2.3m	\$6.8m	• 1 MW _{DC} solar PV • 234 kW / 367.2 kWh BESS • Cloud Prediction Technology
Kidston	LSS	\$8.85m	\$126.0m	• 50 MW _{AC} solar PV
Longreach	LSS	\$1.3m	\$33.7m	• 15 MW _{AC} solar PV

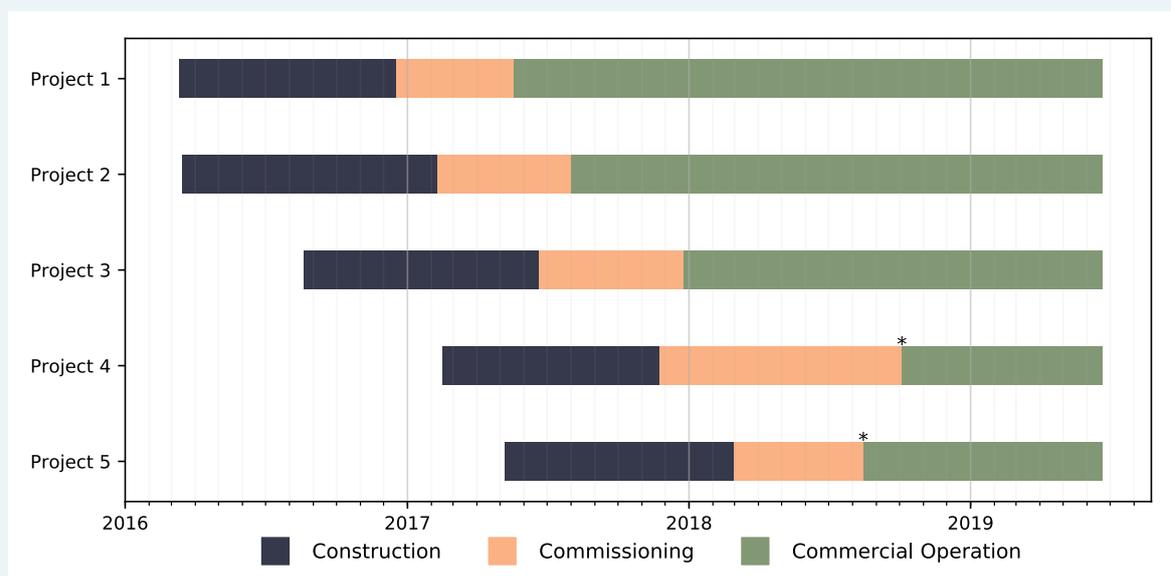


Figure 3. Approximate timelines for ARENA-funded FOG projects, noting strict comparison is complicated by the differing interpretations of project phases reported by different project proponents (e.g. * indicates 'full generation' interpreted as 'commercial operation')

LESSONS LEARNED: BARCALDINE SOLAR FARM

Barcaldine Solar Farm (BSF) network impacts analysis has been a notable piece of work in the FOG space and is the main focus of this paper. BSF is a 25 MW_{DC} / 20 MW_{AC} solar PV plant commissioned in May 2017, located as shown in Figure 4, and connected to the Barcaldine-Clermont 132 kV feeder via Barcaldine Substation and, upstream, the Lilyvale-Clermont 132 kV feeder, a 300 km line experiencing 5-6% losses. Barcaldine's incumbent power supply is a gas-powered generator, and ARENA's investment was made with a view to sharing insights about the impact of this solar farm on the transmission network as well as the existing gas generation.

