EnergyConnect
Connecting Community through Micro-Grids

Napranum Microgrid

Feasibility Study

April 2023

Acknowledgements

The authors of this report acknowledge the Traditional Owners, those people with historical association, and all members of the Napranum community, and their customs and traditions that have nurtured and managed the land and sea for centuries.

Ener-G, ITP Renewables, Missing Link and Planz as EnergyConnect thank and acknowledge the Kauri Group for preparing the financial analysis of the project options, and the Ergon Energy Microgrid and Isolated Systems Team (MIST) for their assistance in performing network studies and providing data and reports for the Napranum electricity network, to assist with this study.

The authors also thank the University of the Sunshine Coast for their assistance in preparing a systems analysis model for the Napranum microgrid to highlight the interconnectedness of the microgrid and its operating environment.

We acknowledge the cooperation and support of Rio Tinto for assisting to build our understanding of Weipa's electricity supply arrangements, their history, and challenges associated with providing reliable electricity supply for their mining operations whilst also meeting the energy needs of the Weipa and Napranum communities.

We thank the Napranum Aboriginal Shire Council for their advice and support in engaging with the Napranum community, for participating in project workshops, and for providing office space and meeting rooms when the project team was visiting the community.

Finally, we thank the people of Napranum who welcomed us into their community, invited us into their homes, and gave us their time to discuss the challenges of living in a remote location like Napranum, and how we can work together to build a more resilient community there and in similar locations in the future.

EnergyConnect

Email: projects@energy-connect.net.au

www.energyconnect.net.au

About the Partners

EnergyConnect

EnergyConnect is the brand name for microgrid projects being undertaken in regional Australia by the following businesses led by Ener-G Management Group.

Ener-G

Ener-G Management Group specialises in renewable energy, sustainability, and remote energy supply. We provide renewable energy project concept planning and feasibility studies, with specialities in off-grid and remote power station planning and management, grid connection assessment for embedded generation, opportunity evaluation for energy efficiency, and preparation and implementation of energy efficiency and demand management programs.

Ener-G Management Group has a broad range of experience in general management and senior management roles for over 30 years with electricity and gas energy distribution companies in Victoria and Queensland. Ken, Oscar and Geoff have undertaken many electrical engineering and asset management functions such as system specification, design, construction, procurement, standards, maintenance and project management for integrated grid networks, and including Isolated diesel/renewable generation sites in northern and western Queensland, and across the Pacific. Ken has also led large initiatives such as the introduction of mobile substations and mobile generators and providing standardised maintenance programs across Queensland.

ITP Renewables

ITP is a global leader in renewable energy engineering, strategy and construction, and in energy sector analytics. Our expertise spans the breadth of renewable energy, energy storage and smart integration technologies. Our range of services cover the entire spectrum of the energy sector value chain, from technology assessment and market forecasting right through to project operations, maintenance and quality assurance.

ITP provides specialist services that encompass the full spectrum of project development, from project scoping and feasibility studies through to construction and monitoring, ITP has a strong track record providing specialist technical expertise and strategic advice on the development and implementation of microgrids in Australia and New Zealand. ITP have undertaken feasibility studies of microgrids for utilities and local/state government and been engaged to design, specify and provide construction supervision of projects at precinct scale, to entire developments and towns. ITP are known as experts in batteries and distributed energy technologies.

The Missing Link

The Missing Link - Resource Coordinators assist communities, businesses, government agencies and not-for-profit organisations to reduce their environmental impacts, improve their strategies for sustainability and to engage meaningfully with stakeholders. For over 20 years our knowledge and expertise has taken complex science, engineering or government policy and translated it into 'real language' helping clients to understand what applies to their operations and providing practical advice on how to make it work.

Focusing on the transition to low carbon economies we work with a wide range of clients across the energy sector delivering quality support to individuals and organisations, advancing communities and large-scale renewable generators.

Planz Town Planning

With over 25 years' experience in local government and private enterprise in the region, Planz has strong working relationships with Far North Queensland councils and regional communities. Planz have been involved in the drafting and review of many of the planning schemes in the region, including 14 Aboriginal Shire Councils, Hinchinbrook Shire Council, Cassowary Coast Regional Council, Tablelands Regional Council, Cairns Regional Council and Richmond Shire Council. We understand living and doing business in regional and rural areas and are committed to proving tangible, culturally appropriate outcomes for communities.

Planz has been awarded multiple times for public engagement & community planning by the Planning Institute of Australia (Q). From public notification to workshop facilitation, we are experienced in engaging a diverse range of stakeholders to understand projects and participate in the planning process. Nikki Huddy is a Fellow of the Planning Institute of Australia, Australian Planner of the Year 2020-21 and Queensland Planner of the Year 2019.

About This Report

The Napranum Microgrid Feasibility Study aims to analyse the options to showcase Napranum as a self-reliant, sustainable microgrid that can be implemented at other similar remote communities.

This report was commissioned through the Australian Government's Regional and Remote Communities Reliability Fund currently administered by the Department of Climate Change, Energy, the Environment, and Water.

The work for this study has been led by Ener-G Management Group working in collaboration with ITP Renewables, Planz Town Planning and The Missing Link.

This report complements microgrid feasibility studies also prepared by EnergyConnect for the Yarrabah and Muralug Island communities.

Abbreviations

ABS	Australian Bureau of Statistics
ACR	Automatic Circuit Reclosers
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ATSI	Aboriginal & Torres Strait Islander
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Service Systems
BoM	Bureau of Meteorology
BTM	Behind the Meter
CB	Circuit Breaker
CEFC	Clean Energy Finance Corporation
COMs	Card Operated Meters
CSO	Community Service Obligation
DER	Distributed Energy Resources
DEPW	Department of Energy & Public Works
DNSP	Distribution Network Service Provider
DOGIT	Deed Of Grant In Trust
DRED	Demand Response Enabled Device
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
EEN	Ergon Energy Network
EER	Ergon Energy Retail
EE MIST	Ergon Energy's Microgrid and Isolated Systems Test team
EQL	Energy Queensland
EV	Electric Vehicle
FNQROC	Far North Queensland Regional Organisation of Councils
GHI	Global Horizontal Irradiance
GOC	Government Owned Corporation
GST	Goods & Services Tax
HVAC	Heating, Ventilations & Air-Conditioning
IAP2	International Association for Public Participation
IAS	Indigenous Advancement Strategy
ILSC	Indigenous Land & Sea Corporation
IRR	Internal Rate of Return
ISO	International Organization for Standardization
kV	Kilovolt
kVA	Kilovolt-ampere
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
LED	Light Emitting Diode
LGA	Local Government Area
LGAQ	Local Government Association of Queensland
LGCs	Large Scale Generation Certificates
LRET	Large-Scale Renewable Energy Target
MCS	Master Control System
MID	Ministerial Infrastructure Designation
ML	Megalitre
MVA	Megavolt-amperes
MW	Megawatt
MWh	Megawatt hour
NASC	Napranum Aboriginal Shire Council
NBN	National Broadband Network
NEM	National Electricity Market

NEPS	National Energy Performance Strategy
NER	National Electricity Rules
NIAA	National Indigenous Australians Agency
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation & Maintenance
PCYC	Police-Citizens Youth Clubs
PDR	Peninsula Development Road
PMO	Project Management Office
PPA	Power Purchase Agreement
PV	Photovoltaics
QCA	Queensland Competition Authority
QMPF	Queensland Government - Microgrid Pilot Fund
QREHJF	Queensland Government - Renewable Energy Hydrogen Jobs Fund
QREZ	Queensland Renewable Energy Zones
RAMPP	Regional Australia Microgrid Pilots Program
RET	Renewable Energy Target
RNTBC	Registered Native Title Body Corporate
RRCRF	Regional & Remote Communities Reliability Fund
RTA	Rio Tinto Australia
SAIDI	Supply Average Interruption Duration Index
SAIFI	Supply Average Interruption Frequency Index
SAPS	Stand-Alone Power Systems
SCADA	Supervisory control and data acquisition
SEIFA	Socio-Economic Indexes for Areas
SoC	State of Charge
SPV	Special Purpose Vehicle
SRES	Small-Scale Renewable Energy Scheme
STCs	Small-Scale Technology Certificates
TCICA	Torres Cape Indigenous Council Alliance
UPS	Uninterruptible Power System
VF	Voltage Frequency
VRE	Variable Renewable Energy
WCCCA	Western Cape Communities Co-Existence Agreement
WCCT	Western Cape Communities Trust

Tables

Figures

Executive Summary

This feasibility study assesses a range of options for a self-reliant, sustainable microgrid to enhance community resilience at Napranum, an Aboriginal community of about 900 residents, located on the north-western coast of Cape York Peninsula in North Queensland, Australia.

The study considers the relationship between the Napranum community, the local Distribution Network Service Provider (Energy Queensland) and the energy producer and upstream network owner and operator, Rio Tinto.

The most financial and technically viable option was identified, with the aim that the deployment model used can be rolled out to other, similar, isolated communities.

The Napranum Microgrid Feasibility Study was one of the successful projects in Round 2 of the Australian Government's Regional and Remote Communities Reliability Fund (RRCRF) and complements a previous feasibility study undertaken by EnergyConnect project partners for the Yarrabah community near Cairns and a third study concurrently being undertaken for the Muralug community in the Torres Strait.

The feasibility study was conducted in accordance with several documented core principles:

- Self determination
- Economic opportunity – revenue generation
- Reliable local energy supply
- Build community resilience
- Long-term and on-going employment
- Reduce reliance on fossil fuels
- A social enterprise business case – not just a technical solution
- Demonstration value for other remote and fringe-of-grid communities

Figure 1: Aerial view of Napranum township

Microgrid Definition

This study defines a microgrid in a manner consistent with the US Department of Energy's definition:

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

Typically, the reference to the grid is the main distribution or transmission grid. However, in the case of Napranum, it refers to the local 11kV distribution network operated by Energy Queensland, and the upstream power supply infrastructure (diesel power station and distribution network) that powers the Rio Tinto Weipa bauxite mines and Weipa mining township. There is no physical connection to the National Electricity Grid that interconnects cities and towns across the eastern States and Territories of Australia. The nearest point of the national grid to Napranum is located at Cooktown which lies approximately 650km to the south-west.

It should be noted that a microgrid can be designed for different durations of island mode operation. For example, it could be designed to be capable of 1 hour or 6 hours or 3 days guaranteed power supply in the event of an upstream network or generation failure.

A microgrid could also be designed to be able to provide 24-hour power, 365 days of the year in island mode but draw on generation from the main grid when this is the most economic option. An islandable microgrid with the capacity to support the load for the entire year could also be physically disconnected from the upstream Rio Tinto network if this was the most economic option.

The study focuses on energy efficiency and distributed energy resources (DER) including local power generation systems such as solar photovoltaics (PV), either behind-the-meter or metered separately, in conjunction with battery energy storage systems (BESS), and assesses the regulatory environment, social, cultural, and economic factors, barriers to implementation, and potential funding sources.

Napranum Social Snapshot

The Napranum township is positioned adjacent to the mining town of Weipa.

There are approximately 200 dwellings at Napranum, mostly owned by the Napranum Aboriginal Shire Council and maintained by the Queensland Government. As with most indigenous communities in Queensland, there are barriers to building private homes due to a complex system of land tenure arrangements, involving overlapping native title, leases, sub leases and Indigenous land use agreements.

The community experiences overcrowded housing conditions and a high level of unemployment, currently 22.2%, compared to the Queensland average of 4.6%.

Energy affordability is a significant issue for the community with many residents spending a large portion of their weekly income on credit for their card operated electricity meters, especially during the summer period when air-conditioning is heavily relied upon.

The project team has worked closely with the Napranum Aboriginal Shire Council, Rio Tinto, Energy Queensland, a range of local stakeholders and the broader community, to ensure that all inputs were considered when developing microgrid options. Community feedback was valuable in identifying opportunities, clarifying community expectations and needs, cultural requirements, and to flag potential barriers to implementation.

The enhanced reliability and affordability of electricity supply provided by the microgrid removes multiple levels of disadvantage for isolated communities like Napranum by addressing cost-of-living pressures, providing reliable access to on-line services such as banking, improving health and education outcomes, supporting reliable communications infrastructure, and ensuring safe and reliable water supply is available.

Existing Energy Snapshot

The Napranum community experiences frequent and extended power outages which can be caused by planned and unplanned events at the Rio Tinto Weipa power station and on the local distribution network.

The Weipa power station and network were established primarily to service the local bauxite mining operations, and priority is generally given to ensuring that mining operations and associated activities experience the least impact in the event of a power disruption.

Restoration of supply following a local network fault within Napranum township can be further delayed as there are no on-site Energy Queensland staff, and personnel must be deployed from depots located approximately 800km to the south-east.

Energy Queensland owns and operates power stations and associated networks in 33 other isolated communities across regional Queensland including the Torres Strait islands. However, Napranum is the only remote isolated community where power is purchased from a third-party provider, Rio Tinto, and is on-sold to local residents. Despite this different model, Napranum residents do have access to uniform electricity tariffs set by the Queensland Government, and a range of subsidies and consumer protections that are available to other regional Queensland residents.

Development at Napranum is subject to an additional layer of planning approvals due to the requirement to obtain Rio Tinto's (RTA) permission for the connection of additional infrastructure to the Weipa power supply network. There is currently a blanket policy that bans the deployment of rooftop solar PV systems or other embedded generation throughout Weipa and Napranum to avoid the risk of destabilising the local mining electricity supply.

Based on an analysis of electrical load data supplied by Energy Queensland, the project team assessed that the total electrical load of the Napranum community fluctuates between around 330 kVA and 750 kVA.

The low load periods tend to occur between 3:00am and 6:00am in the mornings, and the peak loads tend to occur later in the day and throughout the evening.

The reliance on air-conditioners to provide relief from hot, humid summer conditions is evident with maximum demand increasing from around 560kVA in the cooler months to 750kVA in summer. Inefficient box-type air-conditioner units are prevalent throughout the community.

The project team have identified recent trends that have changed the economics of power supply by making local generation less costly, even at small scale, including falling solar PV and BESS costs, improvements in battery performance and life, new developments in inverter-based power conversion technologies, control systems, metering and communications, and a changing energy system regulatory environment.

In Australia, it is now generally economical to design new, isolated power systems so that their annual energy requirements are predominantly met (i.e., 50%-95%) with solar PV and BESS, while retaining standby generation for the balance of annual generation.

This new way of thinking usually requires careful management of supply and demand via intelligent microgrid control systems. In most new isolated power system cases, investments in local renewable energy and BESS reduce the overall cost of electricity supply, reduce emissions intensity, and maintain or improve reliability when compared to energy produced primarily from diesel-fuelled generators.

The trends described above are widely expected to continue over the medium-term, increasing the incentive for substituting diesel-only generation with renewable energy sourced isolated microgrids.

Asset Ownership and Management

The microgrid could be developed using a range of investment and ownership models. The preferred model, as adopted for this study, includes Napranum Aboriginal Shire Council (NASC) retaining outright ownership of the project assets as this option is likely to generate the most economic benefit to the Napranum community.

However, the authors also acknowledge that there are potential advantages in EQL owning and operating the Napranum microgrid assets outright, given its long history and experience operating remote and isolated power supply infrastructure across regional Queensland.

The preferred operating structure for the microgrid generation assets (solar PV, diesel generator and community BESS) could be achieved through a commercial operate and maintain arrangement, with a third-party operator, such as Energy Queensland Limited (EQL). Energy generated would be sold via a Power Purchase Agreement (PPA) to the energy retailer for on-sale to consumers in the community.

Alternate ownership and operating models considered include NASC entering a lease arrangement with a third-party entity for the microgrid assets, EQL (or a related entity) owning and operating the microgrid generation assets outright, or these assets being owned and operated by an independent third-party entity.

Based on the preferred operating model, it has been assumed that NASC will fund, construct, own and operate the microgrid generation assets. The microgrid assets would be held in a separate legal entity, beneficially owned by NASC and held separately of ordinary Council dealings. NASC would be supported by a dedicated project management team that will coordinate the pre-construction activities, construction, commissioning, and operation of the microgrid. NASC would also engage a local operations team to oversee day to day management of the microgrid assets.

The project team has not discounted alternative operating models at this early stage and recommends further detailed examination of options to ensure that the most appropriate model is implemented. An operating model whereby EQL is responsible for the microgrid would be consistent with service provision arrangements in other remote communities and could leverage existing skills and capabilities necessary for the safe and reliable performance of the microgrid whilst providing a reliable and affordable outcome for Napranum community and government stakeholders.

Financial Summary

The total estimated capital cost for the establishment of the microgrid in line with the current concept plan is expected to be $20.00 million over a 2-year period (excluding GST).

For the financial assessment it has been assumed that project construction funding will be sourced from Government funding programs for the full capital value of the project and major capital refurbishments. The ultimate funding mix for the project would be dependent on the ownership, operating and management structure adopted for the project.

Whilst the current gate price paid for energy at Napranum is not publicly available, this study considers a range of potential energy purchase prices between $0.24/kWh and $0.80/kWh and concludes that, without grant funding, the project could generate positive internal rates of return if the power purchase price exceeds $0.65/kWh.

Due to the preliminary nature of the project concept and the assumptions required for input to the model, the financial assessment is indicative only and a more detailed financial assessment will be required once details regarding ownership, management, technical requirements, and commercial arrangements are refined.

Recommendations

The Napranum microgrid is intended to be designed and operated as an 'islandable' microgrid, which will retain the connection to the RTA electricity network but will be able to switch over seamlessly to operate in island mode for short periods of time, when the RTA system is either not available due to an outage event occurring, or in a planned manner when maintenance is undertaken.

It is intended that Napranum would primarily be supplied from the new microgrid, with the RTA network providing back-up supply.

Solar PV energy is the most reliable and technically suitable renewable energy source recommended for application in Napranum, and when combined with energy storage systems such as batteries, is expected to meet the total energy requirements of the community in a more sustainable manner than the current fossil-fuelled system.

Behind-the-meter rooftop solar PV installed on council-owned houses, and replacement of inefficient appliances such as air-conditioners and hot water systems with more energy efficient alternatives, will contribute to an efficient microgrid design and assist with addressing energy affordability issues for Napranum residents.

Operation of an embedded Distribution Network Service Provider (DNSP) owned microgrid network connected to the RTA network is complex, but technically achievable, and the DER resources can be controlled in an orchestrated manner to support grid performance and reliability both in the grid connected mode, and in the islanded mode when required.

The Napranum microgrid design envisages that the DNSP will control the DER within the embedded network to minimise electricity demand across the microgrid connection point by using a mix of local residential and large-scale solar PV generation, battery storage, residential demand management, and when required, the standby synchronous generator.

The key components of the proposed Napranum microgrid solution based on this preliminary assessment include:

- 60 x 5Kw rooftop solar PV systems
- 2MW solar farm
- 1MW diesel standby generator
- 2.7MW / 10.8MWh BESS

To maximise the benefits of the implementation of the Napranum Microgrid project, an educational/engagement program is proposed, that includes energy audits for each house, feedback on current performance and information on appliance selection and operation to minimise power use and cost.

Approximately 100,000 tons of Greenhouse gas emissions could be saved over a 25-year period by commissioning the microgrid.

This project will assist the Queensland government to realize several objectives of the recently published Queensland Energy and Jobs Plan, including:

- Achieving its published renewable energy targets.
- Supporting households to manage energy use and save on electricity bills.
- Continuing to implement the uniform tariff policy.
- Supporting deployment of more rooftop solar.
- Decarbonising remote communities.

It will also contribute to achieving the desired outcomes of a range of other government programs, including:

- Local Thriving Communities
- Tracks to Treaty
- Queensland Reconciliation and Action Plan 2018-21
- Queensland Plan
- Climate Action Plan
- Draft State Infrastructure Strategy, and
- Powering Queensland Plan

The benefits and limitations of remaining connected to the RTA network or operating a standalone system at Napranum should be examined in more detail taking into consideration factors such as the cost of energy production, current energy purchase price, the restrictions imposed on operating embedded generation such as rooftop solar PV systems, operational priorities associated with bauxite mining, and the uncertain future life expectancy of the Weipa and Andoom mines.

The Napranum Microgrid Feasibility Study delivers a realistic opportunity to improve the sustainability, reliability, and affordability of power supply to the Napranum community as well as co-benefits such as improved health and education outcomes, and increased community resilience.

1

Introduction

1 Introduction

1.1 About the Regional and Remote Communities Reliability Fund

The Australian Government's RRCRF was established in October 2019 to support up to 50 regional and remote communities to investigate whether replacing, upgrading, or supplementing a microgrid[1] or upgrading existing off-grid and fringe-of-grid supply with microgrid or related new energy technologies would be cost effective.

The intended outcomes of the RRCRF are:

- Viable projects attract funding to support scale-up / implementation of microgrid systems in regional and remote communities.
- Increased human capital (skills/knowledge) in the design and deployment of microgrids.
- Demonstrated commerciality and/or reliability and security benefits of deploying and upgrading microgrids.
- Reduced barriers to microgrid uptake in remote and regional communities.
- Increased dissemination of technology and/or project knowledge regarding the deployment and upgrading of microgrids.

1.2 About EnergyConnect

The project is led by Ener-G Management Group working in collaboration with ITP Renewables, Planz Town Planning and The Missing Link. This collaborative group uses the name EnergyConnect for the purposes of this study.

Key stakeholders for the study include:

- Napranum Aboriginal Shire Council (NASC) – responsible for operating the land on behalf of the community under a Deed of Grant in Trust.
- Ergon Energy Network (EEN)– responsible for the distribution networks in regional Queensland, including within the Napranum community.
- Ergon Energy Retail (EER) – responsible for providing electricity retailing services throughout regional Queensland including application of the Queensland Government's Uniform Tariff Policy.
- Rio Tinto Australia (RTA) – responsible for generating, distributing and selling power in the Weipa and Napranum area.
- EEN and EER are subsidiary companies of Energy Queensland Limited (EQL) – a Queensland Government-owned Corporation.

[1] The RRCRF uses the term microgrid to also include isolated power systems with their own network. Isolated power systems with a relatively small network are often used in areas away from the main grid, such as remote towns and islands. This study refers to these systems as isolated power systems or isolated 'microgrids' as they only have one mode of operation, i.e. they don't have a main grid-connected mode.

1.3 Microgrid definition

This study defines a microgrid in a manner consistent with the US Department of Energy's definition:

> A group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island mode.

Providing generation and storage located close to consumers, microgrids can range in size from a few buildings, such as a retirement village, to entire towns and regions. Microgrids are becoming increasingly viable, in part because the price of energy storage is falling.

In times of peak demand when the network companies impose a rolling blackout regime, or during grid outages due to weather or other events, microgrids can also disconnect from the network and operate independently.

Microgrids may provide for hours, days or weeks of independent operation. This is particularly attractive for remote communities and regions situated on the end of a long power line, who are vulnerable to prolonged outages and electricity infrastructure rebuilds taking weeks or months.

1.4 Study Scope

This study explores a range of potential local energy generation solutions that may be available at Napranum that may be compatible with the existing electricity supply system operated by RTA and EQL, either in a standalone or parallel configuration.

Four scenarios were examined:

1. Operating primarily RTA network-connected but can be islanded and self-sufficient as required during contingency or for network support.
2. Operating a primarily islanded microgrid that is self-sufficient but uses the RTA network as backup supply during contingency.
3. Operating a fully standalone self-sufficient microgrid with no connection to the RTA network.
4. Operating a fully standalone self-sufficient microgrid with no connection to the RTA network but allow for capacity expansion to supply the Weipa township.

Detailed technical and financial analysis is undertaken to assess the most viable options with a view to developing a business case for the deployment of the preferred solution.

The study assumes that the EEN 11kV distribution network will be retained and can be utilised to host distributed energy resources (DER) that may be deployed at various locations at the community.

The microgrid is expected to operate in island mode to seamlessly power the entire Napranum community in the event of an outage affecting the upstream RTA 11kV network or power station for the relevant options.

Alternatively, it could operate as a completely separate system with no connection to the RTA network, meeting the full energy requirements of Napranum, providing the community with energy independence.

The study examines a range of:

- Energy efficiency options
- Renewable generation and energy storage technologies
- Microgrid and load control systems
- Ownership and business models
- Social and financial outcomes

The study includes detailed analysis of options incorporating energy efficiency and demand management strategies, various combinations of small power generation systems such as solar photovoltaics (PV) both behind-the-meter and centrally located as a solar farm, in conjunction with BESS and standby generation.

1.5 Project Plan and Methodology

RRCRF funding was made available for EnergyConnect to undertake joint studies of the feasibility of establishing microgrids at both the Napranum and Muralug Island communities.

An integrated project management plan was developed to undertake the Microgrid Feasibility Studies concurrently. This approach was adopted to efficiently allocate EnergyConnect project team resources, coordinate stakeholder engagement activities and undertake site visits to remote locations on Cape York Peninsula and in the Torres Strait in the most economical manner.

Regular stakeholder engagement was an essential component of the project plan, and regular site visits were undertaken to Napranum to meet with Napranum Aboriginal Shire Council, RTA representatives, and local residents to provide background information on the project, to gather local input and feedback, to assess site conditions and requirements, to install data recording devices at selected residential premises, and to complete surveys and undertake energy audits at residences at Napranum.

Check points were embedded within the project plan for focused stakeholder engagement activities at logical points during the project life cycle. The formal stakeholder forums were designed to engage a broad range of stakeholders to optimise the potential benefits for Napranum and to keep stakeholders informed of progress.

The project commenced in October 2021 with a target end date of April 2023. A timeline outlining the key project stages is presented in Figure 2, and a brief description of each phase of the project plan is outlined below.

1.5.1 Project Establishment

As the EnergyConnect project team had previously been established for the Yarrabah Microgrid Feasibility Study (July 2020 – February 2022), the team was able to rapidly mobilise for the Napranum – Muralug Microgrid Feasibility Study project.

This phase of the project plan was focused on formalising project team membership, establishing partner engagement contracts, developing detailed project plans and budgets, and establishing project administrative and reporting arrangements.

1.5.2 Planning and Data Gathering

During this phase preliminary stakeholder engagement activities were undertaken to identify and secure essential data and reports required for understanding the current state and for the development and assessment of options. This included data pertaining to housing, population and other demographic information, energy consumption and usage information, existing electricity supply infrastructure at Napranum and Weipa, and other general background and site information.