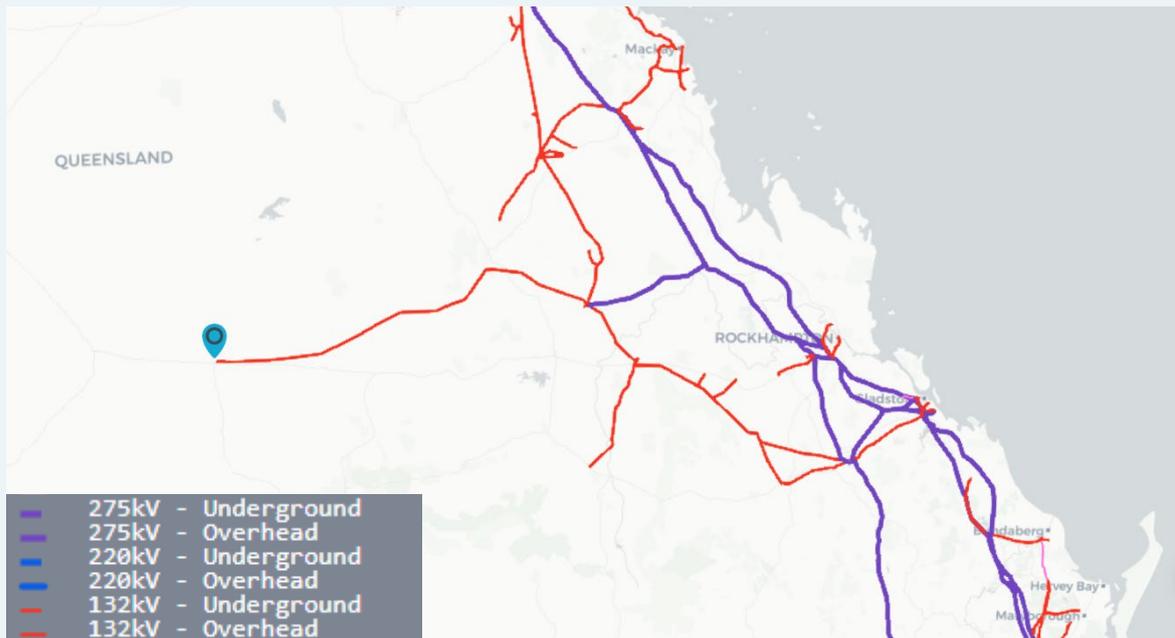


Figure 4a. Location of Barcaldine in relation to the NEM (source: AREMI)



Figure 4b. Reference points to aid interpretation of the main feeders discussed in this analysis, these being the Barcaldine-Clermont 132 kV (closer to fringe) and Lilyvale-Clermont 132 kV (upstream from fringe) feeders (note BSF and LSF are located close to - within 5 km and 10 km respectively of - the mapped town areas)

True to expectation, the lessons derived from BSF include a tangible demonstration of line loss reduction when the solar farm came into operation, consistent with the premise of FOG distributed generation. The continued stability of voltage levels on the network - and the consequent potential for FOG solar to perform a network support function by regulating voltage levels - is also affirmed, as is the non-detriment to grid operation during reverse power flows from the PV plant. Another observation is the lack of, or limited, operational impact on the existing gas plant.

But while BSF was also intended to allow study into the effects of solar generation on the broader network, the recent operation of Longreach Solar Farm (LSF) approximately 90 km west introduces another variable into the system that muddies the waters of attribution to BSF per se. With BSF first generating in May 2017, and LSF first generating in March 2018, there is a period of 10 months in which the effects of BSF on the grid can be observed without influence of LSF.

LESSON LEARNED 1: REDUCTION OF LINE LOSSES

A fall in resistive and reactive line losses was observed during BSF operation, as shown in Figure 5 which combines six days of data (all within the period of BSF's full-scale operation) into an indicative daily profile. Tellingly, the loss-reduction effect is most apparent between 8am and 4pm, the main solar generating times, which owes to the reduced power flows on the Lilyvale-Clermont feeder during this time.

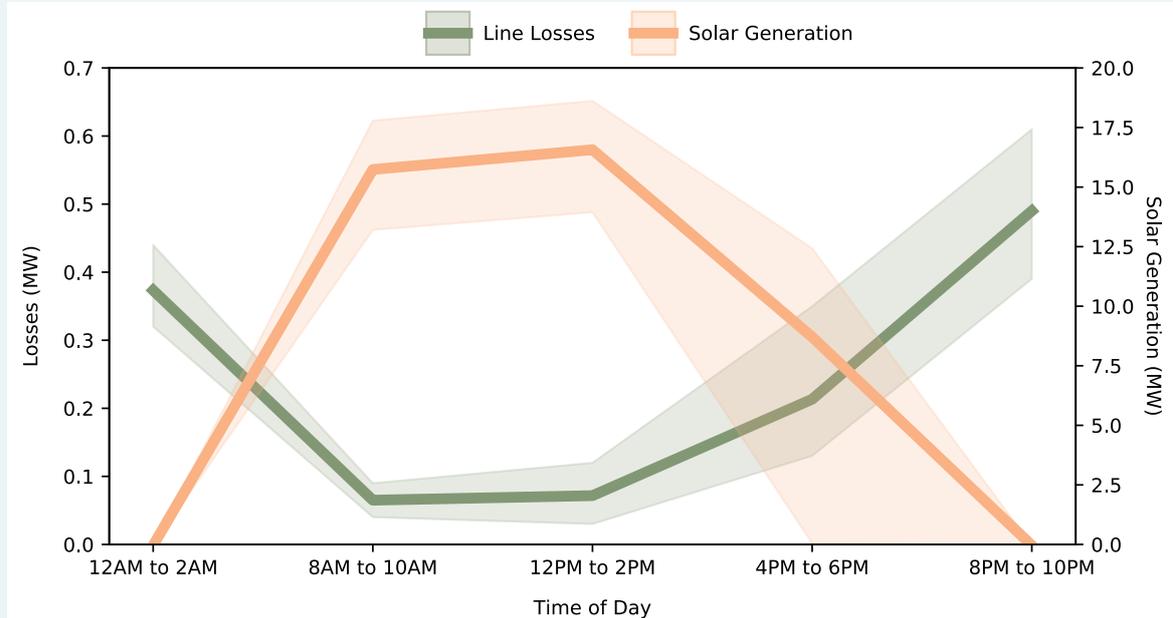


Figure 5. An example day of solar generation on the Lilyvale-Clermont 132 kV feeder showing correlation between high solar generation and low line losses, based on six days of data made available by the proponent (translucent regions indicate the spread of values around the solid-line mean)

That said, at certain times, line losses do increase on the immediate Clermont-Barcaldine 132 kV feeder owing to reverse power flows that arise when solar generation exceeds the load, i.e., BSF generation is not consumed locally. However, these increases in line losses are not 'net' increases, inasmuch as the solar still confers an overall benefit compared to the line losses experienced in its absence (see Figure 6a, March 2018). Furthermore, the effect is largely restricted to the more local feeders - at least on the quantities sampled in this analysis - which leads to discussion on a second lesson learned on the BSF project.

LESSON LEARNED 2: MINIMAL DETRIMENT FROM REVERSE POWER FLOW

With a reduction in line losses generally in step with higher solar generation, as discussed regarding Figure 5, if demand is too low for all generated solar to be consumed, this loss-reduction benefit can be reduced while reverse power flow is experienced. In Figure 6a, the phenomenon can be observed in March 2018 (again acknowledging the small sample of points averaged to represent that period), whose noon-time sees a small uptick in losses while PV generation is high. However, such rise in line losses does not translate to the upstream Lilyvale-Clermont 132 kV feeder as shown in Figure 6b ('upstream' here meaning 'further from the fringe') where reverse power flows are outbalanced, i.e., do not have such an effect on these feeders as they do the more immediate ones closer to the point of load imbalance. This insight also holds up to extrapolation, with 66 kV transmission lines further upstream experiencing no discernible detriment.

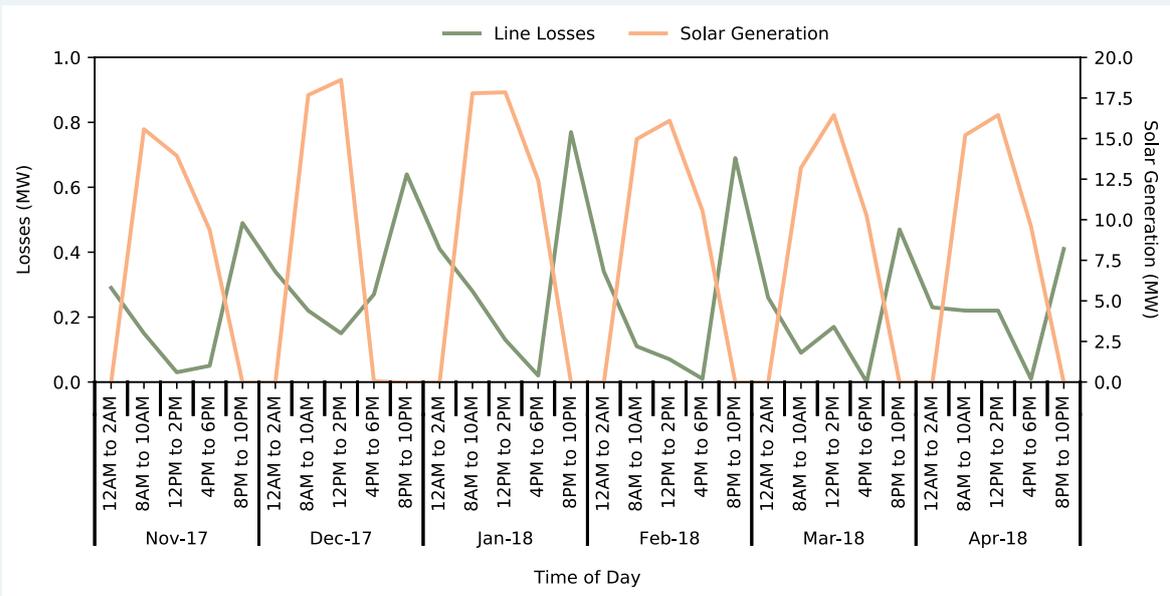


Figure 6a. Losses on the Clermont-Barcaldine 132 kV feeder mapped against solar output from BSF, where the correlation between high generation and low losses is generally illustrated but a small rise in losses in March 2018 owes to reverse power flow as solar generation exceeds demand; note this coincides with LSF beginning operation