Key stakeholders and residents were briefed on the scope of the project, the project team, project objectives and the delivery plan. An initial site visit was undertaken to assess site conditions and the layout of the community and key infrastructure.

WattWatcher energy monitoring devices were installed at selected residences at Napranum to obtain detailed data on daily energy consumption patterns within the community. The devices were installed at small, medium and larger households to assess the variation in energy usage patterns across these demographic groups.

1.5.3 Stakeholder Engagement Stage 1

During phase 1 of the project focused on engaging with key stakeholders and community members to provide an initial overview of the project, introduce the project team, and to establish baseline data and community sentiment.

This phase operated in parallel with the Data Gathering activities described previously, and the establishment of appropriate communication protocols was essential to ensuring the timely and accurate provision of input data for the project.

Key stakeholders consulted during this period included:

- Napranum Aboriginal Shire Council

- Rio Tinto
- Department of Seniors, Disability Services, and Aboriginal and Torres Strait Islander Partnerships (Queensland)
- Torres and Cape Indigenous Councils Alliance
- Department of Communities Housing and Digital Economy (Queensland)
- Energy Queensland
- Department of Energy and Public Works (Queensland)

1.5.4 Technical Solutions Development

The project team developed a range of concepts for developing a microgrid at Napranum for technical and economic assessment during this phase of the project.

Data collected during earlier phases of the project were further assessed and modelled using min-E version of openCEM modelling tool to provide preliminary assessments of alternative renewable generation to meet 100% of Napranum residents' current and future energy requirements.

The data assessed included:

- Potential electricity distribution network configuration and operating regimes.
- Energy consumption and load profiles derived from WattWatcher data.
- Local site information and geography.
- Weather patterns and an assessment of renewable energy generation sources.
- Future demand including e-mobility considerations.
- Building configuration and orientation (for rooftop solar PV).
- RTA's mining operations, network configurations and policies on renewable energy export.
- Power outage history.

A preliminary review of energy efficiency initiatives was undertaken, based on energy audit results, observations, data measurements and community feedback, and an assessment of potential options was undertaken, and shortlisted options were identified for optimisation analysis.

Ergon Energy's Microgrid and Isolated Systems Test department were engaged to assist with developing a network model and to undertake simulations of potential microgrid configurations proposed by the project team.

A risk assessment was completed including consideration of local constraints and barriers. This included land availability, weather and seasonal impacts assessment, local mining operational requirements, and anticipated development costs.

Significant considerations at Napranum include:

- RTA generates power primarily for its Weipa and Andoom mining operations.
- EQL operates the local Napranum distribution network and electricity retail operations but has no local staff.

- RTA has restrictions on rooftop PV systems and new load connections.

1.5.5 Social Impacts Assessment

During this phase of the project a detailed assessment of the social benefits of developing the Napranum microgrid has been undertaken. The University of Sunshine Coast (School of Law and Society – Biotechnical and Socioclimatic Cities Lab Project) was engaged to assist with the development of a model to quantify the social benefits for incorporation into the economic assessment.

Opportunities for improving the well-being of Napranum residents are investigated as part of these activities including energy affordability, education, health, and employment outcomes.

1.5.6 Stakeholder Engagement Stage 2

Stage 2 of stakeholder engagement focused on validating outcomes of the initial technical options analysis with key stakeholders, including:

- Preliminary designs, land requirements and budget costs.
- Land tenure considerations, including Native Title.
- Operational arrangements and constraints.
- Energy efficiency opportunities including housing design and appliance selection.
- Local preferences and needs.

A formal workshop was convened in Cairns with participation from a range of interested parties including stakeholders identified in Stage 1 activities, as well as representatives from:

- Community Enterprise Queensland
- Energy Consumers Australia
- University of Sunshine Coast
- CA Architects
- P & E Law

1.5.7 Project Report Preparation

A period of five months was allocated to preparing the final report for this project.

This enabled the project team to collate reporting resources, finalise feasibility study outcomes and business models, and for drafting and reviewing the final report. Separate standalone reports have been prepared for the Napranum and Muralug feasibility studies.

Preparation of Financial Analysis of project outcomes was undertaken between November 2022 and February 2023.

Report preparation commenced in December 2022 with the establishment of the Table of Contents and allocation of reporting responsibilities for relevant sections to the appropriate project team members.

A project reporting coordination and review team was established to ensure timely drafting of sections of the report, to ensure consistency and quality of the content of the report and to report back to the broader project team on progress.

The final report will be completed by 30th April 2023.

1.5.8 Stakeholder Engagement Stage 3

This is the project closure phase during which the final report is presented to government, key stakeholders and community via various media and face-to-face presentations.

The Napranum Microgrid Feasibility Study Report will be a key document to support funding applications for pre-implementation activities, and ultimately delivery of appropriate energy supply solutions for Napranum and other similar communities.

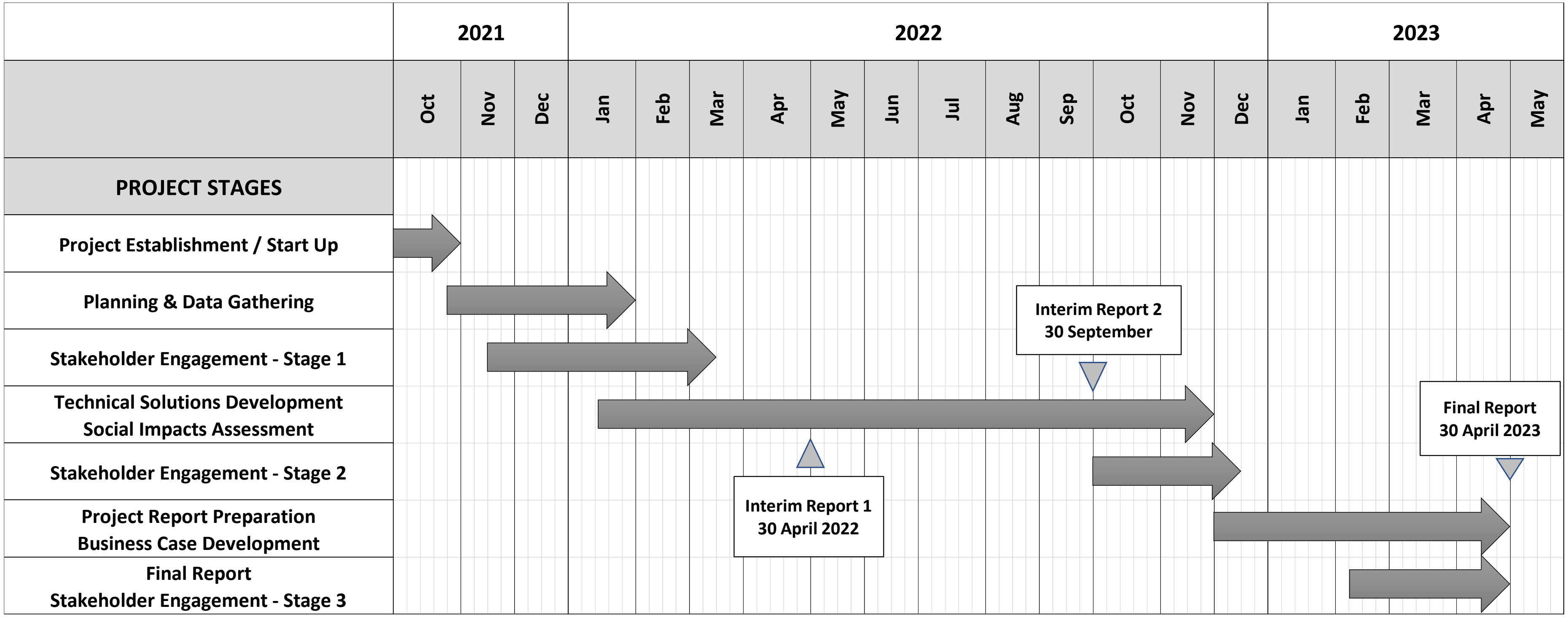


Figure 2: Napranum & Muralug microgrid feasibility study project stages and timeline

2

Napranum Profile

2 Napranum Profile

2.1 Location

Figure 3: Napranum Aboriginal Shire Council location

Napranum is located on the north-west coast of Cape York Peninsula 13km south of the mining town of Weipa (Figure 3) and is approximately 800km from Cairns via State Route 81. This road can be closed for periods of time during the wet season. Napranum Aboriginal Shire has an area of 2,005 square kilometres to the north-west, north-east, and south of Weipa (Figure 4 and Figure 5).

Napranum township is well serviced by a general store, a community health centre, a pre-school, PCYC, an aged care centre, a 'splash park', church, library, and a cultural centre. Additional services such as hospital, primary and high school, sporting clubs, banking facilities, hardware and grocery stores, and airport are located nearby in Weipa.

The Napranum Aboriginal Shire is fragmented into several parts, formed around the Weipa Town and RTA's mining areas which includes three bauxite mines, processing facilities, ship-loaders, an export wharf, two ports, power stations, a rail network and ferry terminals. RTA's

Amrun mine south of Weipa was established in 2018, extending the life of Weipa bauxite operations and subsequently the Weipa town by decades[2].

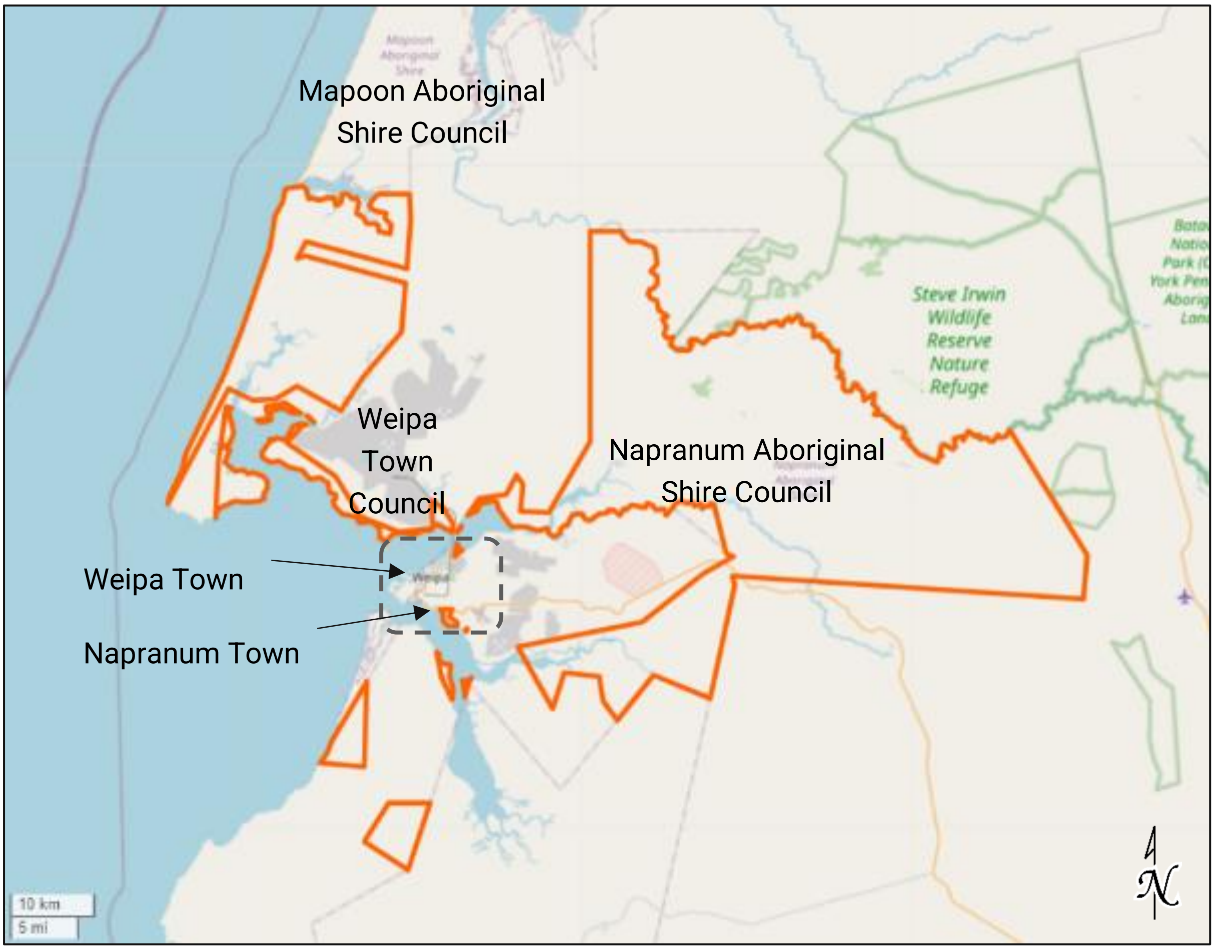


Figure 4: Napranum Aboriginal Shire Council locality map[3]

[2] https://www.riotinto.com/en/operations/australia/weipa

[3] OpenStreetMap 2023

Figure 5: Napranum Town and Weipa Town locality map[4]

The area has an average daily temperature range of 21.6°C to 32.0°C and an average annual rainfall of 1,776mm. Heat waves and above normal temperatures result in temperatures much higher than the long-term daily average (Table 1).

Northern Australia experienced almost 3 weeks of heat wave conditions over 2 months during October-November 2022 (Figure 6). The average daily temperature was 36.9°C with a highest daily temperature of 40.1°C. Combined with an average overnight temperature of 23.7°C, there was little relief from extreme temperatures.

Napranum is also vulnerable to tropical cyclones and heavy rains between October and April each year, and a considerable proportion of the Napranum township is vulnerable to storm tide inundation. Increases in extreme storm events due to climate change are expected to cause more flash flooding affecting infrastructure including water, sewerage, stormwater, transport, and communications.

[4] OpenStreetMap 2023

Table 1: Average daily temperature at Napranum and Muralug (°C)[5]

Average Daily Temperature °C										
	Long term Average		September 2022		October 2022		November 2022		December 2022	
	Highest	Mean	Highest	Mean	Highest	Mean	Highest	Mean	Highest	Mean
Napranum / Weipa	40.1	32.8	38.6	35.8	40.1	36.9	39.5	36.2	40.1	36.9
Muralug / Horn Is.	46.7	30.5	34.0	31.1	33.9	32.9	34.6	33.0	31.2	29.9

[5] Australian Bureau of Meteorology, Queensland Daily Weather Observations

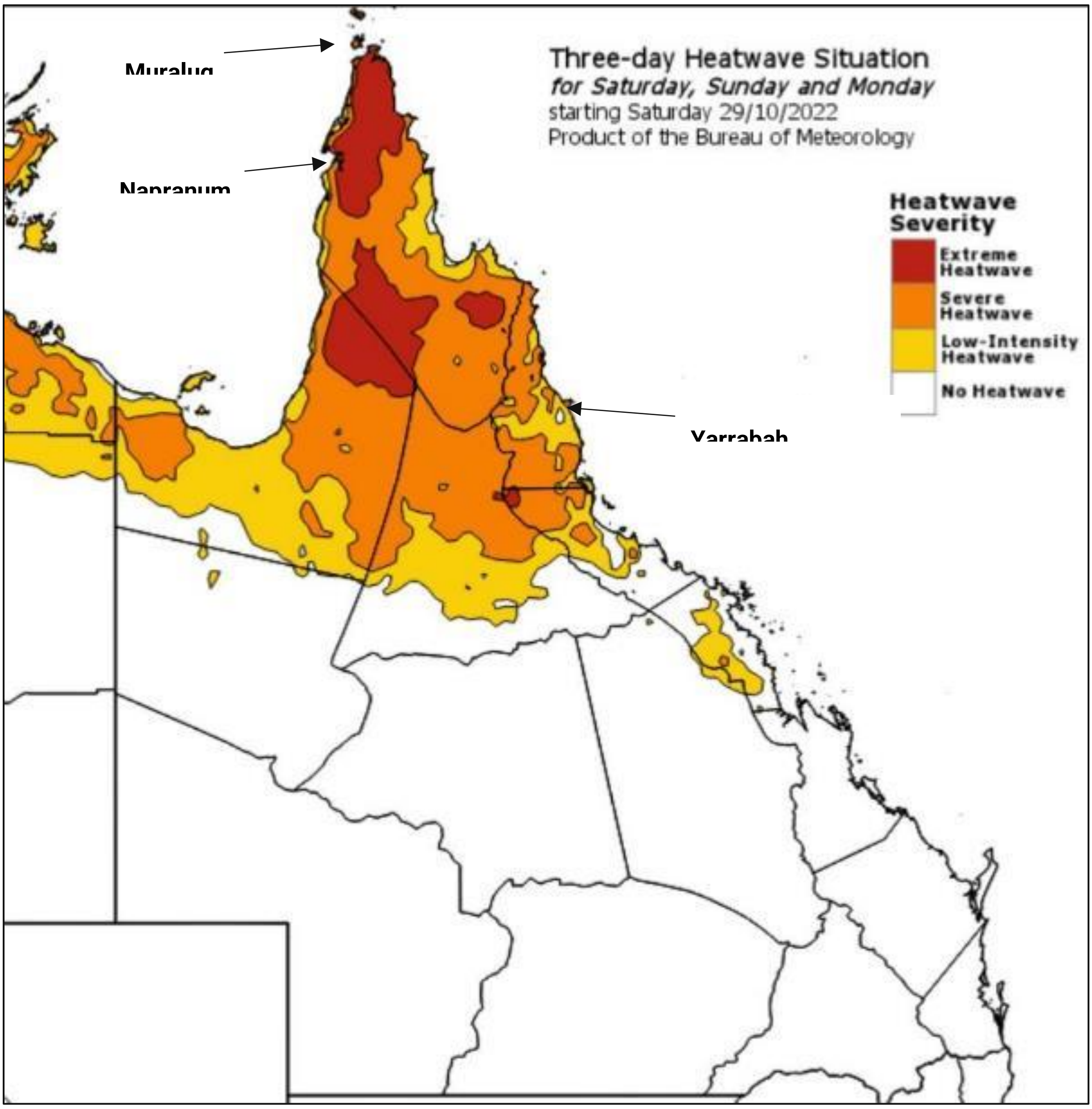


Figure 6: Heat wave warning map - Bureau of Meteorology October 2022

2.2 Tenure

The Weipa South Aboriginal Council was established in March 1985 and the Aboriginal reserve held by the Queensland Government was transferred to the Weipa South Aboriginal Council in October 1988 under a Deed of Grant in Trust (DOGIT)[6].

In 1990, the Weipa South community became known as Napranum which translates to 'meeting place of the people'. The DOGIT lands became known as the Napranum DOGIT in

[6] https://www.qld.gov.au/firstnations/cultural-awareness-heritage-arts/community-histories/community-histories-n-p/community-histories-napranum#:~:text=History%20of%20Napranum,Traditional%20Owners%20of%20this%20area.

1991. In January 2005, the Napranum Aboriginal Council became the Napranum Aboriginal Shire Council.

The number of changes around tenure in the last 30-60 years foretells of the complexity of land ownership and development. No development of any form can be undertaken without landowner consent – the nature of land ownership is complicated and varies depending on the nature of the development.

Land within the Napranum Aboriginal Shire comprises inalienable freehold including land held under DOGIT and non-freehold (reserve) land. Inalienable freehold land held by Council as the trustee via DOGIT for the benefit of Aboriginal people is located within the township and other settled areas within the Shire.

In accordance with the Aboriginal Land Act 1991 trustees are appointed by the Queensland State Minister for Resources to hold the freehold title for the traditional owners. The most significant aspect being the land cannot be sold or mortgaged.

Additionally, under the Aboriginal Land Regulation 2011, approval to issue leases must be made in accordance with Aboriginal tradition and residential leases require Ministerial consent. There is one undetermined native title claim over the Napranum township (QC2014/008 - Cape York United Number 1 Claim).

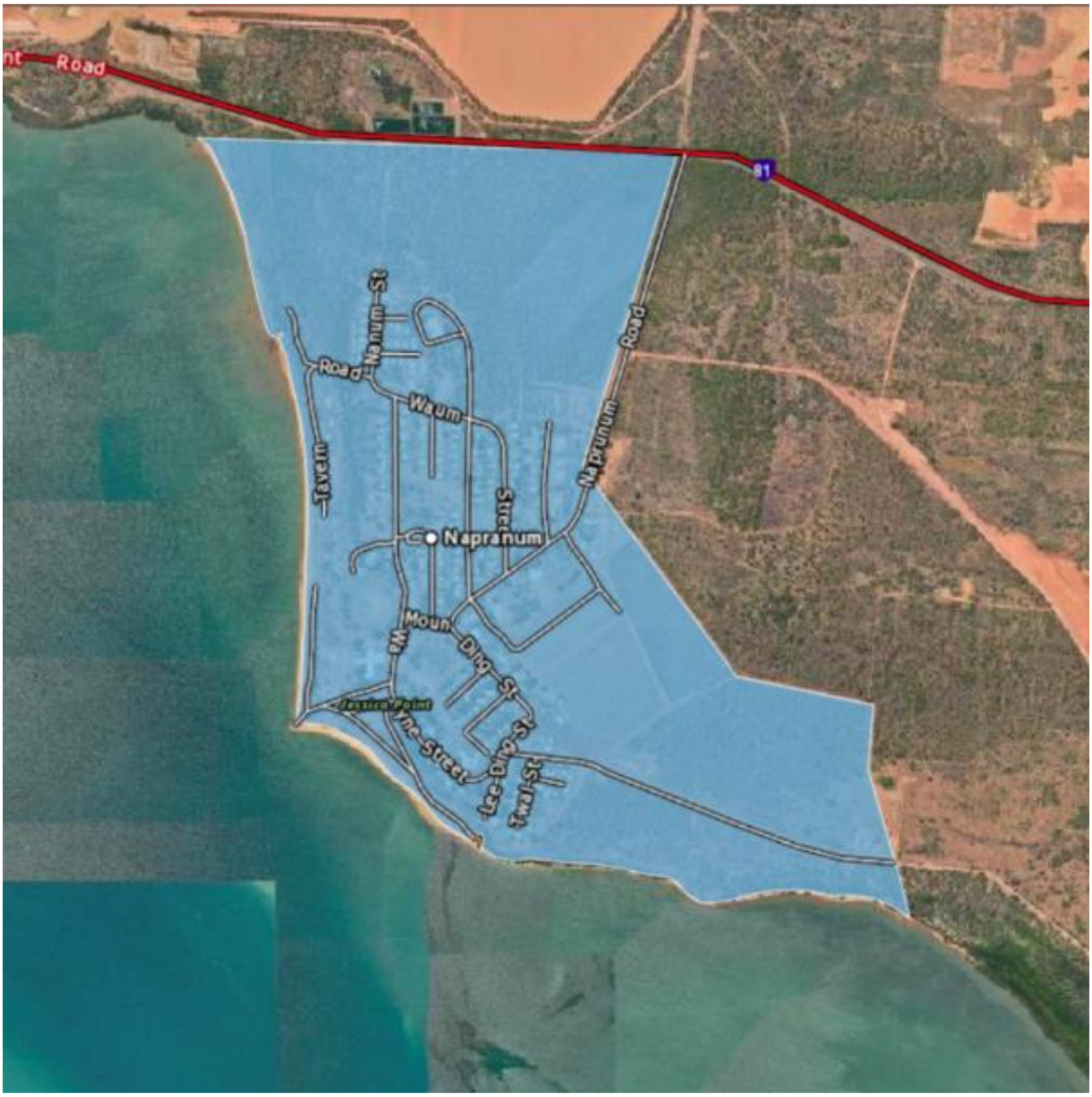


Figure 7: Native title claim at Napranum (in blue)

The presence of both a Native Title claim and DOGIT land tenures over land means the traditional owners have not been officially recognised as having common law right to their traditional lands, however residents have rights to the land under the DOGIT regime. Those with rights under the DOGIT are all Indigenous residents, including those Indigenous people who were removed from their traditional lands to reserves or missions under various Acts of Parliament.

The Commonwealth Native Title Act 1993 provides for Indigenous Land Use Agreements (ILUAs) between native title holders or claimants and other interested parties which outline how land and waters covered by an agreement will be used and managed into the future. As of November 2022, no ILUAs are registered over the Napranum Township area.

Figure 8: Napranum ILUA area (in purple)

2.3 Population

Napranum has a recorded population of 907 at the 2021 census, compared with a population of 989 in 2016 and 908 in 2011, which translates to an average annual growth rate of 0.0% over ten years. The state of Queensland has had an average annual growth rate of 1.5% over the same 10-year period[7]. The age profile of the recorded population is considerably different to that of Queensland, however it is similar to other remote areas and Aboriginal Shire local government areas (LGAs). For context:

- The Torres Shire Council demographics have been included as Muralug Island, in the Torres Shire, forms part of this Microgrid Feasibility Study.
- Australia's largest discrete Aboriginal community – Yarrabah Aboriginal Shire Council has been included in the statistics. Of note this community has also been the subject of a Microgrid Feasibility Study.

---

[7] https://statistics.qgso.qld.gov.au/qld-regional-profiles

The age profile identifies that Napranum, Torres and Yarrabah have a significantly greater percentage of population aged 0-24, a similar population aged between 25 and 64, and a significantly lower population of aged 65+, when compared to Queensland (

Age Group										
	0-14		15-24		25-44		45-64		65+	
	Number	%	Number	%	Number	%	Number	%	Number	%
Napranum	263	29.0	162	17.8	239	26.4	205	22.6	38	4.2
Torres	958	27.1	550	15.6	1,002	28.4	774	21.9	249	7.0
Yarrabah	789	30.3	497	19.1	703	27.1	493	19.0	116	4.5
Queensland	989,461	19.0	651,113	12.5	1,416,854	27.2	1,295,777	24.8	864,448	16.5

).

This is reflected in the median age for Napranum being 27.3 which is an increase of 2.2 years from median age of 25.1 years as of 30 June 2011 compared to 38.4 for Queensland, which is an increase of 1.8 years from median age of 36.6 years on 30 June 2011[8].

The Demographic information for Napranum, indicates a community of young families with children and indicates poor health outcomes for the aging population.

Table 2: Estimated Resident Population by Age, 2021[8]

Age Group										
	0-14		15-24		25-44		45-64		65+	
	Number	%	Number	%	Number	%	Number	%	Number	%
Napranum	263	29.0	162	17.8	239	26.4	205	22.6	38	4.2
Torres	958	27.1	550	15.6	1,002	28.4	774	21.9	249	7.0
Yarrabah	789	30.3	497	19.1	703	27.1	493	19.0	116	4.5

[8] ABS 3235.0, Population by Age and Sex, Regions of Australia unpublished data and Queensland Treasury estimates

Queensland	989,461	19. 0	651,113	12. 5	1,416,854	27. 2	1,295,777	24. 8	864,448	16. 5

Table 3 shows migration in and out of Napranum. The comparison considers the usual address of household members on Census Night 2021 (10 August 2021) with their usual address one year earlier (10 August 2020) and their usual address five years earlier (10 August 2016). The figures show that over 1 to 5 years no more than 11% of Napranum residents have moved (in or out of the LGA) compared to between 17 and44.8% of Queenslanders.

Table 3: Place of usual residents 1 year ago, and 5 years ago Napranum LGA and Queensland, 2021[9]

Place of usual residence over time, Napranum (S) LGA and Queensland, 2021					
	Same Address	Within Qld	Rest of Australia	Overseas	Proportion with Different Address
	Number	Number	Number	Number	%
Napranum 1 year ago	663	53	-2	0	6.3
5 years ago	553	73	10	10	11.0
Torres 1 year ago	2,617	424	59	6	19.9
5 years ago	1,765	933	112	57	35
Yarrabah 1 year ago	2,272	123	0	0	5.0
5 years ago	1,873	273	9	0	12.8
Queensland 1 year ago	3,909,222	719,541	97j770	34,773	17.0
5 years ago	2,348,034	1,635,871	276,658	215,572	44.8

The family composition of the Napranum community presents a substantial difference when compared to Queensland for families with no children where Napranum has substantially less (15%) of couples with no children compared to 40.3% of Queensland couples, and a substantially higher number of one-parent families (32.2%) compared to 16.8% of Queenslanders as shown in Table 4. The average number of people per household in Napranum is 3.7 compared to 2.5 for Queensland.

[9] ABS, Census of Population and Housing, 2021, General Community Profile – G45

Table 4: Family composition in Napranum and Queensland, 2021[10]

Family composition							
	Couple family no children		Couple family with children		One-parent family		Total
	Number	%	Number	%	Number	%	Number
Napranum	27	15.0	79	43.9	58	32.2	180
Torres	187	24.6	332	43.7	205	27.0	760
Yarrabah	71	12.5	223	39.3	255	45.0	567
Queensland	551,069	40.3	563,327	41.2	230.026	16.8	1,366,657

The 2021 Census indicates a near equal population of females and males, consistent with Queensland, with 81.1% of the Napranum population identifying as Aboriginal and/or Torres Strait Islander, compared to 4.6% for Queensland.

2.3.1 Home Ownership and Affordability

The dominant dwelling structures in Napranum are separate private houses (155 (77.9%)) with the balance of the dwellings being semi-detached or apartments, which is comparable to Queensland which has 74.8% occupied private dwellings. Most of the housing stock is owned by the Queensland State Government (social houses). The housing stock includes several dwellings that have been erected without land ownership (tenure) or building approval.

The rate of homeless persons (i.e., living in a dwelling that is inadequate, has no tenure, does not allow a person to have control of space for social relations) is 280.1 people per 10,000 persons, compared to 280.4 persons per 10,000 for the Torres Shire, 549 persons per 10,000 for Yarrabah and just 45.6 people per 10,000 persons across Queensland.

Rent for a social house is based on 25% of a total household's assessable income and ranges from $90/week to $180/week. The higher the rent the more registered adults in a house (income earning or higher jobseeker allowance). Lower rent generally indicates there are more children under 16 years of age. Housing is income-assessed through the State Government's public-community-housing scheme. Many households have "floating tenants" that are not reported as part of the income.

2.4 Income and Employment

The median total personal income in Napranum was $342 per week compared to $787 for Queensland, with a median total family income of $924 for Napranum compared to $2,024 for Queensland. The poverty line in Australia is $968.41 per week or $50,357 per year for a

[10] ABS, Census of Population and Housing, 2021, General Community Profile – G29

household with 2 adults not working and 2 children[11]. Many households in Napranum are below the poverty line. Most employed people in the area either work for the Council, the local mining company or for state government agencies.

Table 5 shows that the medial, total personal income (i.e., the total of all wages/salaries, government benefits, pensions, allowances, and other income a person usually receives) in Napranum is $17,784. This low personal income is reflected in the most recent Socio-Economic Indexes for Areas (SEIFA) from 2016 in which Napranum had a score of 664, compared to 650 for Yarrabah, 932.5 for Torres Shire and 1,060 for Brisbane. That is, Napranum and Yarrabah are in the bottom 20% (quintile position 1) (Table 6) on the index of social and economic advantage / disadvantage, compared to Brisbane which has an overall quintile position of 5 (top 20%)[12].

Table 5: Total Personal Income, 2021[13]

Total Personal Income											
	Less than $20,800 per year		$20,800 to $51,999 per year		$52,000 to $103,999 per year		$104,000 or more per year		Personal Income Not Stated		Median ($/year)
	Number	%	Number	%	Number	%	Number	%	Number	%	$
Napranum	191	30.3	82	13	57	9	19	3	156	44.7	17,784
Torres	591	23.4	660	26.2	702	27.8	300	11.9	241	10.7	45,604
Yarrabah	986	56.1	535	30.4	93	5.3	23	1.3	113	6.9	17,524
Queensland	999,942	23.9	1,316,078	31.4	1,084,654	25.9	461,162	11	301,223	7.8	40,924

Table 6: Population by Index of Relative Socio-Economic Disadvantage quintiles(a) by LGA, 2016[14]

Index of Relative Socio-Economic Disadvantage quintiles					
	Quintile 1 (most disadvantaged)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (least Disadvantaged)
	%				

[11] Poverty Lines: Australia. Melbourne Institute of Applied Economic and Social Research December quarter of 2020

[12] Source: Australian Bureau of Statistics, Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016 (cat. no. 2033.0.55.001)

[13] Source: Australian Bureau of Statistics, Census of Population and Housing, 2021, General Community Profile - G02 and G17

[14] Source: Australian Bureau of Statistics, Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016 (cat. no. 2033.0.55.001)

Napranum	100	0.0	0.0	0.0	0.0
Torres	44.7	45.4	0.0	0.0	0.0
Yarrabah	100	0.0	0.0	0.0	0.0
Cairns	27.2	19.5	16.5	19.1	17.8
Brisbane	2.6	9.6	18.7	24.6	41.6
Queensland	20.0	20.0	20.0	20.0	20.0

Table 7 shows the unemployment rate in Napranum for the June quarter 2022 is reported as being 22.2% compared to 4.6% for Queensland[15]. Yarrabah LGA has the highest recorded unemployment rate of 56.8% and while Torres had the lowest unemployment rate of 10.6%, it is still remarkably high compared to the Queensland rate of 4.6%.

Table 7: Unemployment and labour force by LGA, June quarter 2022[15]

Employment			
	Unemployed	Labour force	Unemployment rate
Napranum	98	441	22.2
Torres	182	1,721	10.6
Yarrabah	182	713	56.8
Queensland	128,979	2,833,277	4.6

2.5 Energy Affordability

While regulated electricity tariffs provided by EER for Napranum residents are the same as tariff charges for other EER customers throughout regional Queensland, most residents were unaware of their current tariffs with very few installations having secondary economy tariffs connected.

In line with current RTA policy, and social housing standards, there is no rooftop solar PV installed at Napranum. Accordingly, residents cannot offset their energy consumption with a behind-the-meter embedded generator.

The average annual energy consumption for a residence in regional Queensland (Ergon Energy Network supply area) was 5,588 kWh in 2020[16].

[15] Australian Government, National Skills Commission, Small Area Labour Markets Australia, various editions

[16] AER Residential Energy Consumption Benchmarks December 2020

A review of energy consumption data provided by EQL revealed that the average annual residential tariff consumption at Napranum was 8,819kWh which is 1.58 times the Queensland average.

EnergyConnect installed WattWatcher devices at six Napranum residences to monitor daily load profiles for the 7-month period between May and November 2022. The average daily usage recorded ranged between 36.0 kWh and 67.9 kWh for these premises and the annual average pro-rata consumption for these six installations was calculated as 16,582kWh which is 2.97 times the Queensland average.

Card meters are installed at all houses in Napranum and residents pre-pay for their energy by purchasing credit for their meter cards from a local retail outlet. The card meters have an emergency credit function that can be activated outside normal business hours or on weekends. Residents often rely on this emergency credit to maintain power to their homes. Consequently, when meter cards are recharged, the debt is deducted from the value on the card when it is uploaded to the meter before any additional credit is added to the meter.

Poor energy usage habits, like running air-conditioners all day with doors and windows open, were observed during energy audits. This also contributes to higher energy usage within the households. The replacement of inefficient appliances, combined with an energy efficiency education program may assist in addressing energy affordability issues at Napranum.

2.6 Housing Design and Construction Standards

Houses are primarily single-storey, block construction with between 2 and 4 bedrooms, and range from 30 years old to a few newer houses built in the past 2 years. The current housing design meets cyclone rating construction requirements however the houses are built from standard government plans, and the design does not respond to the tropical climate.

The State Government's public-community-housing scheme ensures an ongoing maintenance program for housing. New houses are designed in accordance with the *Design and Construction Standards for Remote Housing*[17] (see also *Social Housing Dwellings Minimum standards for building products, fixtures, fittings and other items typically required in dwellings*[18]).

2.6.1 Mechanical Cooling

The current Queensland government housing standards require the following provisions.

[17] August 2016. Queensland Department of Housing and Public Works. Design and Construction Standards for Remote Housing.

[18] June 2016. Queensland Department of Housing and Public Works. Social Housing Dwellings Minimum standards for building products, fixtures, fittings and other items typically required in dwellings.

Air Movement and ceiling fans

House design must facilitate good cross-ventilation. Typically, habitable rooms with two or more external walls shall be provided with openable windows in both walls.

Ceiling fans (minimum 1300m diameter) or an alternative method of creating equivalent air movement, should be provided to all habitable rooms.

Air-conditioning

Air-conditioners are not supplied by the department. However, a knockout panel and power outlet are provided in all habitable rooms for future installation of air-conditioners by tenants. *Note that this is for installation of standard box-type air-conditioners, not the more energy-efficient inverter split system air-conditioners.*

Thermal insulation

Thermal insulation is installed to the entire roof, and/or over ceiling linings of all indoor and outdoor living spaces, and to attached carports.

Accordingly, houses have an almost universal supply of fans throughout, however if air-conditioning is installed it is to a standard that can be afforded by the tenant. This has led to installation of many ‘box’ air-conditioners in windows or by knocking out four of the wall blocks and resting the air-conditioner in the space without gaps sealed or insulated, resulting in very inefficient cooling.

Overall, house design is not supportive of living comfortably in a tropical environment, without mechanical cooling. The houses often do not have covered outdoor living spaces, they often have shallow eaves and small windows and at times, security concerns limit the desire to open windows and doors to take advantage of crossflow ventilation. Over time, houses may be extended, with garages built in or additional rooms added, which in turn reduces the through-breeze that the Design Standards seek to establish.

Solar PV and Solar Hot Water Systems

Solar PV is not provided on any social housing. Solar hot water systems are not common in older houses, although there is a trend for installation of solar hot water systems on newer buildings.

Solar Hot Water Systems are specified according to the water quality at the community and all solar collector plates are fitted with steel mesh grilles for additional mechanical protection. The systems are also fitted with a booster switch to heat water when the solar source is insufficient or unavailable at night or due to inclement weather. In many cases the booster is used daily to meet hot water demand requirements especially in overcrowded households.

There is no evidence of widespread installation of heat pump hot water units. The most common systems are electric thermostat-controlled hot water tanks.

There is also limited application of controlled tariff use for water heating due to the household demand for continuous hot water. Gas hot water systems are not installed at Napranum.

2.7 Economic Development Plans

Council is the largest employer in the Shire and the following information in relation to Council services is taken from the Napranum Disaster Management Plan 2021 - 2022[19].

2.7.1 Road network

Roads within the township of Napranum are mostly sealed, but roads outside the township are of unsealed gravel construction. The main road from Napranum to Weipa is sealed, and rarely floods, although there are some low-lying areas which have been known to be affected for several hours in the past.

2.7.2 Power Supply

Napranum is connected to the local electricity network - supply is provided through the RTA power station located at Weipa. Electricity supply is distributed via overhead and underground reticulation throughout the community. Electrical infrastructure within Napranum is managed and maintained by EEN.

The Council has standby generators set up that will power the major facilities during a power outage including:

- Council Office (Disaster Coordination centre)
- Community Hall
- Radio Station
- Aged and Disability Services
- IBIS Supermarket
- Water Treatment and Pumping Station
- Sewage Pumping Stations
- Primary Health Centre Allied Health Care - Apunipima

2.7.3 Fuel storage

Napranum has a fuel storage capacity of 30,000 Litres. In case of emergency there is a portable fuel storage and delivery unit.

[19] Napranum Disaster Management Plan 2021 - 2022

2.7.4 Water Supply

Provision for a safe and adequate supply of water is essential and, in most instances, the provision and treatment of water is the responsibility of Council. During power outages auxiliary power is required to ensure correct chlorination of the water supply is maintained. Council has backup generators to maintain services in times of power loss.

2.7.5 Sewerage

Napranum Township has reticulated sewerage. During extended power outages auxiliary power is required to ensure sewage pump stations remain operational. Council has backup generators to maintain services in times of power loss.

2.8 Planning and Approvals

There are a range of approaches to obtaining a development approval for a microgrid at Napranum. Each has different timeframes and offers different levels of 'appeal rights' to the public.

2.8.1 Ministerial Infrastructure Designation

The *Planning Act 2016* includes provisions for consultation by the Minister and the process for making (deciding) a Ministerial Infrastructure Designation (MID). The Minister for Planning is the decision maker for a MID.

A MID allows for the delivery of essential community infrastructure including electricity operating works (*Planning Regulation 2017, Schedule 5, Part 2*).

The MID provides an alternative process to lodging a development application with Council.

An approved MID doesn't directly authorise development; instead, the effect of the MID is to make specified work 'accepted development' under the *Planning Act 2016*, i.e. development that does not require a development approval.

A MID does not prevent other development from taking place on the designated premises, subject to the appropriate approvals being obtained.

There is no timeframe for the MID process. The assessment and decision-making process is likely to take 8-12 months and objectors do not have appeal rights in the Planning and Environment Court.

2.8.2 The Planning Scheme and Planning Act

Development of land in Napranum is in accordance with the *Planning Act 2016*, which is consistent with all local governments across Queensland. Council has a Planning Scheme and to develop land or use it for a specific purpose, a development application is required to be submitted to Council for Planning approval.

Council is typically the Assessment Manager for land-based aspects of development. State interests are triggered through this process and these interests are assessed via the State Assessment and Referral Agency. However, the State may be the Assessment Manager for developments such as Wind Farms.

The assessment and decision-making process typically takes 4-8 months and objectors have appeal rights in the Planning and Environment Court.

2.8.3 Prescribed Project

A Prescribed Project is one which is of significance, particularly economically and socially, to Queensland or a region. Declaring a prescribed project enlivens the Coordinator-General's powers to ensure timely decision-making in relation to prescribed processes and prescribed decisions. The Coordinator-General is not bound to declare a Prescribed Project.

The project would be coordinated by, but not decided by the Office of the Coordinator-General. The Napranum Aboriginal Shire Council will still be responsible for deciding the application.

This approach allows for an outcome focused approach across the State Agencies and allows Council to be involved in the decision-making.

The assessment and decision-making process typically takes 4-8 months and objectors have appeal rights in the Planning and Environment Court.

2.8.4 Co-ordinated Project

A Co-ordinated Project under the *State Development and Public Works Organisation Act 1971* would result in the State undertaking the complete assessment. This approach can be requested where the development has:

- complex approval requirements, involving Local, State and Federal governments
- significant environmental effects
- strategic significance to the locality, region or state, including for the infrastructure, economic and social benefits, capital investment or employment opportunities it may provide
- significant infrastructure requirements.

The Coordinator-General chooses the weight attributed to each of the above factors. The Coordinator-General is not bound to declare a project a coordinated project merely because it satisfies one or more of these characteristics.

Typically, there are no appeal rights for submitters. In making the declaration decision, the Coordinator-General must have regard to:

- detailed information about the project given by the proponent in an initial advice statement

- relevant planning schemes or policy frameworks of Council, the state, or the commonwealth
- relevant state policies and government priorities
- a pre-feasibility assessment of the project, including how it satisfies an identified need or demand
- the capacity of the proponent to undertake and complete the environmental impact statement or impact assessment report for the project
- any other matter considered relevant.

3

Stakeholders and Community Engagement

3 Stakeholders and Community Engagement

3.1 Key Stakeholders

This study defines stakeholders as individuals, groups, or communities who may be directly or indirectly impacted by the project or have an interest in it. This diverse group includes locally affected communities and individuals, their formal and informal representatives, national, state, or local government authorities, political leaders, community organisations, groups with special interests, the academic community, and other businesses.

For EnergyConnect, working closely with the Napranum community, its leaders, Energy Queensland, government representatives, RTA, and a range of other important stakeholders was essential to earn and maintain its social license to operate. The company aimed to deliver a project feasibility report that met community expectations and received broad support for project implementation.

Throughout the scoping stage and project progression, stakeholders were categorised based on their level of interest and influence on the microgrid project. This categorisation is outlined in Figure 9.

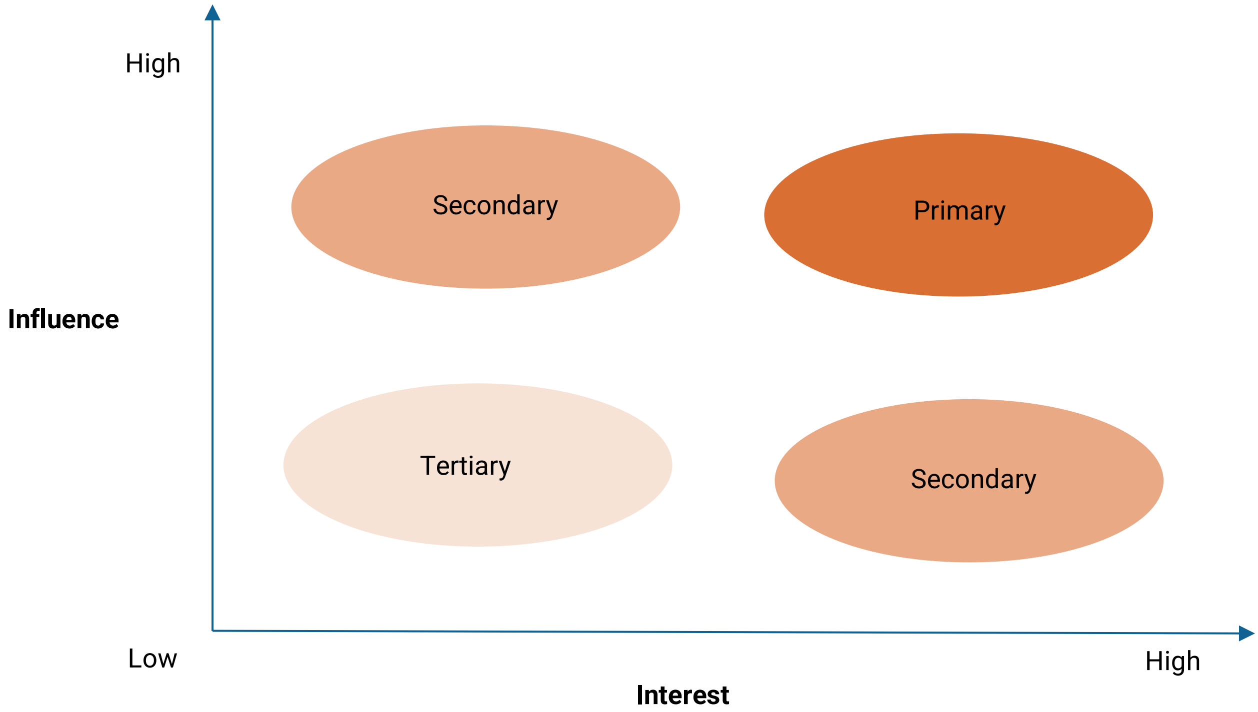


Figure 9: Stakeholder classification matrix

To ensure effective stakeholder engagement throughout the project, a broad stakeholder list was developed, and stakeholders were classified into three categories based on their level of interest and influence on the microgrid project. As the project progresses, stakeholders' interests may shift, which highlights the importance of continuous stakeholder identification and analysis.

The primary stakeholder group, consisting of those with the highest level of influence and interest in the project, was identified as:

- Napranum Aboriginal Shire Council
- Traditional Owners – Anathangayth, Alngith, Peppan, Thanakwithi, Wathyn and Wik Waya peoples represented by the Mokwiri Aboriginal Corporation
- EQL
- RTA
- Department of Climate Change, Energy, the Environment and Water
- Department of Seniors, Disability Services, Aboriginal and Torres Strait Islander Partnerships

The Secondary stakeholder group included:

- Elected State and Federal Members of Parliament
- Other local government councils, including The Torres and Cape Indigenous Council Alliance
- State and federal government departments
- Local businesses and other community representative bodies
- Local, state and national media outlets

The Tertiary group of stakeholders identified for the project included:

- Other residents
- Weipa Town Authority
- Universities and other educational institutions

These stakeholder groups formed the original basis of the stakeholder engagement strategy and stakeholder database.

Targeted communication strategies were developed for each of the stakeholder groups and individual stakeholders depending on their level of knowledge, understanding, interest and influence over project outcomes, or their ability and willingness to engage and inform EnergyConnect. To track stakeholder engagement activity, a register of communications was maintained throughout the project, and statistical data on the number of stakeholder engagement sessions[20] undertaken is summarized in Table 8.

Table 8: Composition of engagement activities

Total Number of engagement sessions	98
Total duration of engagement sessions (hours)	130

[20] Combined data for Muralug and Napranum stakeholder engagement activities.

Total number of stakeholders consulted	285

3.2 Stakeholder Engagement Strategy

Stakeholder and community engagement was recognised as a key determinant of success in this project, with early and effective engagement with its stakeholders and 'interested parties' as a priority. The Project Delivery Plan defined a clear program of community and stakeholder engagement, including a Stakeholder Engagement Strategy, to scope expectations and match potential microgrid solutions to community preferences. The Stakeholder Engagement Strategy was developed to effectively coordinate communication, consultation, and engagement with the key stakeholders and the Napranum community. The strategy was developed in line with best practice principles from IAP2, Australian Federal Government and as described in ISO 14001:2018 Environmental Management Systems guidance.

The Community Engagement Strategy aimed to:

- proactively address and respond to stakeholder and community issues, concerns, ideas, and opportunities associated with the project through ongoing consultation and engagement
- identify stakeholders with a potential to influence the project and seek their input and involvement during the project
- provide factual, timely and relevant information to all stakeholders
- maintain and nurture existing stakeholder relationships and build new ones as opportunities arose
- profile EnergyConnect's capability to engage in sustainable energy generation practices
- continue to build and refine robust frameworks that manage potential and real stakeholder issues and opportunities effectively and in a timely manner
- provide engagement activities that meet or exceed community expectations.

Within the Stakeholder Engagement Strategy, a Communication Plan was outlined to provide a framework for subsequent project communication. This facilitated the building of new and strengthening already established relationships with key stakeholders. All communication, consultation and engagement were based on the Stakeholder Engagement Strategy however the Strategy evolved slightly throughout the course of the project. These evolutions allowed for enhanced engagements within the community and built a strong foundation upon which future project implementation activities can start.

Key themes, messages and delivery protocols were developed to support the deployment of the Strategy, to ensure information was timely and accurate, to reaffirm EnergyConnect's commitment to the community, including its approach to managing environmental, social, and economic impacts.

Through its community and stakeholder engagement program, EnergyConnect was able to form a comprehensive understanding of community context and social framework. Using the program, EnergyConnect were also able to gather a clear understanding of concerns, desires, strengths, weaknesses, and opportunities in relation to potential project impacts. The project team also forged or cemented relationships with key community members, groups, and stakeholders.

Regular site visits were vital in building relationships and establishing effective communication links between the community and the EnergyConnect team. The regular visits also ensured feedback was timely and responded to promptly; communication mechanisms and protocols were complied with effectively; and that relationship-centric stakeholder engagement was prioritised and achieved.

EnergyConnect is proud of the relationships it has built with the community and appreciates the advice and support that it received.

3.2.1 Major Stakeholder Activities

A range of communications and stakeholder engagement activities were undertaken to ensure broad awareness of the Napranum microgrid feasibility study, including:

- Presentations to Napranum Aboriginal Shire Council members
- Meetings with Cape York Partnerships
- Stakeholder engagement workshop (Cairns)
- Direct engagement with residents via a community barbecue, information day, household surveys and energy audits
- Ongoing engagements with EQL
- Meetings with Torres Cape Indigenous Council Alliance (TCICA)
- Ongoing engagements with RTA
- One-on-one meetings with stakeholders
- Meetings with Queensland Government Agencies:
    - Department of Seniors, Disability Services and Aboriginal and Torres Strait Islander Partnerships
    - Department Communities, Housing and Digital Economy
    - Department of Energy and Public Works
    - Department of Resources

A range of media was developed and used to support the community engagement activities, these included:

- Project update newsletters.

- The EnergyConnect website[21].
- EnergyConnect YouTube videos[22] to explain concepts and provide regional and cultural context to the project and provide educational information to local students.
- Napranum Residents' Energy Usage Survey.
- PowerPoint Presentations developed for specific audiences and briefings.