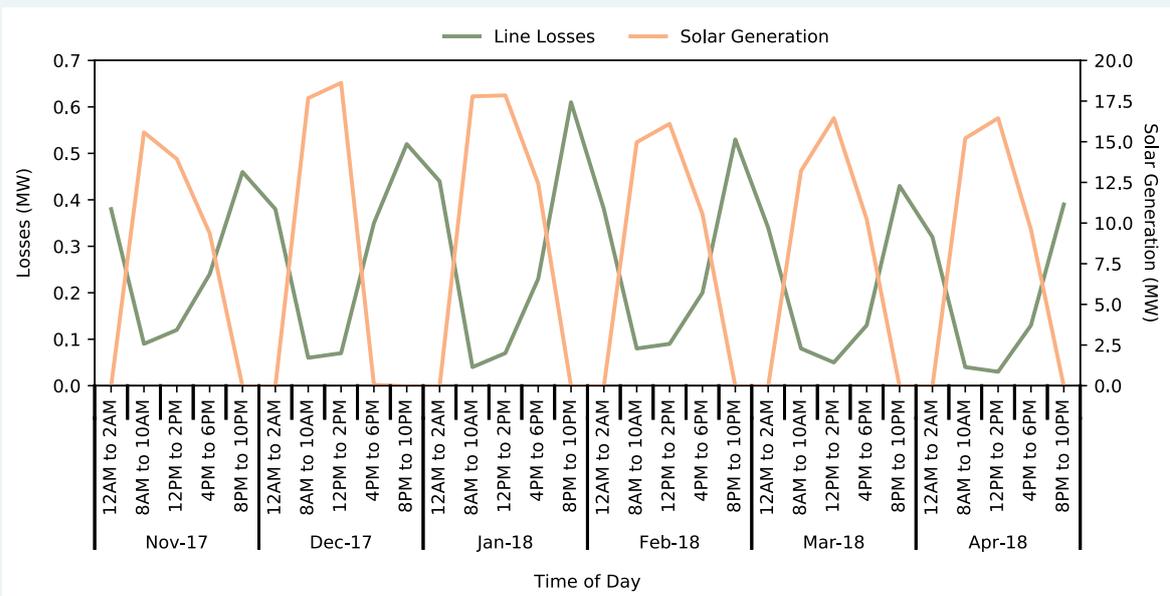


Figure 6b. Losses on the Lilyvale-Clermont 132 kV feeder (upstream of the Clermont-Barcaldine feeder shown in Figure 6a) mapped against solar output from BSF, illustrating a consistent correlation between high generation and low losses, despite the exceedance of demand in the local area by solar generation in March 2018

Equally noteworthy from Figure 6a is the recognition that LSF came online in March 2018 - albeit not at full capacity - accounting for higher overall levels of solar on this feeder. This in itself underlines the importance of holistic grid planning to predict not only the network impact of distributed generation in FOG areas and upstream, but the expected returns when other actors come online in the vicinity. Currently, proponents claim that BSF is not curtailed - but this does not predetermine the future, and proponents expect it to confront curtailment in coming years, both as LSF scales up in operation and as the limit of transformer capacity and line constraints are approached.

LESSON LEARNED 3: VOLTAGE SUPPORT AND STABILISATION

Addressing queries about the effect of solar generation on voltage levels, not only in an overall network but the local FOG areas, Figure 7 illustrates the BSF experience: that there was no detriment to stability and indeed, little observable difference to the average voltages observed.