Figure 10: Meeting at Napranum Shire Council to coordinate community engagement activities

Throughout the project, a Stakeholder Register was maintained to record the details of each stakeholder engaged, as well as the major communication activities. This Register was a shared document updated by all EnergyConnect team members upon completion of engagement activities. Each engagement activity was accurately recorded, including attendees, purpose, duration, and venue, along with the key points raised and any required actions to address concerns in a timely manner. The project team assigned responsibilities to a specific officer and set a targeted resolution date for each action. Progress on the status of these actions was reviewed during fortnightly team meetings.

3.3 Community Attitudes and Current State Assessment

Community attitudes were assessed through a series of meetings with Napranum leaders and key stakeholders including the Napranum Aboriginal Shire Council throughout September and November 2021. The project team also undertook 22 targeted surveys of households to better inform the project of individual experiences from within the community.

---

[21] https://energy-connect.net.au/

[22] Our YouTube Channel (energy-connect.net.au)

The outcome of these activities provided essential information to the team that were used to guide and influence elements of the microgrid feasibility study.

From initial interactions with the Napranum Aboriginal Shire Council the key benefits they saw from the project were:

- improving regional business, community services and emergency resilience through innovative microgrid solutions
- scaled up and improved microgrid systems in regional and remote communities
- demonstrated commerciality and/or reliability and security benefits of deploying and upgrading microgrids
- reduced barriers to microgrid uptake in remote and regional communities.

Subsequent meetings held with stakeholders and leaders, community survey interviews and discussions formed 5 key themes in community sentiment for Napranum. These key themes are outlined in Table 9:

Table 9: Key themes of community attitudes

Key Themes	Findings
Current state – energy challenges for Napranum community	Energy costs are high for many people and power cards can run out Power supply experiences regular outages that originate from within Napranum but also from Weipa and the Mining operations Maintenance and repair within the township required personnel to be flown in from other regions increasing time taken to restore supply High cost of energy and outages have cascading effects and disruptions including social and economic costs and health impacts
Future energy supply beyond mining in Weipa	Electricity supply is currently reliant on generation from the RTA mining operation near Weipa Uncertainty of electricity supply beyond mine life
Energy autonomy and ownership of an independent power supply for Napranum	Community owned standalone power supply for Napranum Reduced power costs for households, businesses and Council Ability to operate and maintain infrastructure including opportunities for training, jobs and career paths for locals Reliable power supply to the community Energy education and efficiency program
Development plans and future growth of sustainable industry at Napranum	Responsible use of community land respecting planned future growth and Native Title Constraints Complement existing and emerging commercial and cultural initiatives within Napranum

Sustainability and environmental factors	Access to renewable power sources for government, services, business, and residents is currently not an option Upgrade housing stock to incorporate better more appropriate designs

EnergyConnect has been guided by these findings and has provided a range of feedback mechanisms during the project to illustrate how community ideas have been incorporated into the Feasibility Study.

3.4 Community Awareness over Project Lifecycle

Throughout the Feasibility Study project, the community's awareness of the potential benefits and challenges associated with microgrid technology has increased. This can be attributed to the project team's regular communication and engagement activities, including newsletters, updates, and direct meetings with stakeholders. The consultation conducted to date has facilitated information sharing and raised awareness of the potential benefits of microgrids for the Napranum community. The project team actively sought feedback from the community and stakeholders, encouraging collaboration to determine the most appropriate technical solutions and suitable siting locations for proposed microgrid elements.

The project team engaged with Council members and Infrastructure Team employees, who provided valuable insights on future growth planning and operational aspects of important council infrastructure and assisted with energy audits and site assessments. These in-depth discussions allowed for knowledge sharing between the project team and council officers.

The feedback from the community has been positive, with few imposts resulting from the feasibility project. Individuals who participated in the energy audits or completed surveys volunteered their time and were rewarded with a small thank-you gift in the form of USB chargers used for small devices and Power Card recharges. No negative feedback was received from this or any other part of the project, and the project team welcomed all feedback from the community throughout the project.

4

Social Impact, Benefits and Considerations

4 Social Impact, Benefits and Considerations

4.1 Introduction

An affordable, reliable, sustainable, and modern energy supply is globally recognised as a necessity for sustainable development. It is a key driver towards creating thriving, resilient communities, and elevating people from disadvantage[23]. Improving access to modern energy services for fringe-of-grid and low-socioeconomic groups is essential for achieving favourable outcomes in the areas of employment, health and well-being, education, clean water and sanitation, and sustainable communities[24].

Access to reliable and safe energy allows lighting, security, refrigeration, cooling and heating, and communications. The cost of energy limits community access to these benefits, with resulting impacts to the economic viability and social outcomes of communities[25].

In Australia, the provision of electricity to remote and regional communities is subsidised by government, due to Australia's size and dispersed population. Subsidies have primarily been on cost equity or standalone / supplementary fossil fuelled alternatives in the form of diesel generation, and in more recent times supplemented with small scale renewables, predominantly solar. Despite these efforts the supply of reliable, affordable, and sustainable energy to fringe-of-grid and off-grid communities has not been fully realised.

It is generally accepted by both residents and energy providers, that there are lower service standards for electricity supply (more outages, longer outages) in fringe-of-grid locations. Microgrids can facilitate improved service standards and place these communities on a more level playing field with urban centres.

The social impacts, benefits, and considerations for the Napranum microgrid are strongly linked to the technical and operating decisions of how the microgrid is structured, owned, and delivered. The design, modelling, and planning for the Napranum microgrid has been undertaken with extensive consideration of the operating conditions, policy environment, community capacity, governance capabilities and technology options, with the intent that the solution will provide both technical benefits and social benefits. That is, the approach is to

---

[23] Goers, Rumohr, F., Fendt, S., Gosselin, L., Jannuzzi, G. M., Gomes, R. D. M., Sousa, S. M. S., & Wolvers, R. (2021). The Role of Renewable Energy in Regional Energy Transitions: An Aggregate Qualitative Analysis for the Partner Regions Bavaria, Georgia, Quebec, Sao Paulo, Shandong, Upper Austria, and Western Cape. Sustainability (Basel, Switzerland), 13(1), 76–. https://doi.org/10.3390/su13010076

[24] UN, United Nations Open Working Group proposal for Sustainable Development Goals. New York: United Nations; 2014.

[25] Parag, & Ainspan, M. (2019). Sustainable microgrids: Economic, environmental and social costs and benefits of microgrid deployment. Energy for Sustainable Development, 52, 72–81. https://doi.org/10.1016/j.esd.2019.07.003

deliver more than just a technology solution, the microgrid has been designed to also improve social outcomes for the residents of Napranum.

4.1.1 Additional layers of social disadvantage

Napranum is in the decile 1 ratings for each of the Socio-Economic Indexes for Areas (SEIFA) of: relative disadvantage; advantage and disadvantage; economic resources; and education and occupation, making residents amongst the most disadvantaged in Australia[26].

Napranum and many other fringe-of-grid; off-grid and Indigenous communities experience additional layers of disadvantage and reduced social outcomes when compared to urban centres, due to limited access to affordable, reliable and sustainable energy. Significantly these communities may also be underserviced by commercial, retail and recreation infrastructure, and when power is not available, there are no alternative places to go.

4.1.2 Drivers of residential electricity demand

Drivers of residential electricity demand include[27]:

- Time spent at home.
- Weather and climate.
- Size and thermal efficiency of the home.
- Financial pressure or energy usage patterns.

In considering the drivers of residential electricity demand in Napranum, the unemployment rate is 22.2% compared to 4.6% for Queensland as at the June 2022 quarter[28]. That is, the high level of unemployment means people typically spend more time at home and are more likely to incur higher household electricity expenses associated with heating, cooling, and lighting than households where people go to work.

Houses are primarily single-storey, block construction with between 2 and 4 bedrooms, and range from 30 years old to a few newer houses built in the past 2 years. The current housing design is reasonably consistent across Australia, having been built from standard government plans, which also means across the nation, housing design does not respond to the local climate. Typically, tenants of social housing have little capacity or incentive to install more energy efficient air-conditioners or hot water systems.

---

[26] Queensland Government Statistician's Office https://www.qgso.qld.gov.au/statistics/theme/economy/prices-indexes/seifa-socio-economic-indexes-areas

[27] Queensland Council of Social Services, 2020 Consumer Energy Vulnerability in Queensland Consumer Impacts, Behaviours, Responses and Recovery Priorities. https://www.qcoss.org.au/wp-content/uploads/2020/11/COVID-19-consumer-energy-vulnerability-in-Qld_FINAL.pdf

[28] Australian Government, National Skills Commission, Small Area Labour Markets Australia, various editions

4.1.3 The unfavourable impacts of electricity demand

Time spent at home, as a driver of residential electricity demand is not limited to unemployed, underemployed, or retired people. The unfavourable impacts of residential electricity demand were experienced across Australia during the COVID-19 lockdowns which resulted in noticeably higher residential electricity consumption, associated with the increase in people working from home. The cost of lighting, heating and cooling that is usually borne by the workplace shifted to the household and the change in consumption patterns was significant. Ultimately, the Australian Taxation Office introduced a new shortcut method for claiming work-related tax deductions (from 1 March 2020 until 30 June 2022) of 80 cents per hour for additional household running expenses incurred while working from home. All State Governments also responded with measures that directly support individuals in being able to afford their energy bills.

4.2 Systems Analysis and Leverage Points

The ultimate objective of the microgrid technology is to support and improve the lives of people, however it is a complex and multifaceted challenge.

To better understand the array of impacts, including social and technical elements of the microgrid project, a systems analysis has been undertaken in partnership with the University of the Sunshine Coast. A systems analysis seeks to identify:

- the range of actors involved in the microgrid project and their interactions (Actor Map)
- the interdependent components of the project that are often looked at in isolation (Work Domain Analysis). E.g., infrastructure planning, electrical engineering and design, land acquisition, and end user requirements, technology, regulators etc.

Napranum Microgrid Actor Map

The Actor Map considers the system from a risk management perspective, which comprises various levels (e.g., government, regulators, company, management, staff, and work). It acknowledges that all Actors are co-responsible for efficient, effective and safe operation of the system. Decisions and actions at all levels interact with one another to shape performance, with controls coming from above and feedback from below. The success or degradation of the system is shaped by the decisions of all actors, at all levels, not just behaviours or outcomes of individuals. There are always multiple contributing factors to both success and failure. The Actor Map developed for the Napranum microgrid indeed highlights the complex and interdependent stakeholder relationships and offers unique insights into the opportunities for shared responsibility and is shown in Figure 11.

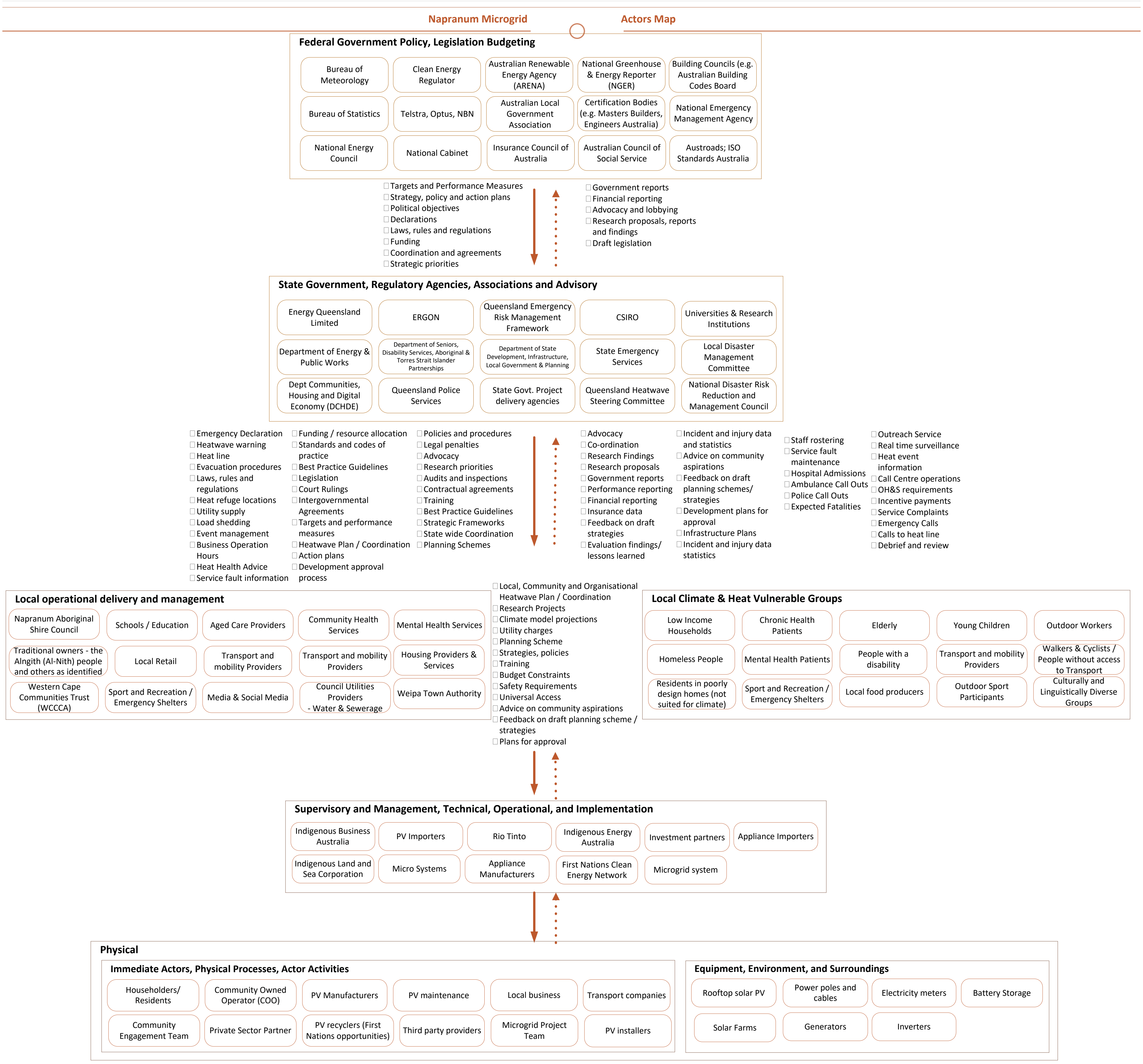


Figure 11: Napranum Microgrid actor map

Microgrid Work Domain Analysis

This system modelling process provides a formative perspective of what *could* happen if the microgrid project is developed, rather than provide normative analyses of what *should* happen[29]. It is a model which links the overall purposes of the microgrid, to priority measures of its success, to the activities that need to be performed, to the resources available to the system. The output provides a model of what activities can be performed, but also how and why they are performed and with what. This modelling reveals interdependencies between the often-subjective aspirations and objective or more technical system elements[30].

It is a holistic approach which brings together all elements into a single model. It is a powerful tool for decision support, as it:

- can be used for the assessment of an existing system or the design of new systems
- creates a visual relationship map of all the components of a complex system and their interdependencies
- allows all stakeholders to see their place and priorities; a shared understanding – limiting silos
- allows for scenario development and prioritisation of strategic policy approaches
- improves policy testing by adding or removing nodes or breaking links and reviewing the implications
- allows for the consideration of issues of system interdependence and complexity.

The online systems model[31] provides a comprehensive view of microgrids, highlighting their context and representing the complexity of delivering reliable and affordable electricity to remote communities in a simple yet not simplistic manner. To analyse the model, we explored the key leverage points within the system, such as fringe-of-grid and off-grid electricity systems, where small changes can have significant impacts on the broader system. These leverage points, or points of power, may not always be intuitive[32].

Figure 12 shows a summary of the leverage associated with Community Resilience and Community Self Determination, two of the seven overall functional purposes of the microgrid system. The level below, priority measures of success, outlines ten ways to

---

[29] Stevens, N. J., Salmon, P. M., & Taylor, N. (2018). Work Domain Analysis applications in urban planning: active transport infrastructure and urban corridors. In N. Stanton, P. M. Salmon, G. Walker, & D. P. Jenkins (Eds.), Cognitive Work Analysis: Applications. CRC Press

[30] Meadows, D. (1999). Leverage points: Places to intervene in a system. Hartland, WI: The Sustainability Institute.

[31] EnergyConnect website

[32] Fazey, I., Schäpke, N., Caniglia, G., Patterson, J., Hultman, J., van Mierlo, B., … Wyborn, C. (2018). Ten essentials for action-oriented and climate change research. Energ Research & Social Science, 40, 54-70

measure the achievement of these purposes, including reducing social disadvantage, improving community health, enhancing household resilience, and establishing community governance models, among others.

The middle level of the model, necessary system activities, represents the critical link between the top two levels and the bottom two levels. These activities must be performed to achieve the system's functional purposes, which are Community Resilience and Community Self Determination in this case. The model identifies that these purposes can only be achieved through employment opportunities, energy affordability, support for domestic activities, efficient transport and mobility, and reduced power outages.

The middle level is essential to the system's operation and success, as it links the priority measures to the system processes and resources. The means-ends relationships demonstrate that the system processes and resources at the bottom two levels support the system's purpose, while the priority measures explain why the system activities are necessary. By identifying the necessary inputs across all five levels of the microgrid model, we can work with the complexity of the opportunity and articulate the significant social, health, and community benefits that the scheme could provide for Napranum.

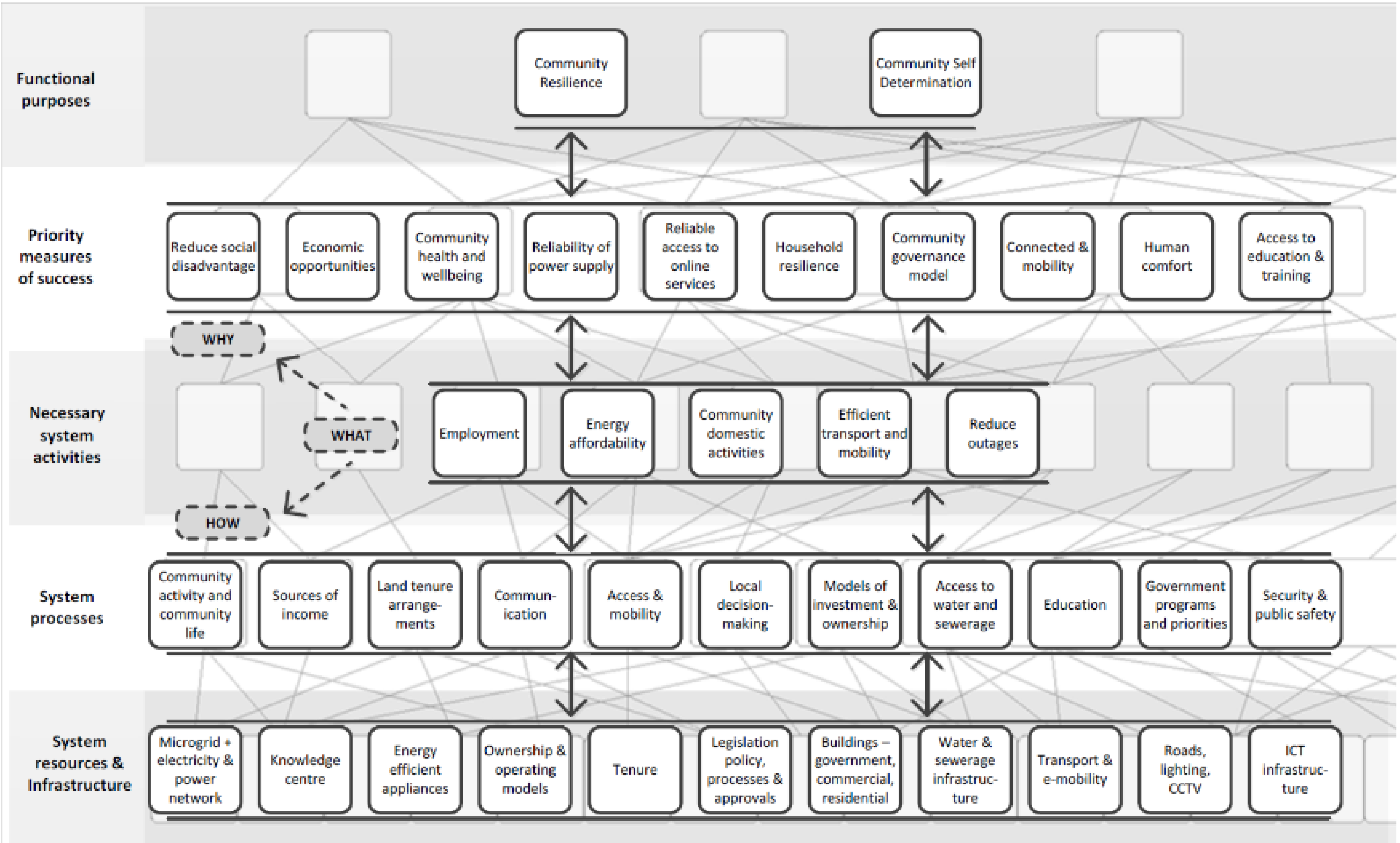


Figure 12: The relationship between community resilience and self-determination, and the microgrid

From a systems perspective, people are assets in the system and technology is a tool to assist. This approach allows for analysis of the role of the microgrid in contributing to a range of outcomes including Community Resilience and Community Self Determination.

Community resilience and self-determination can be measured in different ways. The provision of affordable and reliable electricity supplied by the microgrid reduces social disadvantage.

The microgrid has potential to generate direct jobs through the installation and maintenance of the technology, and a reliable energy supply is also an element of incubating new businesses.

Ultimately, the microgrid provides energy affordability and energy reliability, which in turn allows households to undertake everyday activities from cooking, cleaning, and running the refrigerator, to cooling the home (fans or air-conditioners).

4.3 Social Benefits of the Microgrid

The primary social benefits associated with the Napranum microgrid are discussed in the sections below, and these sections include recommendations for baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations.

4.3.1 Reducing Household Debt

Elevated levels of unemployment and the higher number of persons per household 3.7 compared with 2.7 for Queensland[33], results in increased energy consumption and consequently high electricity costs for many households in Napranum. As discussed in section 2.5 of this report, the average energy consumption (8,819kWh) is approximately 1.58 times the regional Queensland average (5,588kWh).

While electricity consumption is high, the electricity is pre-paid using rechargeable meter cards, and is more likely to be paid than other bills as the consequences of not having electricity outweigh other aspects. The price of paying for electricity is essentially accounted for by going without in other areas.

The microgrid has been structured to:

- raise public awareness of energy efficiency and fostering incentives for energy saving
- incentivise energy efficiency, providing benefits directly to individuals and the community.

[33] www.abs.gov.au/census/find-census-data/quickstats/2021/3

The use of behind-the-meter distributed energy resources as part of the microgrid solution will reduce the amount of energy households purchase from EER and can potentially reduce the cost per unit of energy produced.

The benefits of behind-the-meter solutions on electricity bills for low-income communities with higher unemployment and overcrowding are more significant than in more affluent communities[34]. Furthermore, the behind-the-meter solutions increase household awareness of energy costs and savings and the reward for being energy conscious has flow-on benefits where household behaviour change can easily be observed through cost savings on a week-to-week basis. This type of economic signal (efficiency values created within a microgrid) are a strong driving force for acceptance and promotion of microgrids.[35]

The Napranum microgrid has been designed to consider the local consumer benefit (i.e. end consumer perspective).

4.3.2 Resilience

> Resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.[36]

Resiliency benefits are mainly the ability of the microgrid to maintain system reliability and security during extreme events affecting the upstream network, especially to low-income residential customers with little to no ability to mitigate extreme-event risks.

Electricity supply for Napranum is generated by RTA at its Weipa power station and then distributed to the boundary of Napranum via RTA's powerlines. EQL then distributes the power within the community and manages all electricity retailing functions for Napranum residents and businesses.

Power to Napranum town may be cut off for several reasons including planned and unplanned maintenance at the power station or on the distribution networks; motor vehicle

[34] Dodd, T., Nelson, T., Australian household adoption of solar photovoltaics: A comparative study of hardship and non-hardship customers, Energy Policy, Volume 160, 2022, https://doi.org/10.1016/j.enpol.2021.112674.

[35] Perez-DeLaMora, Quiroz-Ibarra, J. E., Fernandez-Anaya, G., & Hernandez-Martinez, E. (2021). Roadmap on community-based microgrids deployment: An extensive review. Energy Reports, 7, 2883–2898. https://doi.org/10.1016/j.egyr.2021.05.013

[36] National Infrastructure Advisory Council (US), 2009. Critical infrastructure resilience: Final report and recommendations. National Infrastructure Advisory Council.

accidents involving power poles; wildlife impacts; debris on powerlines; storms and natural disasters including cyclones and bushfires.

During a normal year it is typical for Napranum to experience outages lasting for as little as 1-2 hours or more due to generation system interruptions; up to 6-8 hours for scheduled maintenance; and power can be interrupted for more than 24 hours for local network faults as EQL maintenance crews are remotely based and must fly into the community or drive long distances (>800km) to undertake repairs.

Leapfrogging to local renewable energy via microgrids is a cost-effective route to achieving energy security and improved resilience on a day-to-day basis as well as in response to natural disasters.[37]

Baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations include:

- Change in the duration of power outages.
- Change in the number of power outages.

4.3.3 Employment Opportunities

A range of potential employment opportunities arising from the development and implementation of the microgrid have been identified and discussed in Section 11 of this report. These include employment associated with program and project management, construction, operation, and maintenance of the microgrid.

Further analysis is necessary based on the preferred implementation model to identify and quantify specific roles. However, it is envisaged that a dedicated program office initially established within NASC would require a Program Director and Program Support Officer during the implementation phase, and two Operations Officers for the life of the microgrid.

Other opportunities are expected to arise during the construction of the microgrid.

In a community where most jobs are in health services, mining or roadworks, new jobs, in a new field is a substantial offering.

Furthermore, the proposed ownership model facilitates self-determination outcomes and provides opportunities for project administration and contract management roles.

Finally, employment opportunities occur from the simple ability of local businesses to establish and operate locally, through the confidence of reliable service.

A list of potential, direct and indirect employment opportunities are summarised in Table 10.

[37] Batinge, Musango, J. K., & Brent, A. C. (2017). Leapfrogging to renewable energy: The opportunity for unmet electricity markets. South African Journal of Industrial Engineering, 28(4), 32–49. https://doi.org/10.7166/28-4-1702

Table 10: Employment opportunities from microgrid implementation

Microgrid Strategy Element	Employment Opportunity
Microgrid implementation and operation	Opportunities for a team to manage the project and its operations.
Construction, operation and maintenance	Opportunities for direct employment to undertake microgrid works and maintenance.
Energy related skill development	Opportunities for creating career paths through upskilling and training community members in energy related skills including operation and maintenance of microgrid components or energy auditing and energy-efficiency education programs.
Local business stimulation	Opportunities for local businesses to increase their service provision and in turn their number of employees.

Baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations include:

- Change in employment numbers.
- Change in the number of businesses established and operating.

4.3.4 Health

There are significant health impacts associated with current conditions at Napranum due to the cost of energy and irregular and sustained outages.

Power outages affect the local health care services including tele-health and clinical; child and maternal health; social and emotional; and school attendance strategy services. When the electricity fails, electric wheelchairs do not charge and electric hoists and electric adjustable beds and pressure care mattresses used in homes, hospitals, clinics, and nursing homes do not work, making health and hygiene care difficult.

Power outages have implications for patients, staff, costs of services and one of the many flow-on effects is that while there may be a backup generator, staff are required to leave work to pick up young family members from day-care or school to supervise / care for them during work hours when the day-care or school is without power.

Power outages also affect access to critical services such as Centrelink, banking, pharmacy, and medical clinics. Locally operated, renewable energy generation would significantly reduce the risk of power outages associated with natural disasters and would reduce the time taken to restore power to the community.

In addition, current house design has health impacts. Houses not designed 'fit for the tropics' which allow for flow through ventilation, large windows, covered eaves and outdoor living spaces mean that houses are unliveable without air-conditioning. The cost of installing and running air-conditioners adds to the financial burden of low-income families.

Cooking in social houses runs on electricity (rather than gas). When the power goes out, there is no easy means of preparing meals. There are no alternatives such as being able to order takeaway, eat out or go to the local shopping centre. The flow on effects includes poor nutritional options or no meal at all.

Baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations include:

- Change in the number of days that health care services are closed.
- Change in the number of days Centrelink is closed.
- Change in household and commercial electricity bills.

4.3.5 Education

Improved energy reliability has positive education outcomes. Community feedback reported flow on impacts of school and day care closures caused by power outages of any significant period. These impacts included parents having to leave work to pick up children and it is acknowledged that some students don't go back to school for days even after the power is restored. This affects attendance rates and impacts on truancy programs.

Impacts of the enhanced energy reliability offered through this project would include more consistent engagement with school staff and support services - building relationships, trust and knowledge shared leading to better overall educational outcomes. It confirms messaging regarding benefits of regular attendance; access to air-conditioned learning environments with reliable internet for exposure to extensive on-line resources; and to curriculum messaging regarding renewable energy and energy efficiency programs as well as health and social behaviour messaging. An example of the impacts of power outages is provided below.

Example 1: When the power goes out, schools and day care centres close, which typically results in high levels of truancy in the following days. At the same time, the impacts of school closures and day care closures have flow-on effects to those with jobs, as when the power is off for any significant period people must leave work to pick up students and supervise / care for them during work hours.

A reliable power supply results in reduced truancy numbers and improved education outcomes through more consistent engagement with teachers and support services - building relationships, trust, and knowledge. Educational outcomes are also improved through access to an air-conditioned learning environment with reliable internet for access to the curriculum and resources.

Baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations include:

- Change in the number of days that education services are closed.
- Change in truancy numbers.

4.3.6 Environment

At the global level, both technology transfer and capacity building have been included in the Kyoto Protocol[38] and the Paris Agreement[39] as important mechanisms to support sustainable development while working to mitigate climate change.

At the national and regional level environmental benefits include:

- Reduced greenhouse gas emissions by using renewables instead of utilising power generated from fossil fuels and non-renewable sources.
- Reduced distribution and transmission losses from traditional supply methods.

At the community and household level renewable energy is locally supplied energy and is visible to the community. There is a high level of acceptance of microgrid technology due to the development of the Weipa RTA solar farms, the extent of engagement during the feasibility study, and the potential for household cost savings. The community understands the potential social and economic benefits which is reflected in their acceptance of green infrastructure.

Baseline data that can be measured post implementation of the microgrid to demonstrate the social impacts, benefits and considerations include:

- Change in awareness of climate change measured in schools and households.
- Change in behaviour towards energy efficiency – measured by household and commercial electricity bills.

4.4 Drivers for Change

The impact of power outages at fringe-of-grid and remote communities is disproportionate due to the lack of alternative services and amenities.

A reliable and affordable electricity supply removes multiple levels of disadvantage for remote communities like Napranum by:

- relieving cost of living pressures

---

38 United Nations Framework Convention on Climate Change. What is the Kyoto Protocol? ttps://unfccc.int/kyoto_protocol

39 United Nations Framework Convention on Climate Change. The Paris Agreement, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

- providing more reliable access to on-line services including banking, tele-health services, on-line training opportunities
- improving health and education outcomes – access to local medical services that require reliable power such as dialysis treatment, hot water for bathing, air-conditioning, and providing a safe and comfortable environment for children to learn
- supporting reliable communications networks by providing enhanced access to computer networks, data services, mobile phone services
- ensuring that safe and reliable water and wastewater processing services are available for the community.

5

Existing Electricity Supply Arrangements

5 Existing Electricity Supply Arrangements

5.1 Current Generation and Distribution System

Napranum has reticulated electricity supply which is sourced from the RTA Weipa mine electricity system. RTA generates power for its bauxite mines at Weipa and Andoom, Weipa ship-loading facilities, mine railway network, and port facilities and provides electricity for Weipa town (commercial and residential installations), and Weipa airport.

EEN is responsible for the local distribution network at Napranum and takes supply from the RTA 11kV East Weipa Boreline feeder at the boundary of Napranum township.

EER is the local electricity retailer for Napranum residents and businesses. EER purchases electricity from RTA with energy usage measured at a high voltage (11kV) metering installation adjacent to the Napranum connection point.

A schematic diagram of the Weipa-Napranum network configuration is shown in Figure 13. Figure 14 identifies the location of the 11kV distribution network within Napranum community and Figure 15 shows the route of the RTA network from Weipa Power Station to Napranum.

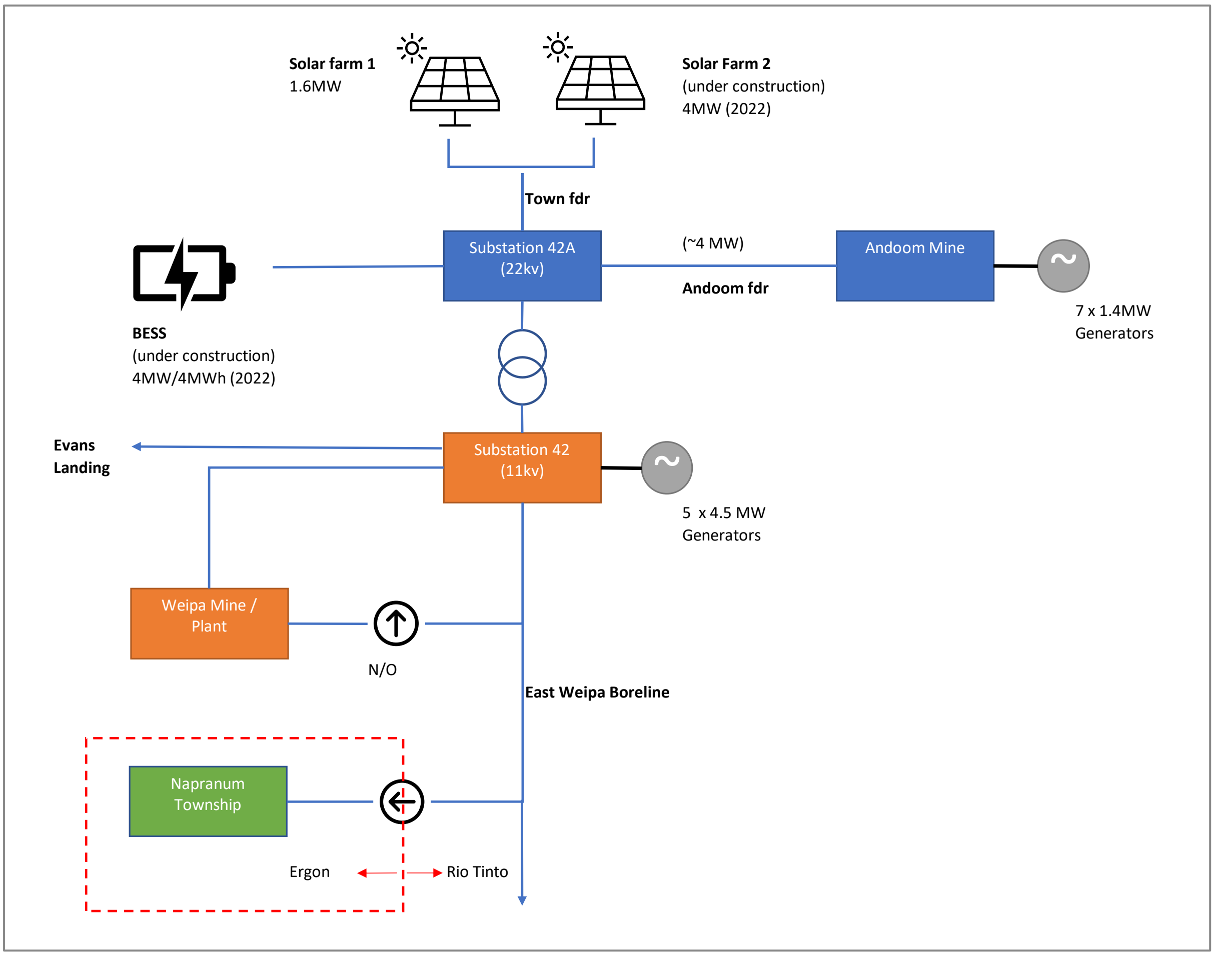


Figure 13: Weipa-Napranum network schematic

The local Napranum electricity network consists of approximately 1.5km of overhead 11kV powerlines, nine pole-mounted distribution transformers ranging in size from 100kVA to 315kVA and associated low voltage reticulation.

There is an Automatic Circuit Recloser (ACR) installed near the RTA connection point.

Figure 14: Napranum 11kV distribution network

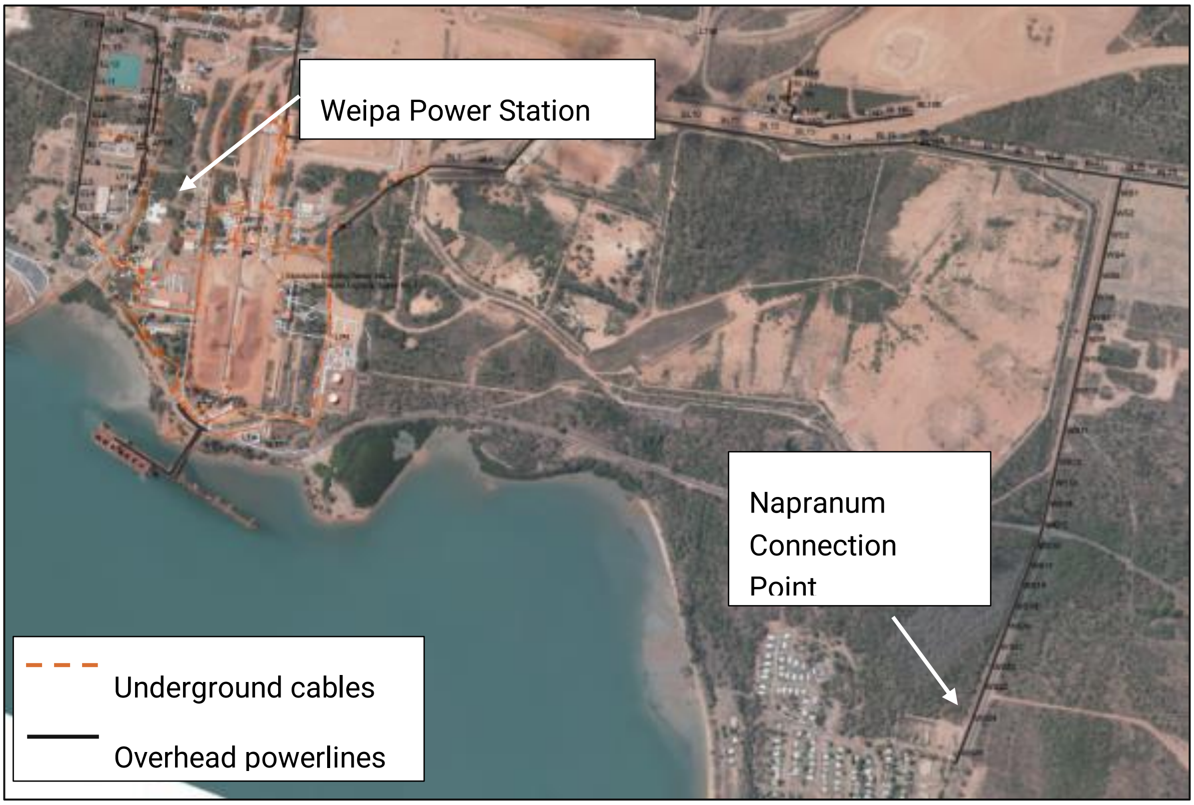


Figure 15: 11kV Network from Weipa power station to Napranum

RTA Weipa has a local workforce of linesmen and technicians that services the Weipa electricity distribution and generation assets but does not provide network services in Napranum.

EQL currently does not maintain a local workforce in the Weipa / Napranum area. Operation and maintenance of the Napranum distribution network is usually undertaken by work crews based at the Mareeba or Cairns depots, approximately 800km by road to the south-east. Charter flights are utilised for emergency response activities. Road access can be impacted by flooding and road closures during the wet season.

EQL operates 33 Remote and Isolated power stations and associated networks located in western Queensland, the Gulf of Carpentaria, Cape York Peninsula, Mornington Island, Palm Island and Torres Strait Islands. Napranum is located on the northwest coast of Cape York Peninsula as shown in Figure 16. EQL does not currently own or operate any power generation assets at Napranum.

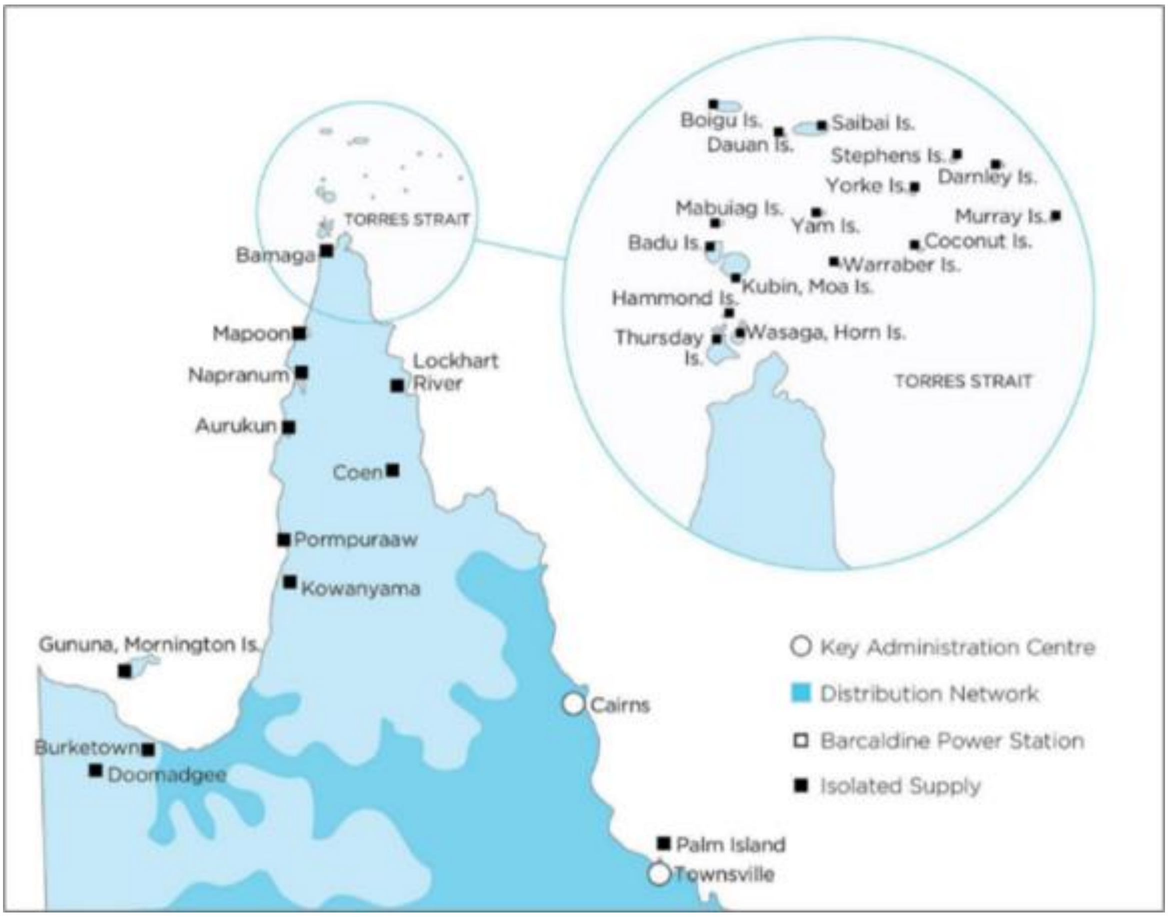


Figure 16: EQL Isolated Power Systems - Far North Queensland

5.2 Community Energy Requirements

5.2.1 Historical and Forecast Demand and Load Profile

The existing load profile for Napranum was derived from 30-minute interval data supplied by EQL extracted from the high voltage (11kV) metering installation at pole WS.25 at Napranum.

Example load profiles for winter and summer months are shown in Figure 17 and Figure 18 below.

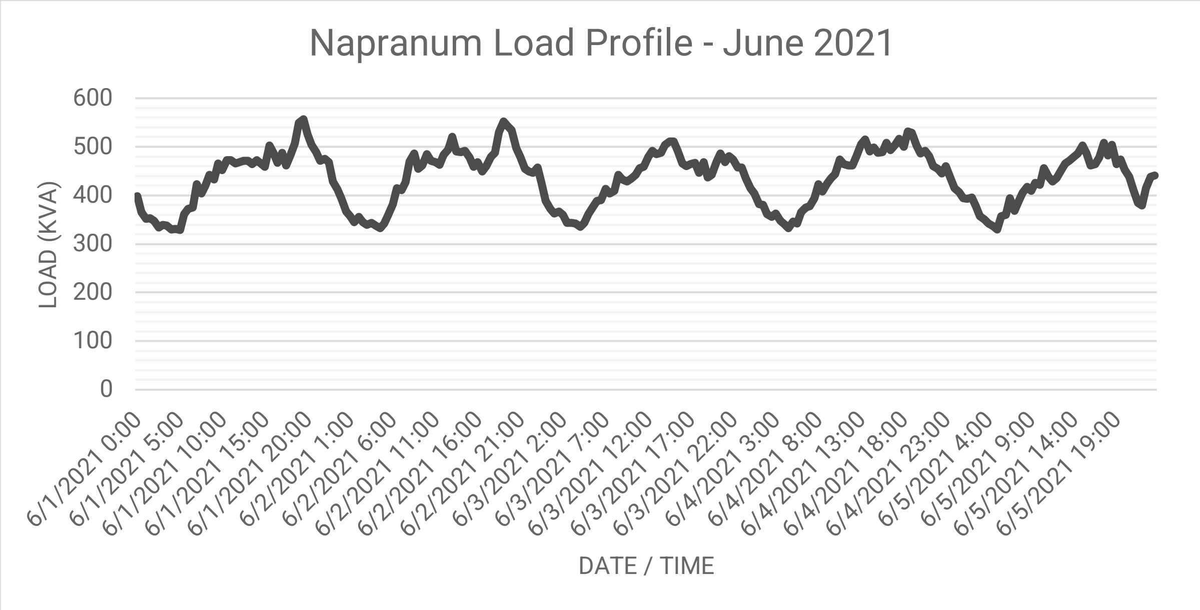


Figure 17: Time series load data for Napranum for 1st-5th June 2021 (sample winter profile)

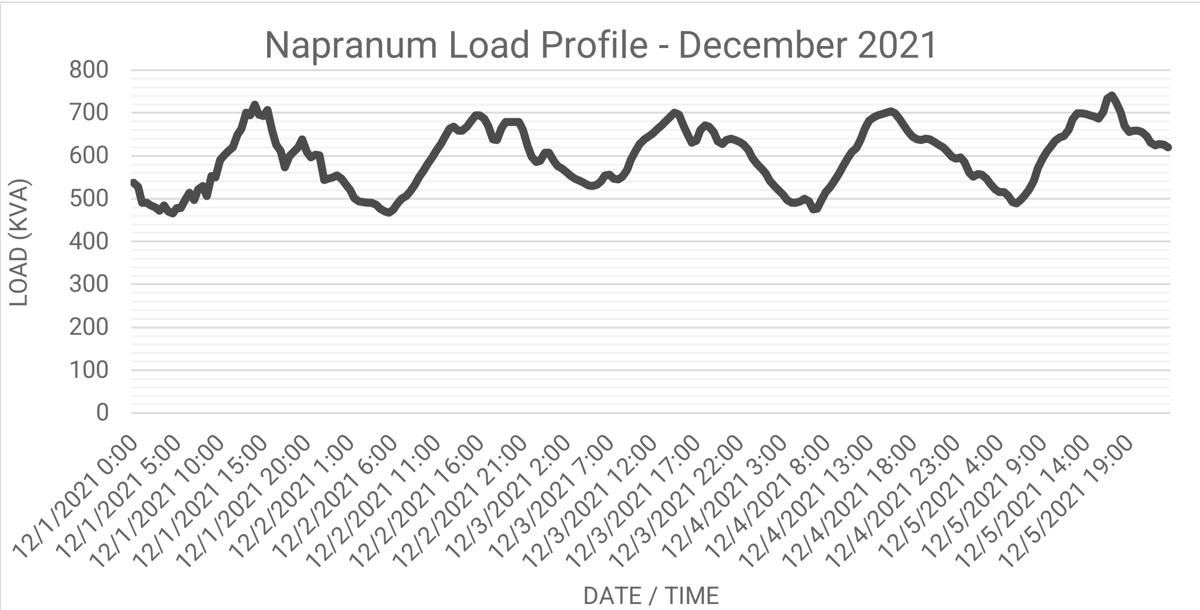


Figure 18: Time series load data for Napranum for 1st-5th December 2021 (sample summer profile)

During the sample winter period (1/6/2021 to 5/6/2021), the load ranged between approximately 329kVA and 556kVA, whilst the load ranged between 465kVA and 741kVA during the sample summer period (1/12/2021 to 5/12/2021).

The peak load recorded at Napranum was 872kVA which occurred at 13:30 on 31/10/2020, when load was restored immediately following a 20-hour outage of the entire community. The outage occurred between 4:30pm on 30/10/2020 and 12:30pm on 31/10/2020. The load profile for the outage scenario is shown in Figure 19 below.

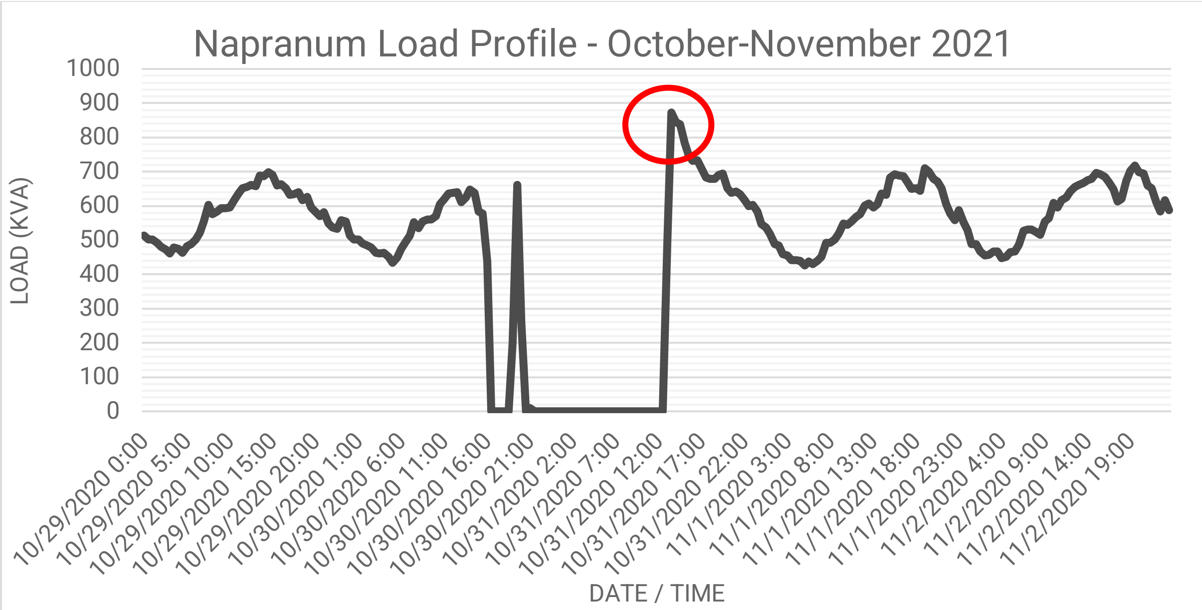


Figure 19: Time series load data for Napranum for 29th October - 2nd November 2020 (community outage condition)

Pump motor, refrigeration, and air-conditioner re-starts following the extended outage are the likely contributors to the peak load recorded.

The use of household air-conditioners during summer months has contributed to peak load whilst the daily load patterns reflect the absence of rooftop solar PV systems at Napranum.

Load profile data for all months (2021) is provided in Appendix B.

5.2.2 Water and Sewerage

Napranum water supply is sourced from two bore pumps located within the council depot site. Water is treated on site and pumped into a storage reservoir also located at the council depot site. At the time of writing council was installing a second reservoir adjacent to the existing tank to boost water storage capacity.

2021 annual energy consumption for the water pumping and treatment plant was approximately 210,000 kWh.