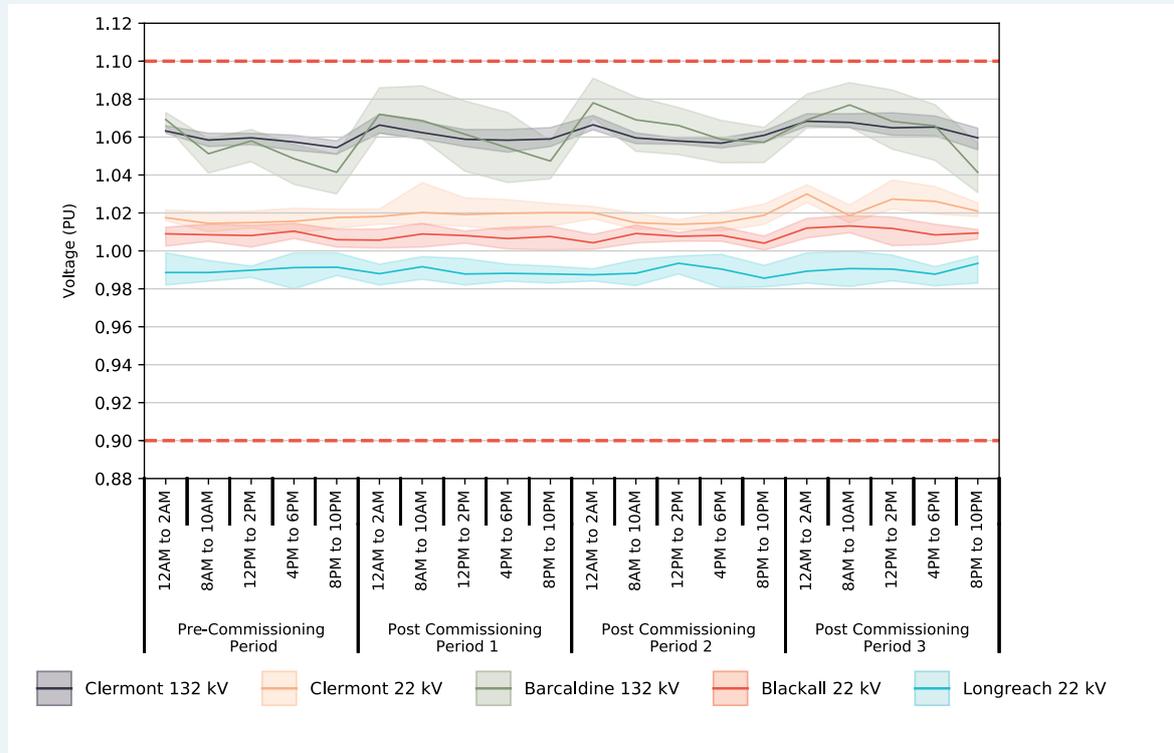


Figure 7. Voltages recorded at various substations amid the progressive commissioning of BSF, showing no discernible rise in voltage levels (translucent regions indicate the spread of values around the solid-line mean, while red dashed lines mark the allowable threshold, i.e., +/-10% from the nominal level)

While there is no clear trend in the overall voltage levels, the BSF's absorption of reactive power during full operation in the day, and its contribution of reactive power overnight by its inverters, theoretically suggests that the solar plant can stabilise voltage on the network; note indeed that in Figure 7 for the post-commissioning periods of the BSF, the voltages of the 132 kV Barcaldine and Clermont Substations in particular dip during the day, as is consistent with the above reasoning since BSF is absorbing reactive power. However, these two downstream substations are not particularly useful candidates for voltage support given their levels typically stay within the defined allowable threshold.

Nonetheless, there remains scope to continue monitoring the potential for BSF to play a grid support role where previously, the highly fluctuating voltage levels in the downstream network (i.e., towards the fringes) - also notable at Blackall and Longreach substations and especially so during summer months with high demand - relied upon voltage control from Lilyvale to improve stability. The presence of BSF and its voltage-regulating influence is a subject of potential usefulness and, therefore, interesting to track further as the system operation continues, although it should be noted that the plant itself cannot assume remuneration or other benefit for any FCAS or pseudo-FCAS support services.

LESSON LEARNED 4: COMPATIBLE GAS PLANT OPERATION

The BSF was intended to explore and demonstrate concurrent operation with the existing combined cycle gas generator, and available generation data from each site displayed in Figure 8 demonstrates that simultaneous operation has occurred. While it appears that the number of operational events of the combined cycle power station has been reducing over the years, this paper is not inferring that either the BSF or LSF has impacted the operations. According to the gas plant operators, the solar farms have not impacted operations and the gas generator operates as a peaking plant, meaning it only runs when there is a high demand for electricity.