Key equipment installed consists of:

- 2 x 9.2kW bore pumps
- 2 x 3kW lift pumps (clarifier)
- 5 x 4kW pressure pumps (constant pressure pumps)
- Ancillary equipment for chlorination

A 50kVA standby generator is connected to the water supply system switchboard for emergency backup.

Refer to Figure 20, Figure 21, and Figure 22 for photos of the existing water pumps and storage facilities at Napranum.

Figure 20: NASC water supply bore pump

Figure 21: NASC water supply pressure pumps

Figure 22: NASC water reservoir, pump shed and chlorination plant

There are 3 sewerage pumping stations at Napranum which pump wastewater to settling ponds located outside the Napranum town area.

Each sewerage pumping station has a dedicated standby generator for emergency backup in the event of a power supply interruption. A typical pump station layout is shown in Figure 23 below.

Figure 23: NASC sewerage pump station number 3 with standby generator

5.2.3 Telecommunications

Napranum has access to a reliable telephone communications network including Telstra 4G mobile phone network (Figure 24) and NBN Satellite services (Figure 25).

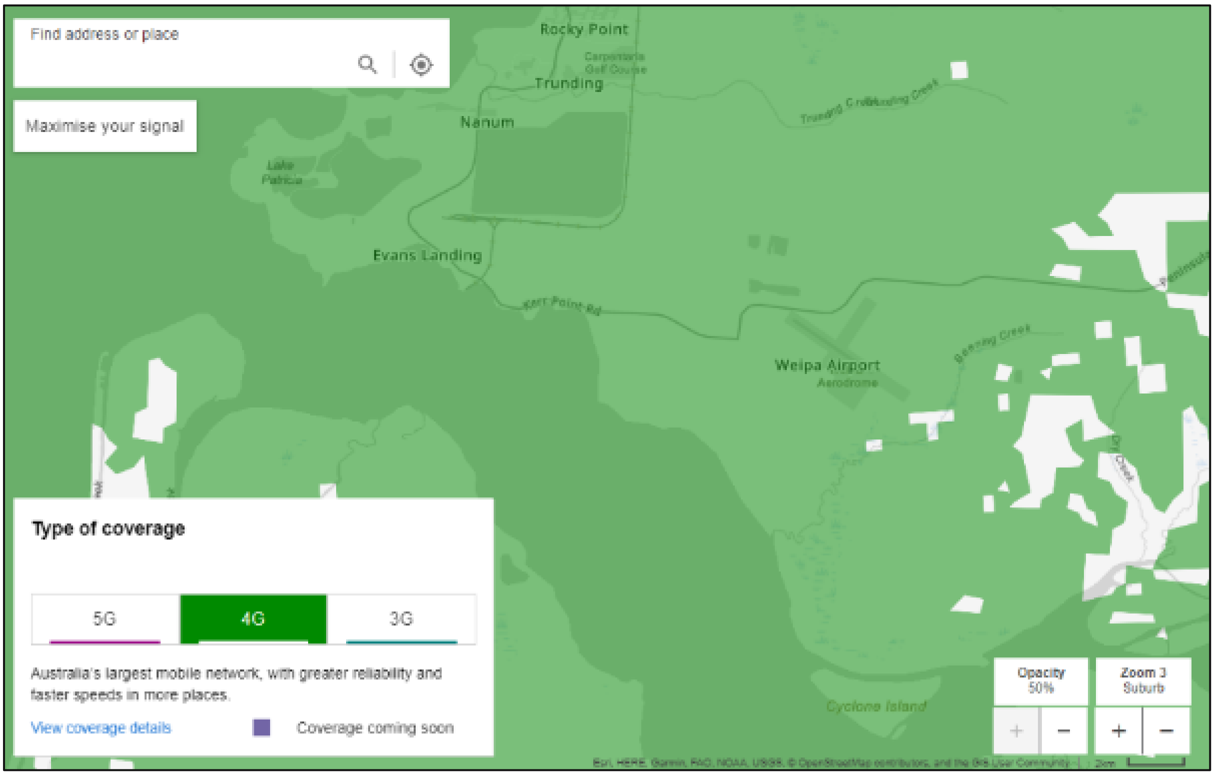


Figure 24: Telstra 4G network coverage map – Napranum

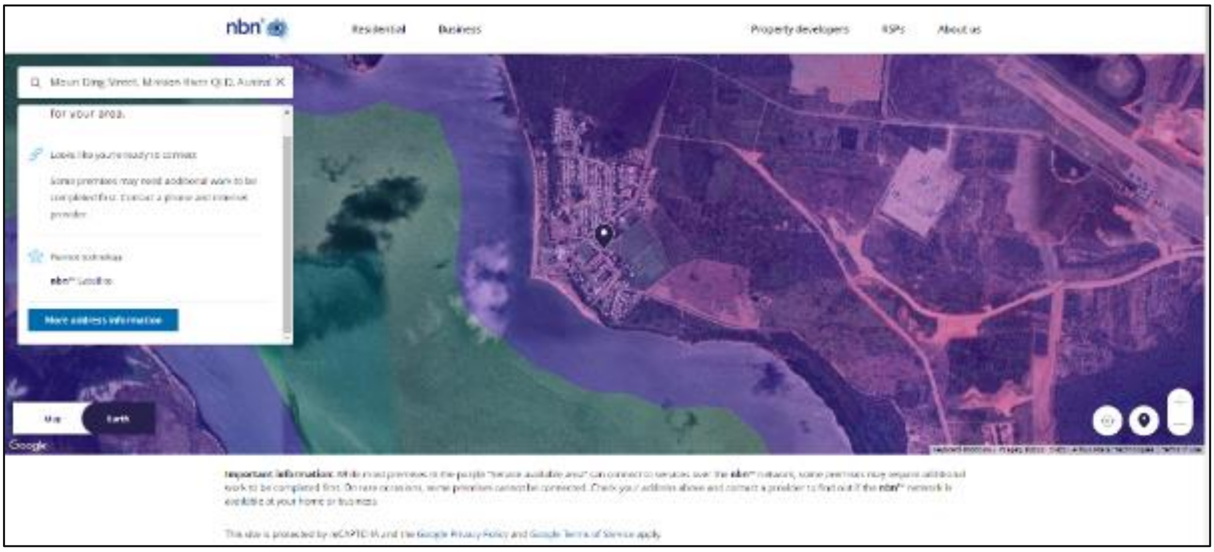


Figure 25: NBN Satellite service map – Napranum

5.2.4 Transport

The road network within Napranum consists mainly of bitumen sealed roads that are in good condition. The road network connects to the Weipa town road network and links to the Weipa airport via bitumen sealed roads.

Access to the Weipa / Napranum area by road is via the Peninsula Development Road (PDR) which extends 571km between Lakeland and Weipa. This road is progressively being sealed with a 5-year upgrading program recently completed, leaving approximately 200km unsealed. This is the only route available for road freight services to Weipa and Napranum. A map showing the general route of the PDR is provided in Figure 26.

There are regular daily commercial air services operating between Cairns and Weipa.

Freight is also carried via sea from Cairns to Weipa by SeaSwift. This is a weekly service currently departing Cairns on Fridays and arriving at Weipa on Mondays. i.e., a 3 to 4-day trip via Torres Strait.

Figure 26: Peninsula Developmental Road[40]

[40] Wikipedia 2023, https://en.wikipedia.org/wiki/Peninsula_Developmental_Road

5.2.5 Waste Processing

All domestic waste from Napranum is collected from a central waste collection site by Weipa-based waste management contractors and taken to the RTA Weipa landfill site for processing and disposal. There does not appear to be adequate quantities of suitable organic waste that could be utilised for power generation at Napranum. The Napranum waste collection site is shown in Figure 27 below.

Figure 27: Napranum waste disposal site

5.2.6 Agriculture

Napranum does not currently produce fresh fruit and vegetables locally and relies on importing its food resources via the local IBIS Supermarket (Napranum) and Woolworths (Weipa). The cost of transporting perishable food to the region can be very high and there are significant logistical considerations that can impact the reliability of food delivery services.

Food security for remote communities like Napranum is a significant issue, and the community is working with government agencies to explore opportunities to build resilience in its food supply chain which can also contribute to a healthier community.

The local farm/orchard that had been abandoned for some time is currently being revitalised. This farm is located adjacent to a potential microgrid development site. Ready access to reliable power for irrigation and refrigeration of fresh food and vegetables is essential and this could be provided via renewable energy resources proposed for inclusion in the Napranum microgrid.

There is potential for the microgrid to be a catalyst for more intensive energy-efficient farming practices at Napranum including hydroponics or aquaponics.

5.3 Power Supply Reliability

A key consideration for the development of a microgrid at Napranum is the desire of the local community to have a more reliable power supply.

Power supply interruptions at Napranum can result from planned and unplanned outages affecting the RTA generators at Weipa, the Weipa distribution network or the local EEN distribution network.

As mentioned elsewhere in this report, RTA has no authority to repair faults within the Napranum distribution network. In the event of a fault at Napranum, RTA will isolate the Napranum network from its distribution network to ensure the community's safety, and EEN will send staff from Mareeba or Cairns to repair and reinstate supply. This can result in extended outages to the Napranum community.

Additionally, in the event of a fault within the RTA power station or distribution network, RTA's priority is to restore supply to its mining operations and critical equipment before restoring power to local residents and the Napranum community.

The number of outages recorded[41] for calendar years 2020 and 2021 are summarised in Table 11 and Table 12 by Category of Forced, Planned or Unplanned.

Table 11: 2020 Napranum outage summary by category

2020	Single customer	Multi customer	Whole Community	Total Number	Customer Minutes
FORCED	0	1	0	1	1,870
PLANNED	0	1	0	1	20
UNPLANNED	8	1	11	20	742,032
Grand Total	**8**	**3**	**11**	**22**	**743,922**

Table 12: 2021 Napranum outage summary by category

2021	Single customer	Multi customer	Whole Community	Total Number	Customer Minutes
FORCED	1	1	0	2	540
PLANNED	12	1	1	14	92,161

[41] Outage data provided by Ergon Energy in Appendix A

UNPLANNED	8	6	6	20	496,154
Grand Total	**21**	**8**	**7**	**36**	**588,855**

5.3.1 Unplanned Outages

There were 20 sustained, unplanned faults affecting Napranum recorded for the 2020 calendar year and the same number of unplanned faults recorded for the 2021 calendar year. However, the number of unplanned outages impacting the whole community reduced from 11 in 2020 to 6 in 2021.

There were 14 planned outages in 2021 compared to 1 in 2020 and this was due to planned maintenance activities performed on the network.

Table 13: 2020 Napranum outage summary by outage cause

2020			
Outage Cause	No. of Outages	Sum of Customer Minutes	Percentage of customer minutes
Animal impact	1	101,604	13.7%
Generation failure (RTA Weipa Power Station)	6	189,193	25.5%
LV-Unassisted failure (apparent defect)	1	312,580	42.1%
RTA Weipa network fault	3	90,588	12.2%
Overload	2	2,655	0.4%
Service Asset Fault	5	43,946	5.9%
Severe Weather	2	1,466	0.2%
Grand Total	**20**	**742,032**	**100%**

Table 13 and

2021			
Outage Cause	No. of Outages	Sum of Customer Minutes	Percentage of customer minutes
Customer Installation Fault	2	80,698	16.3%

Fire (External)	1	13,640	2.7%
Generation failure (RTA Weipa Power Station)	2	30,672	6.2%
Lightning	10	61,005	12.3%
Service Fuse Blown	1	292	0.1%
Severe Weather	2	230,112	46.4%
Trip & Manual Reclose – 15 Mins or more No Trigger Found	1	36,086	7.3%
Vibration	1	43,649	8.8%
Grand Total	**20**	**496,154**	**100%**

summarise the number and percentage of faults by fault cause (unplanned outages), along with the total customer-minutes off-supply for each calendar year.

In 2020, local network failures (i.e., within Napranum town area) accounted for 48% of total customer-minutes off-supply whereas failure of the upstream RTA Weipa network or power station accounted for 37.7% of total customer-minutes off-supply. Wildlife contact with overhead powerlines accounted for 13.7% of total customer minutes off supply due to a single incident.

In 2021, the major cause of outages at Napranum was severe weather conditions and lightning strikes, which accounted for 56.7% of all customer minutes off supply.

Table 14: 2021 Napranum outage summary by outage cause

2021			
Outage Cause	No. of Outages	Sum of Customer Minutes	Percentage of customer minutes
Customer Installation Fault	2	80,698	16.3%
Fire (External)	1	13,640	2.7%
Generation failure (RTA Weipa Power Station)	2	30,672	6.2%
Lightning	10	61,005	12.3%
Service Fuse Blown	1	292	0.1%
Severe Weather	2	230,112	46.4%

Trip & Manual Reclose – 15 Mins or more No Trigger Found	1	36,086	7.3%
Vibration	1	43,649	8.8%
Grand Total	**20**	**496,154**	**100%**

Total unplanned customer interruptions in 2021 was 496,154 minutes compared with 742,032 minutes in 2020, a reduction of 33.1%. Two RTA Weipa Generation failures accounted for 30,672 customer minutes off supply (6.2% of total) compared with 6 occurrences in 2020, totalling 189,193 minutes off supply.

5.3.2 Planned outages

Table 15 and Table 16 summarise customer-minutes off-supply for planned outages for each of calendar years 2020 and 2021 by Outage Cause.

Table 15: 2020 Napranum outage summary - planned outages by cause

Outage Cause	Single Customer (minutes)	Multiple Customers (minutes)	Whole Community (minutes)	Grand Total (minutes)
Coordinated Maintenance lines & substations	-	20	-	20
Grand Total	**-**	**20**	**-**	**20**

Table 16: 2021 Napranum outage summary - planned outages by cause

Outage Cause	Single Customer (minutes)	Multiple Customers (minutes)	Whole Community (minutes)	Grand Total (minutes)
EEN-initiated line works	270	-	-	270
Defect remediation (Planned)	-	3,740	88,151	91,891
Grand Total	**270**	**3,740**	**88,151**	**92,161**

During 2020 planned outages accounted for only 20 minutes off-supply, whereas in 2021 more than 92,000 customer minutes were accrued to planned outages associated with defect remediation works by EEN following the routine asset inspection cycles for Napranum.

The top 3 outages affecting the whole Napranum community over the 2-year period (2020 and 2021 calendar years) were as follows:

Table 17: Top 3 Napranum outages for 2020 & 2021

Date	Duration (hours)	Cause	Category
30/10/2020	21.73	LV – unassisted failure (apparent defect)	Unplanned
31/7/2020	6.51	Animal impact	Unplanned
24/10/2021	5.72	Defect remediation	Planned

The implementation of the microgrid at Napranum will ameliorate the impact of outages on the RTA network and Weipa power station. However, Napranum residents will remain exposed to outages affecting the local EEN distribution network.

This study has not investigated opportunities to improve the reliability of the local distribution network or EEN operational arrangements for responding to faults at Napranum.

5.4 Electricity Retailers, Metering and Tariffs

EER purchases electricity from RTA, metered at the 11Kv metering unit installed at the boundary of Napranum, and on-sells to local residents and businesses.

RTA sets the price that EER is required to pay, and the rate is regularly reviewed and updated.

As customers of EER, Napranum residents have access to government-regulated retail tariff charges which apply throughout regional Queensland. Whilst Weipa residents are not EER customers, RTA has adopted a policy of applying the standard government-set residential energy charges at Weipa to maintain equity with other regional Queenslanders.

Card Operated Meters (COMs) are standard for all residential installations at Napranum.

Customers can access the following EER tariffs[42] via COMs:

- Tariff 11 – residential general supply
- Tariff 31/33 – economy/off-peak tariffs
- Tariff 20 – small business <100MWh per annum

[42] Refer Ergon Energy Retail web site for further electricity tariff options Tariffs and Prices - Residential - Ergon Energy

COMs may also be configured to accommodate measurement of exported energy from rooftop solar systems however a manual process is required to manage payment of accrued Solar Feed-in Tariff credit. There are currently no rooftop solar PV systems installed at residences at Napranum.

Residents can purchase credit for their meter cards at local retail outlets at Napranum and Weipa. Details regarding COMs and power cards can be obtained from the Ergon Energy website[43].

Data provided by EER (November 2021) indicates there were 304 customer premises at Napranum, including 254 that had COMs. Only 37 (less than 15%) of the COMs had a secondary tariff connected (i.e., they have an economy tariff in addition to the general supply tariff).

Standard metering is installed for large customer installations such as Council depot and offices, health and aged care facilities and the grocery store.

Queensland Government electricity rebates are available to eligible Napranum households with a COM. Rebates are made quarterly in July, October, January and April of each year when the “linked” meter card is presented for recharging.

There is an opportunity to enhance the level of energy literacy within the Napranum community via targeted education programs. Increased awareness of electricity tariffs may also lead to increasing the uptake of economy / off-peak tariffs.

[43] https://www.ergon.com.au/retail/residential/billing-and-payments/card-operated-meter-customers

6

Energy Policy and Regulatory Environment

6 Energy Policy and Regulatory Environment

6.1 Current State of Play

RTA Weipa services electricity customers in Weipa (both as a network operator and retailer) and holds a Special Approval under the Electricity Act (QLD) authorising the entity to provide Generation, Distribution and Supply services. RTA Weipa is also a Prescribed Entity under the Queensland Electrical Safety Act and Regulations.

The Australian Energy Regulator (AER) has granted RTA Weipa a Retailer Exemption from National Energy Retail Law and they do not receive subsidies or Community Service Obligation (CSO) payments from the Queensland Government and are not bound by standard retail tariffs determined by the Queensland Competition Authority. However, RTA has adopted standard domestic tariff rates set by the Qld Government for residential installations in Weipa township to ensure consistency with tariff rates applied in other regional Queensland locations, including Napranum.

Electricity customers in Napranum are serviced by Ergon Retail, which buys the electricity from RTA. Ergon Network owns and operates the Napranum network. Historically, Napranum has been classified as a Remote and Isolated community (not physically connected to the National Electricity Grid) and falls outside the regulatory jurisdiction of the AER.

Thus, the Queensland Government and the Queensland Competition Authority (QCA) have to-date provided the regulatory framework for the Remote and Isolated communities by enforcing customer protections under the Queensland Electricity Distribution Network Code and derogations to the National Energy Customer Framework (safety, reliability, customer service standards and economic performance for these networks).

In line with the Queensland Government's Uniform Tariff Policy, a Community Service Obligation (CSO) payment is provided to EQL to compensate Ergon Retail for the increased costs of operating in regional Queensland. This subsidy is provided to ensure Queenslanders, regardless of their geographic location, pay a similar price for their electricity. The budget estimate for the CSO in 2022/23 is $635 million[44].

6.2 Local Rules and Restrictions

RTA closely monitors new load connections at Napranum to ensure there is no adverse impact on its generation and distribution system that may affect its mining operations. All new prospective connections are referred to RTA for approval before an offer of supply is made by EEN.

[44] Queensland Government Budget Strategy and Outlook 2022-23 (page 163)

Additionally, RTA does not currently permit the connection of third-party generation plant to its network, including rooftop solar PV systems. This rule currently applies in the Napranum community and to Weipa township, despite the Napranum network being owned and operated by Ergon Network.

6.3 National Electricity Rules and Microgrids

This section is provided for the sake of completeness and describes the regulatory environment now applied to new microgrids in Australia. However, as discussed in Section 6.1, Napranum is classified as a Remote and Isolated community and so falls outside the regulatory jurisdiction of the AER. In addition, the new SAPS Rules described below are applied on an opt-in basis, and to date, the Queensland government has not shown any indication that the Remote and Isolated community classification will change.

Over the last few years, the Australian Energy Market Commission (AEMC) has been undertaking a significant amount of work regarding the regulatory environment within which microgrids must operate. The most relevant work undertaken by the AEMC has focused on Stand-Alone Power Systems (SAPS). Although the term SAPS has historically been used to a describe a system providing power to one off-grid customer, the AEMC's definition states[45]:

"(SAPS) is an electricity supply arrangement that is not physically connected to the national grid. The Commission uses the term to encompass both microgrids, which supply electricity to multiple customers, and individual power systems, which relate only to single customers."

In 2022 the AEMC released the "National Electricity Amendment (Regulated stand-alone power systems) Rule 2022" and the "National Energy Retail Amendment (Regulated stand-alone power systems) Rule 2022". These Rules are being implemented in a staged process that began in August 2022, and only apply to new DNSP-led SAPS (existing microgrids will be unaffected). They will also operate on an opt-in basis - because the states and territories may need to make amendments to their legislation.

6.3.1 National Electricity Rule Areas

Service delivery model

This relates to the arrangements needed to support the financial settlement of SAPS load and generation through AEMO settlement systems, and so support retail competition. In essence (see Figure 28)[46].

[45] www.aemc.gov.au/sites/default/files/2019-05/SAPS%20Priority%201%20Final%20Report%20-%20FOR%20PUBLICATION.pdf

[46] A similar diagram is provided in the more recent document 'Ring-fencing Guideline Update - Fact-sheet - A guide for SAPS resource providers' provided by the AER, however in error it is missing the payment of the DNSP by the retailer.

The customer receives an electricity bill that includes retail service costs, the energy charge and Distribution Use of System but not other energy charges such as those related to ancillary services, nor the costs of distribution or transmission losses.

An authorised retailer sells the electricity to the customer based on a settlement price determined by AEMO which is calculated as equal to 80% of the average regional reference price for the regional reference node for the prior financial year. This same price is then passed on to the SAPS generator(s).

The retailer passes on to the DNSP the network component of the electricity bill. To the extent that generators (such as batteries owned by 3rd parties) provide network support, they would be paid by the DNSP through a bilateral contract. Such contracts could allow for line losses where they are material.

Where any generation assets are owned by the DNSP, assuming an AER exemption is provided, they can be incorporated into their Regulated Asset Base, and unregulated revenue earned in the wholesale market can contribute to the funding of these assets.

The DNSP would apply the relevant technical standards (e.g., phase balance, voltage and frequency) to ensure that they are not disadvantaged compared to grid-connected customers.

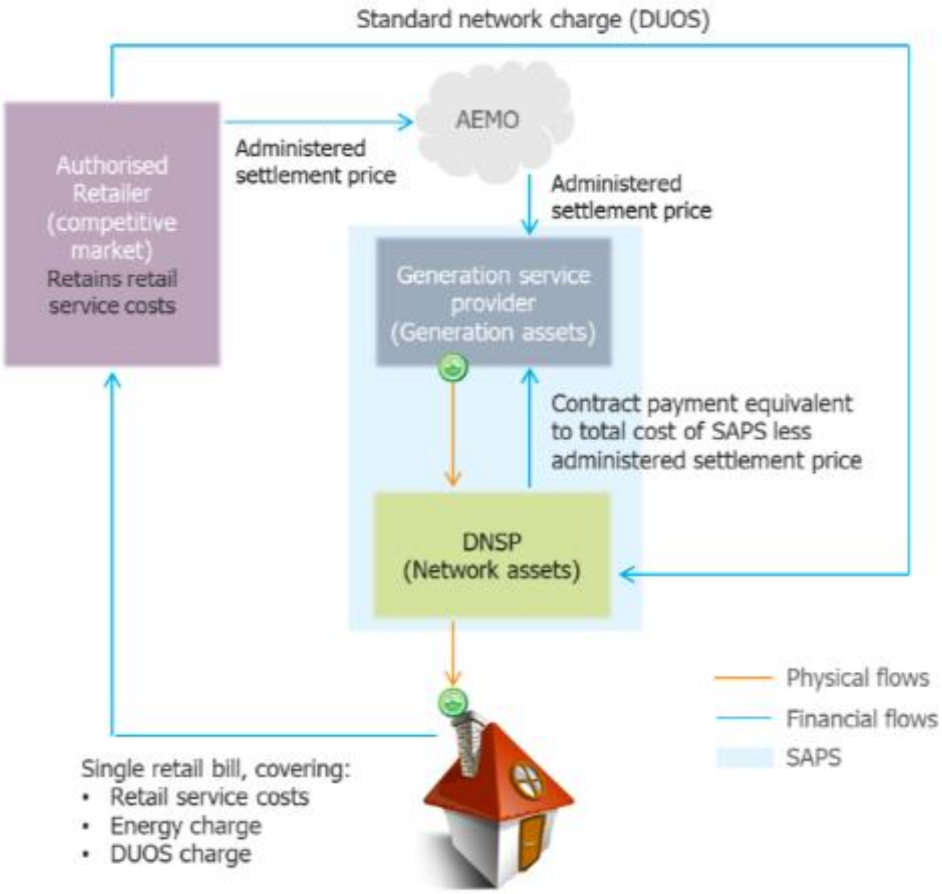


Figure 28: Model for SAPS operation

SAPS Settlement price

This relates to the design of an administered price to be paid by retailers to AEMO, and then by AEMO to SAPS generators, in energy market settlement. The SAPS settlement price for a regional reference node for a financial year is equal to 80% of the average regional reference price for that regional reference node for that financial year.

Service classification

This relates to the regulatory classification of services such as generation and storage provided by DNSPs in a SAPS distribution system.

In the National Electricity Market (NEM), DNSPs generally cannot own and sell electricity from generation assets, including batteries. Although they can own battery assets, these can only be used for network support, such as voltage control or demand reduction during network peaks, not for the provision of electricity for sale by the DNSP. This is because the National Electricity Rules ring-fence ownership of regulated network assets from generation assets (because generation operates in a competitive market).

However, under the new Rules outlined above, SAPS will now be included in the NEM, and DNSPs can now not only include the network (poles and wires) in a SAPS but also the generation and storage assets in their regulated asset base under an exemption framework provided by the AER (only up to a cap on the revenue they may earn from providing these services i.e., a generation revenue cap).

Such an exemption would be granted where it is demonstrated that it would be more efficient, and therefore lower cost, for the DNSP to provide generation services themselves (rather than contracting out to a third-party provider). This could occur because, for example, there may be limited competition in the provision of generation assets in remote areas, or after some sort of disaster such as a cyclone, the need to quickly re-establish power supply may mean there is not enough time to go through the normal procurement processes.

Technical standards

This relates to the requirement for DNSPs to develop their own technical regulations and performance standards suitable for SAPS based on schedules 5.1a and 5.3a of the NER.

7

Microgrid Technology Options

7 Microgrid Technology Options

7.1 Distributed Energy Resources

Distributed energy resources (DERs)are small scale energy generation and storage units that are connected to the local distribution network. They can include generators, such as solar arrays, energy storage units, electric vehicles, and technology that consumers can use to manage their electricity demand such as smart devices, and controllers for appliances such as hot water system boosters and air-conditioners.

DERs work with centralised energy generation systems such as solar and wind farms, and large-scale batteries, to balance demand on the electricity network and improve reliability during equipment failures and periods of high demand. DERs that generate electricity are expected to provide a significant portion of energy as Australia transitions to a high-renewables electricity system.

7.2 Standalone Power Systems

The Australian Government's Large-scale Renewable Energy Target[47] legislation defines eligible technologies and renewable energy sources as hydro, wave, tide, ocean, wind, solar, geothermal-aquifer, hot dry rock, energy crops, wood waste, agricultural waste, food waste, bagasse, black liquor, biomass-based components of municipal solid waste, landfill gas, sewage gas and biomass-based components of sewage. Many of the generation technologies that utilise some of these energy sources are currently not economic at smaller scales, such as the electricity load of Napranum.

The Australian Government's Small-scale Renewable Energy Scheme extends the focus beyond electricity generation to also include solar thermal and air-source heat pump hot water systems.

This section focuses on renewable energy technologies incentivised under the Australian Government's Large-scale and Small-scale Renewable Energy Target schemes in a Napranum context. Appendix C contains background information on each technology.

7.2.1 Solar photovoltaic

Solar PV systems are cost-effective at both small-scale (kW) and large-scale (MW) installations in Queensland, as evidenced by the proliferation of the technology across the state in the previous 10 years. While the market was initially driven by generous government backed incentive schemes, it now largely sustains itself. This is due in part to equipment

[47] https://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Large-scale-Renewable-Energy-Target

costs having dropped markedly and increases in household energy costs. Both of these factors strengthen the financial case for installation of PV.

PV systems can be installed as a ground-mount solar farm that is linked to the main grid, on the roofs of households and commercial premises. Rooftop PV systems are typically connected in a behind-the-meter arrangement which allows energy generated by the PV system to offset energy demand. Options for both rooftop and centralised ground mounted arrays have been investigated within this project to provide for the energy needs of the Napranum community.

Napranum has an excellent solar resource by international standards, and unlike most locations in Australia, the solar resource exhibits little annual variability. However, the data does not fully capture the potential intermittency of the solar resource during the wet season which spans November to April. Bureau of Meteorology (BoM) data is obtained from the nearest weather station on *Weipa Aero QLD* which is 3.3 kms away[48]. The BoM Global Horizontal Irradiance (GHI) at Napranum, reported for the period of 1990 – 2022 from the nearest weather station, Weipa Aero, shows an annual overall average irradiance of 5.78 kWh/m^2/day, with an average low of 4.65 kWh/m^2/day and an average high of 6.68 kWh/m^2/day.

Figure 29 below shows the annual variability and the seasonal nature of Napranum's reported monthly GHI.

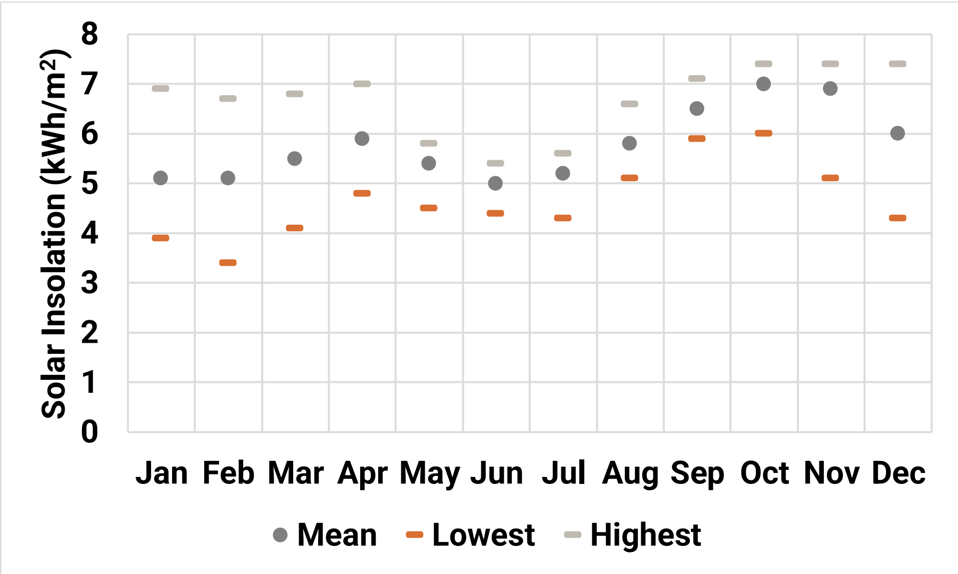


Figure 29: Annual variability and seasonal nature of Napranum GHI

To estimate the potential savings on energy expenditure for residents of Napranum, an indicative annual PV energy yield was simulated using PVWatts, a web-based application developed by the American National Renewable Energy Laboratory (NREL). PVWatts uses

[48] http://www.bom.gov.au/climate/data/index.shtml?bookmark=203

algorithms to estimate the energy production and cost of energy of a PV system based on location, system size, and module type, as well as factors such as shading, system losses, and panel deterioration over time.

A 6kW rooftop PV system with a standard gable roof tilt angle of 20° was used to determine indicative energy production. To get representative outputs that could be applied to a larger number of houses, the system was modelled with orientations to each of the cardinal directions. The north-facing roof yielded the highest annual output of 9,696 kWh/year, while the south-facing roof resulted in the lowest output of 8,236 kWh/year. The east- and west-facing roofs produced 9,286 kWh/year and 8,739 kWh/year, respectively. This indicates that any PV system installed on a roof surface facing between due east or west in the arc including due north would produce at least 90% of the output of a PV system facing true north.

Table 18: PVWatts simulation energy output and specific yield of 6 kW rooftop system

Module Orientation	Energy Output (kWh/year)	Specific Yield (kWh/kWp)
North	9,696	1,616
West	9,286	1,548
East	8,739	1,456
South	8,236	1,373

PV systems have proven very reliable, with most systems requiring no maintenance over many years of operation. PV panels lose some of their efficiency with time, but typically come with 20-year guarantees that provide a minimum level of performance. According to usual test settings, this corresponds to 80% of the rated power output. Thus, over the course of 20 years, it is expected that the annual output of a rooftop 6 kWp PV array facing north with no shading will decrease to 7.68 MWh in the twentieth year from the initial 9.6 MWh annual generation.

Operations and maintenance (O&M) costs are minimal and relate to occasionally washing the solar PV array (if rain has been inadequate), checking that the inverter, safety isolators and cables are operational (i.e., no water or insect ingress) and inspecting for any corrosion, animal interference, and hail or other mechanical damage.

Residences at Napranum are currently supplied under Ergon Retail General Supply Tariff 11 (a fixed rate of 24.34 c/kWh for all energy consumed and daily connection charge of 99.44 c/day[49]), and the use of off-peak economy tariffs is uncommon (refer to the Ergon Energy website for details of residential tariffs[50]). A feed-in tariff is available for excess solar PV

[49] FY 2022-23

[50] https://www.ergon.com.au/retail/residential/tariffs-and-prices/general-supply-tariffs

generation, with the current value being 9.4c/kWh. As Napranum operates a card meter system, Ergon Retail would need to implement administrative arrangements for the payment of the feed-in tariff. This would likely take the form of a quarterly or 6-monthly payment that would be credited to the resident's meter card that is linked to the residence.

Installation of rooftop PV systems “behind-the-meter" has the potential to significantly reduce residential energy costs at the community.

For locations with greater daytime loads, such as Napranum, the cost-effectiveness of rooftop solar PV is enhanced. Therefore, rooftop solar PV systems are considered an important component of the distributed energy solution for Napranum. The deployment of rooftop solar PV systems at Napranum can also serve to offset the size of a central solar farm that will be required as part of a microgrid solution.

7.2.2 Solar thermal and heat pump hot water systems

Four different types of water heaters are commercially available in Australia: resistance water heaters, solar thermal systems, heat pumps and gas water heaters. Resistance water heaters are least efficient, using more than 10kWh to heat 200 litres of water to around 60°C, and therefore unsuitable for SAPS. Solar thermal and heat pump hot water systems can both reduce electricity use by around 70% to 80% compared to a resistance heater, depending on when and how much hot water is used.

An advantage of solar thermal systems over heat pumps is that, in tropical locations such as Napranum, they can provide a reasonable hot water service without using any electricity at all. However, if they have an electric booster, it is almost always a resistance heater. Thus, heat pumps may be a better option if a significant amount of boosting is required. Gas water heaters use no electricity, making them a good option for SAPs, but require replacement gas bottles and also release greenhouse gas emissions when used.

7.3 Centralised Energy Generation

7.3.1 Wind

Wind turbines operate when wind turns blades around a rotor, and the rotational force is then used to turn a generator to create electricity, or in the case of windmills mechanically turn a water pump. Depending on the type of wind turbine used, electrical output from the generator may require conditioning by power electronics to obtain the correct frequency and voltage before it can be exported to the grid.

The most common form of wind turbine has the rotor spinning around a horizontal axis and three blades. Vertical axis wind turbines also exist but they have a very small proportion of the wind turbine market.

For Napranum, small-scale wind is unlikely to be suitable due to practicality and costs of maintenance.

Available high-level data indicates a weak wind resource with an average wind speed of 6.25 m/s[51] as seen in Figure 30. The wind also predominantly comes from an easterly and south easterly direction. This is not an extremely strong wind speed (higher wind speeds of 8 m/s to 10 m/s would be preferred), thus the area does not have a strong enough wind resource for wind turbines and is not feasible.

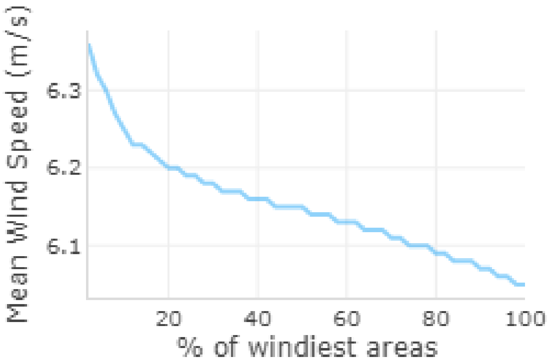


Figure 30: Mean wind speed at height 100m in Napranum

7.3.2 Hydro/Pumped Storage

Micro-hydropower systems can be as small as 5 kW, and up to 100 kW. Full-sized hydropower systems can produce almost any amount of power where there is an appropriate flow of water. The minimum flow required for a 50 kW micro-hydropower system is approximately 1 cubic metre per second, with a height difference, or head, between the intake and outlet of 10 metres. This is equivalent to a river about 5 metres wide and 1 metre deep. Napranum does not have sufficient rainfall or flowing water for hydropower.

7.3.3 Bioenergy

A variety of bioenergy generation technologies are commercially available. However, most of the risk with bioenergy generation lies with the biomass supply and delivered cost. Relative to the purchase cost, biomass resources are expensive to transport. Thus, the lowest cost biomass resources are those local to the user. Bioenergy capital costs are strongly dependent on system size, with large systems being progressively more cost effective.

Napranum does not have sufficient local bioenergy resources or a large enough load to make bioenergy viable.

7.3.4 Tidal power

Tidal energy production is still in its infancy. It requires a turbine to be installed in a fast-flowing tidal reservoir or lagoon, and careful planning is required to minimise impact to the surrounding environment from disruption to seawater flow. Pilot projects are being developed in several countries, but high production costs, high maintenance requirements,

[51] Global Wind Atlas 2023, Global Wind Atlas

and costly technological studies and engineering work make it difficult to propose for remote locations like Napranum.

7.3.5 Energy Storage

A range of energy storage technologies are utilised for various applications around the world. These include various battery chemistries, pumped hydro, compressed air, thermal, flywheels and hydrogen.

Electricity storage can be roughly categorised into two major types:

- Short-term energy storage
- Bulk energy storage

The parameters for energy storage will depend on its designed role. This can vary widely as requirements can be different depending on function and other generators.

For an islandable microgrid, a grid-forming BESS may be a suitable energy storage option. The primary purpose of the BESS is to store variable renewable energy (VRE) generation, to be used later, when there is no or limited output from VRE generation.

It is proposed to incorporate a central BESS, co-located with a solar farm and standby generator at Napranum. This is a more cost-effective option than using distributed household batteries in this situation.

7.4 Generator efficiency

In isolated communities, diesel generation is commonly used throughout the day, with the generators regularly adjusting to cope with load fluctuations. When VRE generation is added, it can further increase the load fluctuations of the diesel generators. However, if these fluctuations remain within the acceptable ramp rate of the diesel generators, they can be managed. As the VRE power fraction increases beyond a certain point, there are potential risks to power quality, which can be mitigated by using some form of energy storage.

There are more cost-effective approaches to high renewable energy fractions, including designs where the diesel generators only operate occasionally, mainly after days with extensive clouds. During the night, when the battery depth-of-discharge reaches certain set points, the diesel generator is automatically started and run at its maximum efficiency to recharge the battery to the required state-of-charge.

The cost of generating electricity using diesel generators is relatively high due to their low efficiency (between 20% to 40% depending on loading) and the high and fluctuating cost of diesel fuel (around $2.30 per litre in Weipa as of February 2023). For instance, the fuel cost of generation for a plant averaging 4 kWh per litre with delivered diesel at $2.30 per litre is $0.57/kWh. Actual costs are higher due to the need to factor in capital costs, operation, and maintenance costs, as well as fluctuations in fuel prices.

When the diesel generator is operational, it is run at peak efficiency at its optimum loading to recharge the battery, rather than varying its output and decreasing efficiency. The typical efficiency curve of a small diesel generator at various loadings is shown in Figure 31.

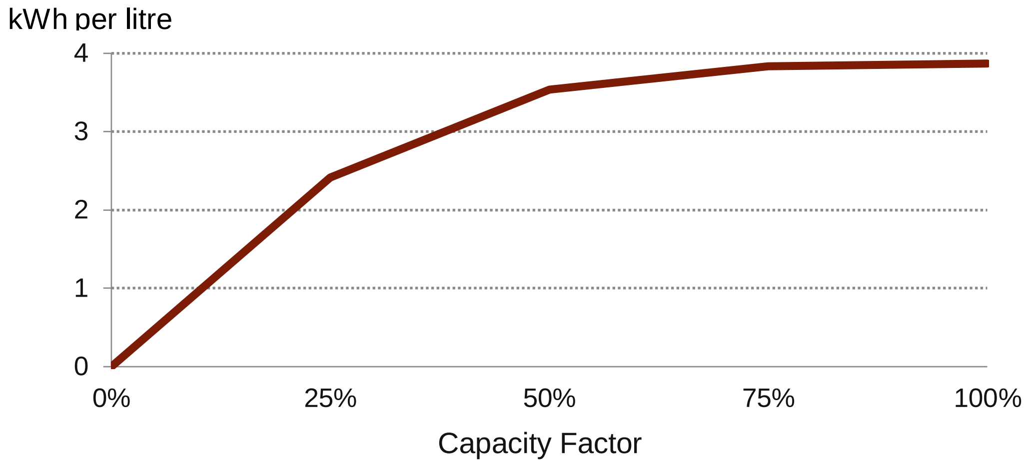


Figure 31: Typical efficiency curve for a medium-scale diesel generator

7.5 Fuel Substitution

Alternative fuels for use in diesel engine generators include biodiesel, biogas, and hydrogen. Gas engines and turbines are also used as generators in some isolated locations with access to cheap gas. Common issues that are considered in determining suitability of these other fuels include cost, transport and storage logistics, generator unit sizes available, costs of upgrading any existing power station equipment, network connection costs, maintenance requirements and the existence of regional supply chains.

The expected capacity factor for the engine generator is also a key factor for determining if the cost of other fuels is worth detailed investigation. As the diesel standby generator is relatively small and only used occasionally, it is unlikely that alternative fuels will be economically attractive. The following discussion is provided only as a high-level overview of the options.

7.5.1 Biodiesel

Biodiesel can be an attractive fuel if a local source is available at a competitive price. Biodiesel can be made from waste cooking oil, animal fats derived from tallow, from cattle or vegetable oils. It can also be made from algae and pongamia trees, which are currently not commercially viable.

Since the source feedstock material can be replenished readily, biodiesel is considered a source of renewable energy. Biodiesel can be blended with normal automotive diesel at various percentages and can typically be used as a direct replacement for diesel fuel with little or no modification to the diesel generator. Although coconut oil fuels are more common in the Pacific, the biodiesel market from all fuel sources is not well established in Australia and thus the availability and cost can vary significantly. The nearest commercial source of biodiesel is Brisbane, and it is expected the delivered cost to Muralug will be significantly more than that for diesel. Furthermore, the supply chain is generally separate to the automotive diesel supply chain resulting in high transportation costs.

Standard diesel generators can operate effectively using a B20 biodiesel alternative – a blended fuel source consisting of 20% biofuel and 80% diesel mix to reduce Greenhouse Gas emissions compared to a straight diesel fuel supply.

The shelf-life of biodiesel is much less than that of standard diesel fuel, biodiesel is not currently widely used in regional Queensland with the nearest manufacturing and distribution hub located in Brisbane.

The additional cost and reduced shelf-life combined with the small volumes required would potentially make this option uneconomical for application in the Napranum microgrid back-up generator.

7.5.2 Hydrogen

Hydrogen on-demand, diesel fuel-saving technologies are being developed. They either use electrolysis to split water to produce a gas comprised of hydrogen and oxygen, or a chemical reaction using sodium borohydride. There are several companies in the USA developing the technology for the automotive industry to be used in fuel cells or internal combustion engines.

Hydrogen on-demand is claimed to increase the efficiency of diesel engines by around 10% to 15%. It works by promoting the full combustion of diesel fuel in the engine (diesel engines normally have small amounts of unburnt fuel in the exhaust and carbon monoxide, which results from incomplete combustion). The energy cost in generating the hydrogen via electrolysis of water is more than offset by the power gains from the complete combustion of diesel fuel, hence the gain in fuel efficiency. However, commercial retrofit kits are available primarily for the automotive industry rather than utility engine generators.

7.6 Microgrid System Control

Microgrids require specialised control and management to ensure a stable and reliable local power system and good coordination with upstream supply sources, and to ensure seamless continued microgrid operation during upstream system outages.

7.6.1 Functionality

- Managed microgrid UPS mode - Control seamless grid separation and resynchronisation based on pre-determined operating modes, state of energy storage devices and available solar PV energy, upstream 11 kV feeder events, and RTA Network SCADA (Supervisory Control and Data Acquisition) signals.
- When in grid-isolation mode, the microgrid controller must ensure that electrical safety devices are activated, such as protection systems, and that the BESS grid forming inverter/convertor is enabled in the correct mode to provide suitable fault levels for system protection devices to function as they are designed.

- Optimise/prioritise local PV energy production for supplying local loads, BESS charging, and then for export into EEN/RTA 11 kV network if surplus is available.
- Optimise BESS charging from local solar PV energy production.
- Optimise BESS State of Charge (SoC) determined by operating modes.
- Initiate solar PV curtailment signals to residential, commercial, and central PV if required by microgrid algorithms, if solar PV energy production is higher than load required for local energy consumption, BESS charging and feeder export limits.
- Manage microgrid black-start mode if required when upstream grid is not available and microgrid is tripped due to a technical or safety issue.
- Manage demand management signals based on optimising incoming feeder load and/or export technical limits.
- Coordinate and/or optimise energy flows within the microgrid, and to upstream network, in conjunction with EER/RTA retail market algorithms and technical control signals, when possible, to optimise financial outcomes for microgrid owners and operators.
- Coordinate residential load control via smart home energy interface units for split system air-conditioners, heat pump hot water service, refrigeration, and other controllable loads via Peaksmart Demand Response Enabled Device (DRED) control by ripple signals, or IP addressable protocols such as IEEE2030.50.
- Coordinate electric vehicle charging sources to optimise time of day charging and optimise charging cost.

7.6.2 Central vs. Distributed

One approach is to have a microgrid master controller that communicates with and controls all microgrid components, manages energy flows in accordance with pre-arranged algorithms, and prioritises the relevant control tasks. A central microgrid control system can also be linked to an upstream network SCADA system to communicate status and accept higher level control signals. The link to the upstream network SCADA system is important for operation in both the grid-connected and grid-isolated mode. This centralised approach to microgrid control is relatively straightforward but has a single point of failure risk. The central controller requires high-speed communication capabilities to manage power system quality and the output of the various microgrid generation assets. The priority must always be stable and safe community microgrid power supply, and the control system is also able to be programmed to optimise generation costs and emissions.

A multi-agent, decentralised microgrid control approach is also feasible but is more complex. This approach allows for some redundancy to be included to minimise risks from single point failures but may be more expensive than the single controller approach due to duplication of controller architecture and software/firmware, and programming automatic fail-over to manage controller failures and maintain continual system control and optimisation.

For Napranum, the proposed approach is to install a highly capable and scalable centralised master controller system (MCS) located at the central, solar-battery-generator community energy facility with a high-capacity communications link to the RTA Network SCADA system and throughout the community microgrid DER devices.

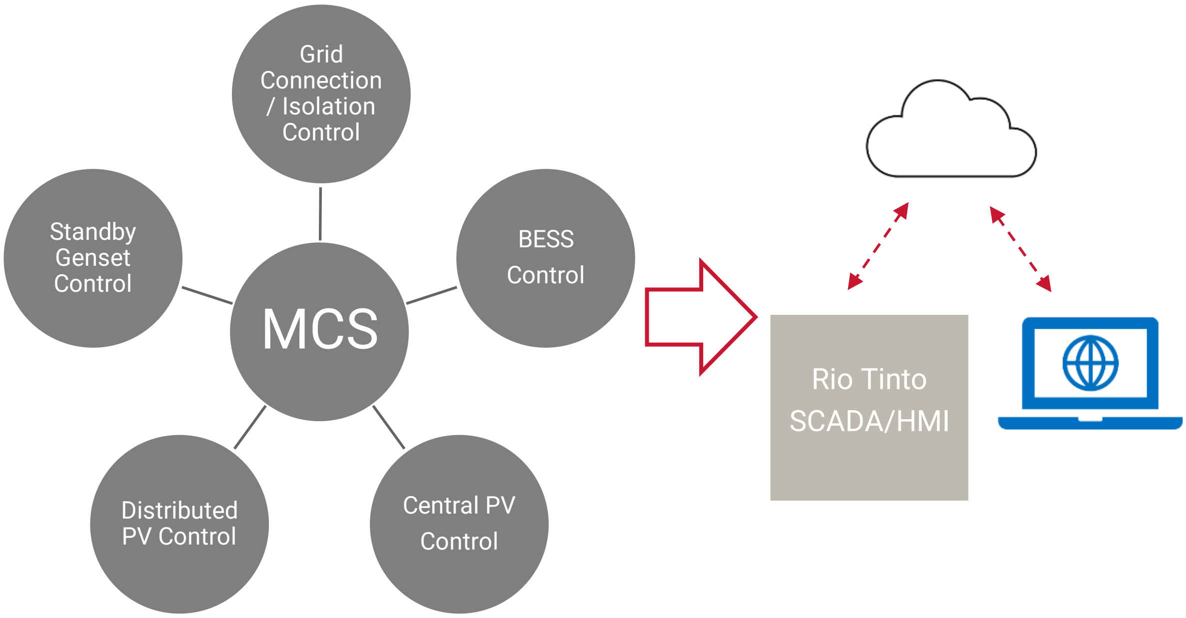


Figure 32: Diagram of the centralised master controller with communications link

7.6.3 Required Features of Master Control System (MCS)

A microgrid will be set up in Napranum Community Energy Facility with an Uninterruptable Power Supply (UPS), communication links, and display screens for control and education purposes. It will be connected to the RTA Network SCADA system to receive control signals and send back status information, as well as to the retail market systems for energy pricing optimization. The microgrid will be connected to the BESS Grid Forming Inverter to manage grid voltage and frequency, and grid fault levels and protection systems.

A central controller will be connected to and control all microgrid DER devices, smart home energy interface units, and EV chargers within the microgrid. Additionally, distributed control gateway devices will be located and connected to each DER device for independent operation in accordance with prescribed algorithms.

7.6.4 Control Modes

When in island mode (grid-disconnected mode) a MCS is required to ensure stable, safe, and reliable power supply when multiple renewable energy resources are generating power and multiple types of consumers are absorbing the power that is generated. The MCS needs to manage frequency and voltage, control active and reactive power flows, ensure sufficient system fault levels for operation of protective devices, BESS charge/discharge, reserve management, curtailment of renewables if required, auto starting, and stopping of standby generation and other functions.

The BESS grid forming inverter/convertor may have a range of available operating modes that will need to be explored to determine the most appropriate one for this microgrid. For instance, Voltage Frequency (VF) droop[52] mode may be suitable to ensure all inverter based renewable energy resources that are connected to the microgrid will share the load in accordance with their available capacities. Other available control modes include conventional droop control (P-F droop control & Q-V droop control) and modified conventional droop control (P-V & Q-F droop control, V-F droop control and Angle droop). The most appropriate control mode for the Napranum microgrid will be explored during detailed design and implementation planning.

In grid-connected mode, the controller can manage network support and active power as well as ramp rate constraints at the main grid connection point. As the microgrid is expected to operate in grid-connected mode for most of the year, the controller could also be programmed to maximise the financial value of the central solar-battery-diesel power output. As an example, the central BESS could be utilised to provide a firm power output of 0.7 MW between 3pm and 9pm every day of the year. This generation profile would have a higher value than a control topology that charges the battery first and then exports variable solar output to the grid.

If there was a main grid failure after 9pm, the battery would still have sufficient capacity to manage the transition to island mode and carry the load for an hour or so. If the main grid outage continues beyond this and the battery reaches its maximum 90% depth-of-discharge set point before the next day's solar recharge, the generator would be auto-started to maintain the islanded microgrid power supply. The control system would turn the standby generator off once the battery reaches a certain state-of-charge set point for the time of day or the main grid connection was re-established.