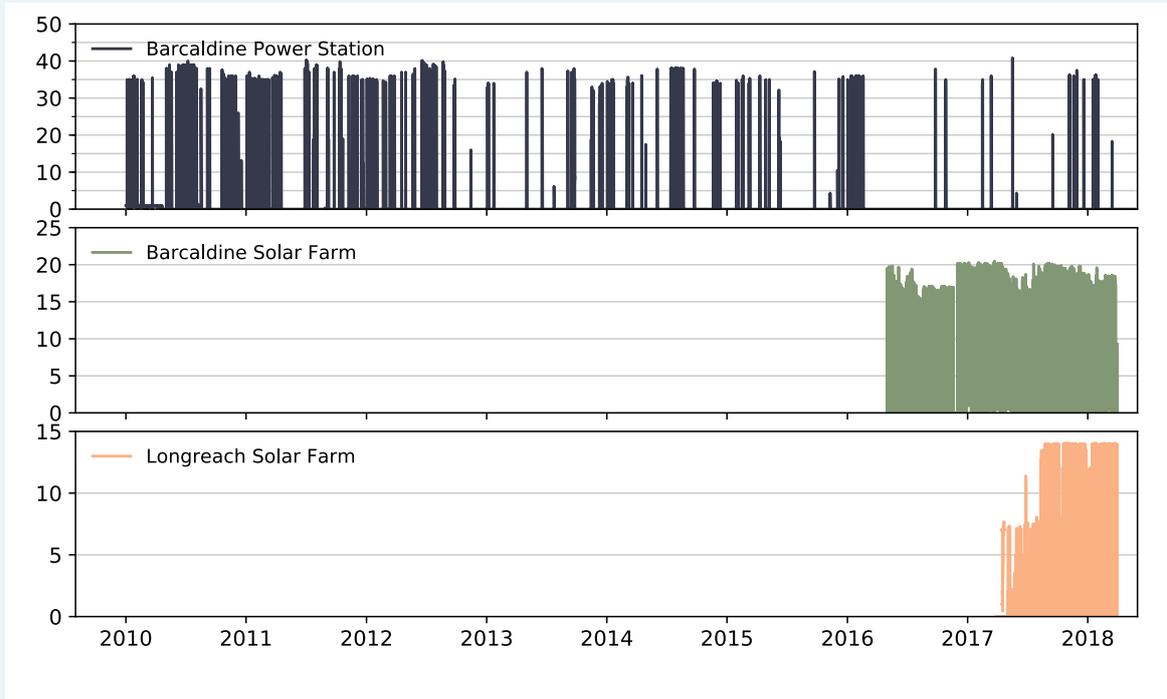


Figure 8. Operational data of the Barcaldine combined cycle gas power station, BSF and LSF (data sourced from power station proponents and AEMO's NEMWEB database - note some data may be missing)

LESSON LEARNED 5: REDUCTIONS IN MARGINAL LOSS FACTORS IN FOG REGIONS

The recent transformation in distributed generation has led to large changes, year-on-year, in marginal loss factors (MLFs) for generators and load centres, which can be observed generally and not least of all in FOG regions. When compared to wind, solar is less resource-constrained and is therefore more able to take advantage of regions with higher MLFs; this why some of the largest decreases in MLF have been in regions experiencing the most rapid influx of large-scale solar. In being located further away from loads, these areas tend to be also considered FOG. Figure 9 demonstrates that all three FOG solar farms have experienced MLF drops of over 10% in less than three years.

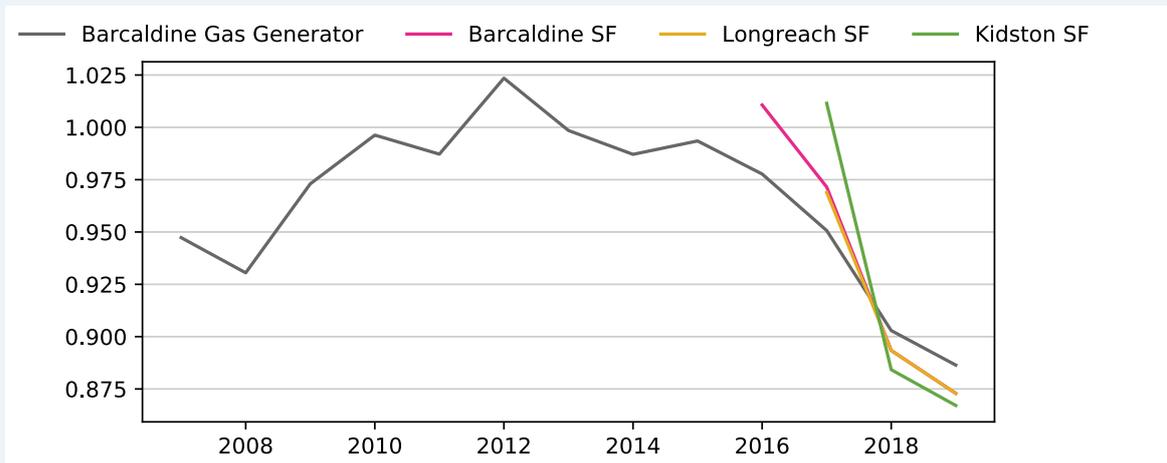


Figure 9. Historical marginal loss factors (data sourced from AEMO)

OTHER LESSONS FROM BARCALDINE

BSF was the first large-scale PV plant connected to Ergon Energy’s network, and as the source of the most meaningful data to date among ARENA’s FOG-related projects, it has already generated useful insights about distributed generation in areas at the fringe of the grid. Not all of its experiences could be discussed in detail here; the load management challenges, reduced pressures of peak demand, and unexpectedly shorter construction but longer commissioning times, are also worthy of note in a case study of this project.

The findings retrieved from BSF bode well for the potential of other FOG projects to contribute knowledge to the area, where interpretation can be made both on their own terms and with comparison to peers such as the BSF, stress-testing the findings and assumptions further and bringing nuance by way of new contexts and applications. BSF’s early insights also pave the way for the project itself to continue its trajectory of learning, both through the natural course of ongoing operation and in the emergence of nearby LSF and its effects, including potential to study their impacts on each other and jointly on the network – both upstream and on local feeders – as well as on incumbent gas generators. Aside from this, BSF’s own research agenda as summarised in Table 3 is also under continued pursuit, while, as ever, findings in serendipity can yield equally important contributions. Developing a body of understanding on distributed renewable generation in Australia’s FOG areas allows future proponents to invest more effectively and meet the inherent challenges of FOG supply.

Table 3. Project-level knowledge-sharing objectives of BSF and their progress at the time of writing

Objectives (study areas of interest)	Status
Tracking systems on remote grids	In progress - conclusions pending after 24 months of full operation
Local and downstream power supply	Addressed for the first year of full operation
Upstream reverse flow	Addressed for the first year of full operation
Island operation	Pending - no islanding events have occurred since connection
Integration with gas plant	In progress - early findings about concomitant operation emerging
Reactive power injection	Addressed for the first year of full operation

FELLOW FRINGE-DWELLERS: INSIGHTS FROM OTHER FOG PROJECTS

Though each project is worthy of discussion, a consolidated, across-the-board analysis of all ARENA-funded FOG projects is the most efficient and meaningful way to derive a consensus of observations as well as acknowledged variations that acts educatively in itself. However, with unequal levels of data available for the different projects and, in many cases, unsatisfactory available data (nature/duration), such analysis lies ahead. However, appropriate to the time of writing, some emergent lessons or their statuses for retrieval are summarised in Table 4. Some speak particularly to the FOG and remote-location contexts of these projects, while others are more common to solar PV systems and their many varieties in general. Similarities among the projects include the challenges of local resourcing in remote areas; network connection and regulatory changes or vagaries; relatively fast construction yet longer commissioning times (and implications for insurance extension and costs); and under-forecasting of MLFs, although exceptions to all of these can exist.

Table 4. Emerging insights from projects of FOG interest from ARENA's RAR and LSS funding programs

Project and features/innovation	Emerging insights or knowledge-sharing progress
<p>Barcardine (RAR) <i>25 MW_{DC} / 20 MW_{AC} PV</i></p> <ul style="list-style-type: none"> • First large-scale PV plant to connect to the Ergon Energy network 	<ul style="list-style-type: none"> • Demonstrates reduction in line losses on network • Demonstrates minimal network detriment from reverse power flows, especially upstream transmission lines • Suggests voltage stabilisation and grid support potential • Holds potential to study network effects in tandem with the solar plant at Longreach (LSF) on same feeder, and further gas plant concurrency • MLFs lower than expected, reducing revenue by 12%
<p>Lakeland (RAR) <i>13.3 MW_{DC} / 10.8 MW_{AC} PV; 1.4 MW / 5.3 MWh BESS</i></p> <ul style="list-style-type: none"> • First Australian utility-scale PV/storage system in a FOG region • Connected to 66 kV Ergon Lakeland sub-station, the northern-most SS on the NEM • 7 hours battery storage 	<ul style="list-style-type: none"> • Intends to test 'islanding', wherein a township's essential services can be supplied during fault events upstream when the network shuts down, and demonstrate the ability to run as a renewable power station reserve on immediate standby • Modular rather than skid solution generally most suitable for remote area; heavy rainfall saw 8-week delay as skids too heavy to use roads • Local sourcing challenges, including for qualified electrical staff (had to fly from Sydney/Brisbane) so higher associated costs and delays; unmanned site is a risk, as when aircon tripped entire BESS and would only require a button-press to rectify had personnel been onsite • Local employment benefit: 60 new construction jobs and 40% of unskilled labour sourced locally • Geotechnical study inaccurate, understating amount of rock and also not identifying all types present • Costs on insurance (longer construction period) and intermediate trading fees both higher than expected • Unforeseen costs/changes included Energy Import Network Charges, AEMO market fee, additional audit fees and revenue loss from MLF adjustment although PPA offers protection to offtaker • Modelling complexity underestimated by inverter provider • Emphasises importance to work closely with DNSP and AEMO from outset and allow more time, especially as BESS commissioning adds time - should be prepared to operate without BESS (re hold points)
<p>Normanton (RAR) <i>5 MW_{DC} / 4.5 MW_{AC} PV</i></p> <ul style="list-style-type: none"> • Power to Normanton supplied by 700 km transmission line, furthest from NEM bulk generation, with 35%+ losses (up to 50%) • Project initiated by a local businessman in response to monthly electricity bills rising \$600-800 (2003) to \$4,000 (2018) largely from network charges 	<ul style="list-style-type: none"> • Finance difficult to obtain for small individual proponent, requiring partnership with larger industry player (Canadian Solar) • Local sourcing challenges, including for electrical engineers, but good local large machine operators • Shipping containers being required to be returned within 5 days was unviable for remote location, so sold in town • Relatively seamless construction due to individual proponent's 40-year experience but issues with PLC for SCADA, spare part delays and lack of clarity on grid connection procedures and activities • Large expense on consultants for ARENA funding application, but project unviable without ARENA support

Project and features/innovation	Emerging insights or knowledge-sharing progress
<p>Karratha Airport (RAR) <i>1 MW_{DC} PV; 234 kW / 367.2 kWh BESS; Cloud Prediction Technology (CPT)</i></p> <ul style="list-style-type: none"> • Strict ramp rate constraints • Connected to the NWIS 	<ul style="list-style-type: none"> • Demonstrates success of CPT to reduce BESS size • Knowledge-sharing reporting is ongoing
<p>Kidston (LSS) <i>50 MW_{AC} PV</i></p> <ul style="list-style-type: none"> • First phase of project on a disused mine site, for which a further 270 MW of solar may be paired with pumped hydro storage 	<ul style="list-style-type: none"> • Site fire incident in this high-irradiance, low-rainfall remote location aptly handled by O&M personnel but led to further strategies to reduce risk in future, including site flora monitoring procedures and routine maintenance to limit grass and other plant growth • Extreme remoteness of project site (mine) saw accommodation facilities set up for construction, with continued utility in O&M phase
<p>Longreach (LSS) <i>15 MW_{AC} PV</i></p> <ul style="list-style-type: none"> • Just west of and sharing the substation with incumbent solar farm at Barcaldine, with first generation 10 months after BSF 	<ul style="list-style-type: none"> • Transformer size limit led to curtailment, especially in winter (lower demand), but investigating feasibility to enlarge capacity • Neighbouring generators modelled and considered beforehand, so no issues from interaction; forecasts have proven accurate, incl. MLFs • Local sourcing challenges were manageable although most difficult for specialty equipment and labour hire especially during contingency (unexpected) events; but local contractors and equipment hire being pre-identified and approved mitigated this, including local civil and electrical contractors recruited from Longreach and Winton • Construction delays due to switchroom procurement owed to late selection by the EPC, but air freight accelerated manufacture; nonetheless, insurance extensions were required • Metering provision scope of Ergon required revision due to inability to provide revenue metering and related services as initially planned • NER rule changes had implications on approach agreed in connection agreement, impacting construction and design phases • Potential for fund withdrawal to be clarified and streamlined with clearer terms in the funding agreements

EMBRACING THE EDGE

With distributed power systems in FOG areas on a notable rise in Australia, bringing their various technical, supply chain, financing and other challenges of remote locations and fringe positions on the grid - not to mention the challenges associated with any emerging deployment trend on the market and regulatory structures around it - lessons from first movers in this field are observed attentively. ARENA-funded projects are so far demonstrating the potential for electricity supply to Australia's fringe areas, as well as the networks to which they are connected, to be improved and strengthened through the installation of FOG-connected systems. Equally, these case studies are unearthing awareness of risks to project developers; industry understanding can only grow as these are successively recognised, addressed and managed by players at both network and regulatory (NSPs, AEMO) and complying (participant) ends. Projects outside the fold of ARENA's funding programs are of equal relevance, not least the Western Power initiative to roll out 57 standalone power systems (SAPS) at farms in Western Australia.

While lessons at both proponent and other levels are effecting continual change and more efficient ways to deliver power to the edges of the grid, it is already clear that there is the opportunity for not just improving how we act within systems but thinking beyond them, namely, considering different regulatory frameworks which can change the way communities connect (or disconnect) and FOG connections are implemented. Further, one may question: Is the next step *off* the grid? With more light shed on 'islanding' modes through some of these early FOG systems, as well as the rise of microgrids, this area may well come into its own. But for now, there still remains plenty to learn about and much value to be leveraged while connected to but at the fringes of the grid. For want of a better term, this topic is 'far from the fringes' of interest in Australia's evolving electricity sector as we find better ways to serve those beyond the most dense and population-centric locations - those who are equally worthy of quality, reliable essential services.

REFERENCES

- [1] Energeia, "Cutting the Cord: The Australian Outlook for New Microgrids to 2026," 2016. [Online]. Available: <https://energeia.com.au/wp-content/uploads/2016/08/Cutting-the-Cord-Australian-Microgrid-Outlook-to-2026-SNAPSHOT.pdf>. [Zugriff am 28 May 2019].
- [2] IEA, "Electric power transmission and distribution losses (% of output)," The World Bank, 2018. [Online]. Available: <https://data.worldbank.org/indicator/eg.elc.loss.zs>.
- [3] Australian Energy Market Operator (AEMO), "New Generation Maps," 2019. [Online]. Available: <https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/NEM-generation-maps>.