7.6.5 Grid Synchronisation

A critical function of the MCS is managing transitions between grid-connected mode and island grid-disconnected mode, as well as reconnecting and re-synchronising back to the main grid seamlessly – otherwise known as UPS mode.

A smooth transition between grid-connected and island mode requires control damping of any transients while also engaging fast response power from BESS energy storage. The transition between island and grid-connected mode requires careful synchronisation with the main grid. The control system needs to ensure the voltage and phase angle are aligned with the grid before reconnection.

[52] A control system term which characterises the control curve that the controller will follow.

7.6.6 Network Protection

As the network power flows will change in island mode, there is a continuing requirement to ensure network protection devices still function as intended, and there may be a requirement to upgrade some network protection assets as part of the transition to microgrid integration. Provision of sufficient fault level by the BESS grid forming inverter/convertor will be one of the microgrid design challenges. The inverter capacity may need to be oversized compared to the typical rating for the proposed BESS to ensure that fault level capacity will be sufficient for the local network design. This will need to be considered as part of the grid-connection application process for the central solar-battery-standby generation power station and the design of the microgrid MCS.

7.6.7 Challenges

In any implementation phase, further investigation will be required to address the following questions.

1. Given the Napranum load profile, what is the most appropriate and cost-effective form/type of smart home energy interface device to manage flows from distributed energy resources within a microgrid– Gateway/droplet, smart meter?
2. Will the microgrid require high-capacity optical fibre links to the RTA Network SCADA and network switches, and optical fibre links to microgrid DER devices, to manage high speed data transfer for microgrid management?
3. What is the existing capability of the Napranum communications networks? What communications augmentation is required?

8

Demand-side Options

8 Demand-side Options

8.1 Energy Audits on Existing Facilities

8.1.1 Energy Auditing

Between March and October 2022, the EnergyConnect team conducted Type 1 Energy Audits at 15 households and 7 commercial or Council sites in Napranum. These audits provide a detailed summary of the energy consuming processes at each site, along with recommendations for reducing consumption. The audit process involves:

1. An on-site visit to discuss the occupant's energy use and inspect building fabric, type, and usage patterns.
2. Listing all energy consuming appliances on site and usage patterns.
3. Assessing annual energy consumption (gas and electricity) and eco-footprint per household and per person.
4. Indicating potential energy efficiency measures available, including management options ranked according to their potential financial return.

The EnergyConnect team used an auditing app designed for this project to identify primary commercial and government sites and sought residents who would be willing to participate in the audit. The audits were conducted during times scheduled and agreed upon by participants to minimize disturbance to operations and household routines. A report was compiled for each site, which identified potential savings for householders via changes to operating regimes or replacement of inefficient appliances with energy-efficient alternatives when upgrading.

For the households subject to audits, the eco-footprint was higher than the Australian average. Council and business premises underwent a similar process, under the guidance of Council officers. The reports identified potential savings and ways to optimize operational regimes and suggestions for upgrading.

8.2 Energy Efficiency

8.2.1 Housing

The EnergyConnect team audited 13 houses and 2 duplex/apartments in Napranum. These dwellings were of concrete block construction and ranged in age from 30 years to 2 years old. All of the houses were single-story structures with small windows, small or no shaded verandas, and poor crossflow ventilation. All houses and townhouses had ceiling fans installed.

The tropical climate in Napranum means that a large number of residents require artificial cooling. In many cases, installed fans are supplemented by residents' own purchase and installation of air-conditioning units. Many of these are 'in-wall' evaporative systems that have been installed by the householder by cutting out four concrete blocks and placing the air-conditioner in the space, without insulation or forming up the space. Evaporative air-conditioners are notoriously inefficient in tropical environments. The number of mobile floor air-conditioners increased during the audit period.

The lack of housing designed to meet the desired lifestyles of indigenous residents in a tropical environment is a missed opportunity for government agencies that build these houses. Engaging with locals to develop a small number of agreed designs that meet local lifestyle requirements - with more open-plan living and shaded outdoor living spaces, oriented to capture prevailing winds to enhance crossflow ventilation - would, in the opinion of residents and Council staff, lead to more care of the house, less maintenance and wilful damage, and fewer health and community issues like domestic violence within the community.

Most houses have electric hot water systems, but few are operated to minimize energy usage. With multi-generational houses, anecdotal evidence suggests that hot water demand is all day long, with early morning demand for bathing and showering for up to 12 people per household, then washing of dishes and clothes daily.

8.2.2 Commercial and Administration

Most of the Council and business buildings used for administrative purposes were constructed with concrete blocks and were equipped with air-conditioning and ceiling fans. The council depot, on the other hand, was mainly made up of large sheds and workshops constructed with steel frames and metal sheets. While the offices in the council depot were air-conditioned and made of concrete blocks, they were not insulated.

The sheds and workshops in the depot had large openings and industrial fans for ventilation but were not insulated. The audits of the council depot recorded a wide range of equipment and machinery, with the highest energy demand system being the water treatment and supply infrastructure. The depot site also included several sheds and workshops that contained various electrical tools and machines, suitable for household fixture manufacturing, plumbing, carpentry, and vehicle workshops.

Audits of the depot facilities revealed that much of the machinery had high potential energy requirements, but due to infrequent usage, the aggregated energy load was reduced. Other workshops within the depot grounds were disused and contained equipment in less serviceable condition suitable for timber milling, brick working, and boiler making/engineering.

Kuku’Nathi Services was a large compound that included workshops for metal and timber working, an industrial kitchen, artistry equipment, accommodation facilities, and offices. The training areas in Kuku’Nathi had equipment that had the potential to generate significant loads, but similarly to the Council Depot, the equipment was infrequently utilized. The office areas of Kuku'Nathi were in use, made of block construction, and equipped with computers, office equipment, and split system air conditioning units.

The main shopping centre in Napranum was operated by IBIS (Community Enterprise Queensland) and was part of the same complex as the Napranum Aboriginal Shire Council Offices. This medium-sized single-room warehouse shopping facility provided a range of retail items, including groceries, food items, clothing and hosiery, household essentials, electrical supplies, and leisure activity equipment. The IBIS Napranum shopping centre was well-utilised, with its main energy consumption being through air conditioning and refrigeration, cooking, lighting, and point of sale equipment.

The PCYC at Napranum was a large hall with main office wings, a kitchen, and a food service hall. All indoor areas were air-conditioned and well-lit, with a mix of LED, fluorescent, and halogen lighting. Outdoor areas were lit with halogen spotlights, some of which were observed to be on during daylight hours. This facility operated on weekdays and was a central hub for children from the community before and after school hours.

8.2.3 Appliances

In the Napranum community, most houses had a typical range of appliances found in any residential house in Queensland. Some houses had multiple fridges and chest freezers. However, the visible Star Ratings of appliances recorded in residential buildings were consistently 3.5 stars or below. While residents were aware of the energy rating system, price and availability were the main factors in appliance choices.

Air-conditioner units in residential buildings were dominated by older box style air-conditioners, which many households identified as a key contributor to high power bills and decreased time between power card recharges. Some of these units were installed incorrectly or set up in makeshift fashion, without effective gap sealing. Although some residents reported a proposed program to replace or install split system air conditioning units, the project had not yet occurred.

Electric ovens and stove cooktops were the primary cooking appliances, and many houses had multiple fridges or freezers, in addition to a large household refrigerator. Most houses had clothes dryers and washing machines, although some appliances were not functioning properly.

Most households had common devices such as mobile phone chargers, computers, laptops, and set-top boxes, while many had multiple TVs and sound systems. In contrast, appliances in commercial and administrative buildings were newer and had higher Star Ratings, presumably due to higher budgets and procurement processes allowing for the purchase of more energy-efficient products.

Many buildings in Napranum had unused or excess appliances that were disconnected or switched off, but devices on standby or switched on while not in use were frequently observed. Additionally, several fridges were recorded to be running while empty or underutilised in multiple commercial, government, and residential buildings. Outdoor flood lights with high wattage halogen globes were also observed to be on during daylight hours.

Upgrading older appliances and heating, ventilation and air conditioning (HVAC) systems with higher efficiency models and improving user awareness could significantly reduce energy demand across the Napranum community.

8.2.4 Energy Efficiency Education

Tailored education and engagement programs have been recognised by many experts as crucial for effective implementation of renewable energy solutions. These multifaceted programs should encompass information on energy efficiency, demand reduction, and maintenance requirements for systems, thereby complementing the roll-out of renewable energy-based microgrid systems. However, it is important to note that such programs cannot be a "one-off" initiative as the players and information change rapidly. Hence, an ongoing education program is essential to maximise the appropriate installation, efficient use, and longevity of appliances and energy delivery mechanisms.

Furthermore, all appliances and energy systems have a maintenance requirement to ensure their effective and long-term functioning, particularly in tropical climates where high humidity and rainfall can cause mould growth and corrosion. Therefore, an ongoing and regular maintenance regime is required.

The education campaign for this project should address several areas, including energy conservation principles, managing the number of appliances being operated simultaneously, choosing appliances with minimal energy consumption and maximum star ratings, turning off appliances at the wall, and unplugging any appliance not being used to reduce demand from standby power. It should also focus on timing the use of high consumption appliances to when local renewable generation (if installed) is at its peak or tariff prices are at their lowest, designing houses to minimise the demand for air-conditioning and other cooling appliances while maximising the use of natural light, and regular proactive/preventative maintenance.

To assist in developing future energy efficiency education programs for Napranum, EEN has previously implemented sustainability initiative programs like PowerSavvy, which was tailored to Indigenous communities on Cape York and Torres Strait Islands. This program could be an excellent resource for Napranum.

8.2.5 Load Shifting and Tariffs

To enhance the effectiveness of the proposed solar PV system deployment in the Napranum microgrid solution, a locally specific education program should be implemented to promote load shifting to daytime, encouraging high consumption activities like hot water services, cooking, washing, drying, and air-conditioning during peak solar generation times.

Furthermore, it has been noted that off-peak tariffs for water heating and air-conditioning may not be fully utilised in Napranum, possibly due to reasons such as older homes not being wired for off-peak tariffs, small hot water systems with insufficient capacity to meet household demands, or tenants' lack of awareness of cheaper tariff options.

To address this issue, appropriate tariff selections and energy-efficient appliances should be considered in an energy-efficiency program for Napranum, as they can provide more affordable energy solutions for residents and deliver optimal outcomes for the microgrid design. For more information on electricity tariffs, refer to Section 5.4 of this report, and for energy-efficient hot water systems, see Section 8.2.3.

9

Analysis of Options

9 Analysis of Options

9.1 Microgrid Scenarios

Four microgrid scenarios were developed in collaboration with EE MIST and were used for both optimisation modelling and power systems modelling. They were designed to cover a range of Napranum's potential microgrid requirements. Power systems modelling used the BESS and solar PV capacities shown in Table 19, and optimisation modelling used these sizes as starting points to find the lowest-cost systems that could be built in each scenario.

Table 19: Summary of sizing of energy resources for the study

Scenario	Description	BESS Capacity (MVA)	Centralised Solar (MW)	Total Rooftop Solar (MW)
1	Primarily grid-connected, and only island during RTA outage	1	0.5	0.3
2	Primarily islanded with RTA as a backup during microgrid outage	2.7	2	0.3
3	Fully standalone, with no connection to RTA	2.7	5	0.3
4	Fully standalone, with future expansion to supply RTA	2.7	10	0.3

9.2 Least Cost Modelling

Data collected during earlier phases of the project were assessed and modelled using the min-E version of openCEM modelling tool[53] and HOMER Pro[54] to find a combination of solar PV and BESS for Napranum that would achieve the goals of each microgrid scenario.

Min-E and HOMER compute the optimal size of solar PV and BESS system for a given load, and the cost of that system over its lifetime, which for this analysis is 25 years.

[53] openCEM is an open-source model for the national electricity market (NEM) that allows for unlimited scenario modeling of NEM development. The min-E model is a tool for simulating generation and storage on a grid-connected electricity network. It computes the optimal combination of embedded generation technology options and energy storage to meet a given electricity load profile over a multi-year period at the lowest cost. openCEM can be accessed at http://www.opencem.org.au/.

[54] HOMER Pro is optimisation software for microgrids that aims to find the lowest-cost viable system within limits set by the user, and a load profile and location information for the site. It tests hundreds or thousands of possible combinations of technologies and designs to find an optimal solution.

For scenarios 2 and 3, different renewable energy percentages were modelled. This allows for a choice between the total cost and emissions from the microgrid. Renewable energy percentages of 90, 95, and 98% were modelled. For scenario 1, as the microgrid only supplies power during an RTA grid outage, no diesel was included, and the system supplies 100% renewable electricity when it is in use.

Scenario 4 was not modelled in detail. It has been included as a potential future opportunity that would require detailed modelling of the Rio Tinto electricity network, which is outside the scope of this study.

Whilst small wind turbines were included in an initial assessment, they have been replaced in these microgrid scenarios with additional PV capacity following a more detailed assessment of the local wind resources and for economic reasons.

9.2.1 Data Sources

Electricity demand data came from an Ergon Energy metering unit at the connection to the Rio Tinto grid, and technology costs came from industry benchmark data. Solar irradiance data was sourced from US National Renewable Energy Laboratory service PVWatts, which is based on weather and satellite observations of irradiation around the globe.

In 2020 and 2021, outages affecting all customers averaged 3.5 hours (see Ergon Energy outage data in Appendix A), and so the microgrid was modelled to supply the town with backup power for this length of time assuming no sunlight or wind. Using the maximum outage time of 21.7 hours would significantly increase the cost of building the microgrid to cater for a couple of very rare outages. The economic cost of these rare, long outages is much lower than the cost of battery storage that would cover them.

9.2.2 Modelling Results

Scenario 1

For this scenario, the microgrid was sized to meet the peak load on a day of low irradiance and wind in case outages in the RTA grid occurred during such times. When there are no outages, the generation capacity in the microgrid would still be used to meet local needs. Scenario 1 does not have a generator, as it relies on the Rio Tinto connection for backup.

Results of min-E modelling for scenario 1 are shown in the tables below.

Table 20: Capacity and dispatch for PV and battery

Technology	Capacity (kW)	Dispatch (MWh/year)
Solar PV	760	333
Battery 4h	810	210

Table 21: Total cost of microgrid for scenario 1

Category	Cost over 25 year lifetime
Build	10,050,000
Operation and Maintenance	575,000
Total	**10,625,000**

Scenario 2

In scenario 2, the Napranum microgrid is primarily islanded, meaning it will meet Napranum's load most of the time. Scenario 2 also uses the RTA network as a backup supply during contingency events, meaning that the only time the RTA network is used is during a microgrid outage. The lowest cost systems for scenario 2 at each renewable energy fraction are shown in Table 22.

Table 22: Modelling results for scenario 2

Technology	90% Renewable		95% Renewable		98% Renewable	
	Capacity (kW)	Dispatch (MWh)	Capacity (kW)	Dispatch (MWh)	Capacity (kW)	Dispatch (MWh)
Rio Tinto Grid	> 1 MW	484.4	> 1 MW	250	> 1 MW	104
Solar PV	1300	3200	1600	3900	1900	4400
Wind	667	1200	500	846	472	657
BESS 4h	761	1973	1044	2898	1261	3996
Total cost over system lifetime	**$26,249,960**		**$27,812,480**		**$30,044,250**	

Scenario 3

In scenario 3, Napranum is powered by a fully standalone self-sufficient microgrid with no connection to the RTA network. As a result, the microgrid requires diesel generation. The lowest cost systems for each renewable energy fraction in scenario 3 are shown in Table 23.

Table 23: Modelling results for scenario 3

Technology	90% Renewable		95% Renewable		98% Renewable	
	Capacity (kW)	Dispatch (MWh)	Capacity (kW)	Dispatch (MWh)	Capacity (kW)	Dispatch (MWh)
Diesel	900	484.4	900	250	900	104

Solar PV	1300	3200	1600	3900	1900	4400
Wind	667	1200	500	846	472	657
BESS 4h	761	1973	1044	2898	1261	3996
Total cost over system lifetime	**$28,390,000**		**$29,400,040**		**$32,500,750**	

Total costs for scenario 3 are higher than scenario 2 due to diesel generation being slightly more expensive per kWh than the Rio Tinto grid electricity.

Emissions

Each scenario reduces emissions compared to consumption from the Rio Tinto network. Quantities shown in Table 24 are over the 25-year lifetime of a microgrid with 95% renewable energy generation. Year-on-year emissions were calculated but did not show significant variation, as the emission rate for diesel (assumed at 0.95kg CO2 per kWh) remains constant throughout the project life.

Table 24: Emissions of each scenario for a 95% renewable system over the project lifetime

Scenario	Base Emissions (tons of CO_2)	Microgrid Emissions (tons of CO_2)	Emission Savings (tons of CO_2)	Emission reduction
1	106,293	61,960	44,333	42%
2	106,293	6,863	99,430	94%
3	106,293	591	105,702	98%

Base emissions correspond to annual consumption of electricity by the town of Napranum from the RTA grid with no microgrid project. Net emissions in scenario 3 (fully isolated mode) are not zero because of the use of diesel generation for backup.

9.2.3 Discussion

For scenario 1, the microgrid must simply provide backup power when the Rio Tinto grid goes down, so its technical requirements are strict. The optimal system suggested by modelling for scenario 1 includes 750 kW of solar PV, and 810 kW of batteries with 4 hours of storage. This would cost approximately $10.6 million over the 25-year life of the system.

In scenario 2 and 3, modelling results in a least cost system with 2 MW of solar PV and wind, and 760 kW of batteries with 4 hours of storage. Scenario 2 would import electricity from the Rio Tinto grid, with a total cost of $27.8 million over 25 years, whereas scenario 3 requires a 900-kW diesel generator, bringing the total cost to $29.4 million, $1.6 million more than scenario 2. This additional cost would change if either the cost of diesel or the cost of importing electricity from the RTA grid changed in the future.

For scenario 2 and 3, our optimisation modelling suggests a microgrid operating with 95% renewable energy. Costs begin to increase significantly at renewable energy fractions beyond 95%, because much more battery storage and solar PV is needed to provide power for long periods of low sunlight. In systems with diesel generators, it is more economical to reduce reliance on solar PV and batteries for these periods and use diesel instead. In the future, other forms of backup energy, including biodiesel, may allow systems with diesel generators to become 100% renewable.

9.3 Pre-connection Technical Feasibility

EE MIST was engaged by EnergyConnect to undertake modelling of the Napranum distribution network and to provide technical advice in relation to a potential microgrid connection for the Napranum 11kV distribution network owned by EEN and supplied by the Weipa power station, owned by RTA. This section summarises the full report, which is presented in Appendix E.

The scope of this study[55] consisted of power system modelling, distribution studies and connection advice related to the pre-connection technical feasibility of microgrid solutions for the 11kV Napranum distribution network.

The study considers 4 microgrid scenarios, as described in Section 9.1. This scope does not cover economic analysis related to microgrid component sizing (i.e., inverter/BESS, generator size, PV capacity, etc.) Technical assessment includes processes such as:

- Reviewing available network data (schematics, load profiles, engineering reports, etc.) as provided by EnergyConnect.
- Modifying and validating the PowerFactory[56] model based on available information.
- Establishing load flow study case and boundary conditions for each scenario.
- Providing general network connection advice and access requirements for the EEN distribution network, based on STNW 1175 - Standard for High Voltage EG Connections.
- Providing general advice on impacts on the EEN Isolated Network.
- Validating microgrid operating scenarios and confirming that proposed sizing is fit for purpose.
- Undertaking steady-state assessment of the power system under various scenarios and boundary conditions.

---

[55] *Napranum Microgrid Pre-connection Feasibility Study,* Ergon Energy, November 2022.

[56] DigSilent PowerFactory is industry standard power systems modelling software, used to study power reliability and disturbances, effects of adding new generators, and a range of other detailed technical performance studies of electricity networks.

- Performing fault studies and making considerations of high-level protection impacts of the microgrid.

The Napranum township is supplied by a 5km 11kV feeder from the Weipa power station to an EEN-owned recloser at the EEN/RTA connection point. The EEN 11kV distribution network is comparatively very short, consisting of 2.4km of 11kV distribution network. However, the Napranum township is highly susceptible to large disturbing loads from the RTA mining operations. The nature of this connection inherently suits the objective of the microgrid solution and conceptually aligns with the microgrid philosophy for reliability improvement and energy independence.

9.3.1 Considerations Moving Forward

Since scenario 3 assumes no connection to the RTA network, only the EEN distribution network impacts are considered. Table 19 shows the assumed sizing for the technical study.

Scenario 4 is considered a conceptual exercise as the total size of the centralised solar is very significant compared with the existing distribution network. As such, any modelling results regarding Scenario 4 should be viewed with caution.

Microgrid connections with grid-forming inverters are still immature in Australia, and connection standards are yet to be updated. As such, this assessment is only a preliminary assessment based on existing standards and best practices, some of which are based on the National Electricity Rules (NER). Table 25 shows the summary of the technical feasibility of each microgrid scenario based on this preliminary assessment. The studies are only considered based on the EEN connection point to the RTA network, and there are no considerations of impact on the upstream RTA network or power station.

Table 25: Summary of microgrid scenarios

Scenario	Grid-Connected		Islanded		Feasible without Major Network Augmentation ?
	Voltage Levels	Power Flow within Limits	Voltage Levels	Power Flow within Limits	
1	✓	✓	✓	✓	Yes
2	✓	✓*	✓	✓**	Yes*
3	-	-	✓	✓	Yes
4	×	×	✓	✓**	No

* - Assuming acceptable power transfer back to RTA.

** - Assumes adequate microgrid operation and curtailment of generation resources to manage the BESS

9.3.2 Site Arrangement

Figure 33 shows the preliminary site arrangement of a potential microgrid site located within the Napranum township. The proposed site includes:

- HV connection point (11kV) with ACR or HV CB.
- The power transformer(s) with total capacity dependent on the microgrid scenario. This may consist of multiple transformers depending on detailed design considerations (flicker, fault levels, redundancy).

- Grid-forming battery energy storage system (BESS).
- Centralised solar PV.
- Backup diesel generators (not grid-coupled) and fuel tanks.

Although not located at the central microgrid site, there may be additional rooftop solar PV to be installed at premises across the Napranum community.

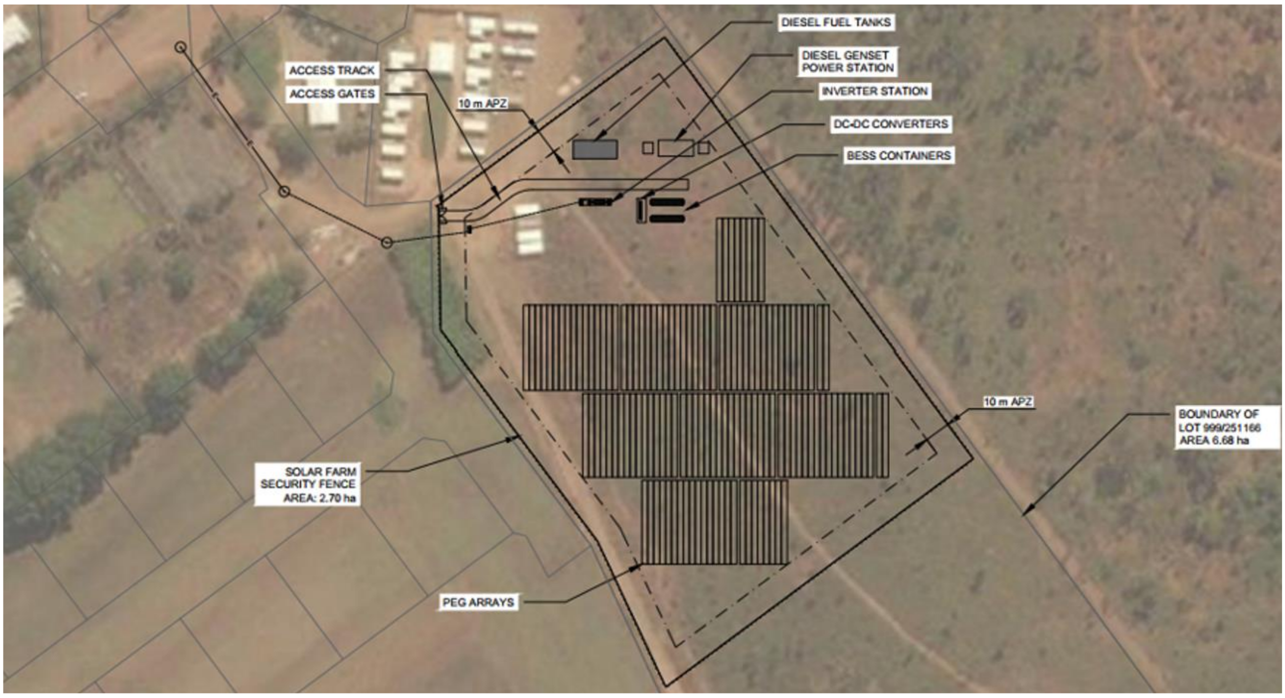


Figure 33: Preliminary site arrangement

The proposed connection to the microgrid site is shown in Figure 34. The preliminary scope of works for connection into the distribution network includes:

- Teeing-off from existing HV pole 1034880 (potential for alternative tee-off points).
- Constructing approximately 200m extension of 11kV overhead from pole 10344880 to the microgrid site.
- Establishing a new 11 kV connection point with ACR or HV CB.
- Depending on a detailed analysis of conductor ratings, additional reconductoring from pole 1034880 to the Napranum recloser may be required to maximise power transfer to the RTA network.
- Installing HV metering point upstream of the Napranum recloser to provide HV voltage sensing back to the microgrid site. RTA-side HV voltage sensing is required for synchronising to seamlessly transition back from islanding to grid-connect operation.
- Establishing direct communication from the microgrid site to the Napranum recloser for control and status indication.
- Establishing communications to the Weipa power station for control and indication by RTA. This may include telemetry to RTA, issuing runback or curtailment commands, and protection intertrips.

- Installing a power quality analyser at the microgrid HV connection point for commissioning and ongoing performance monitoring and validation.
- Upgrading the existing Napranum recloser to allow for additional protection requirements such as sync-check.

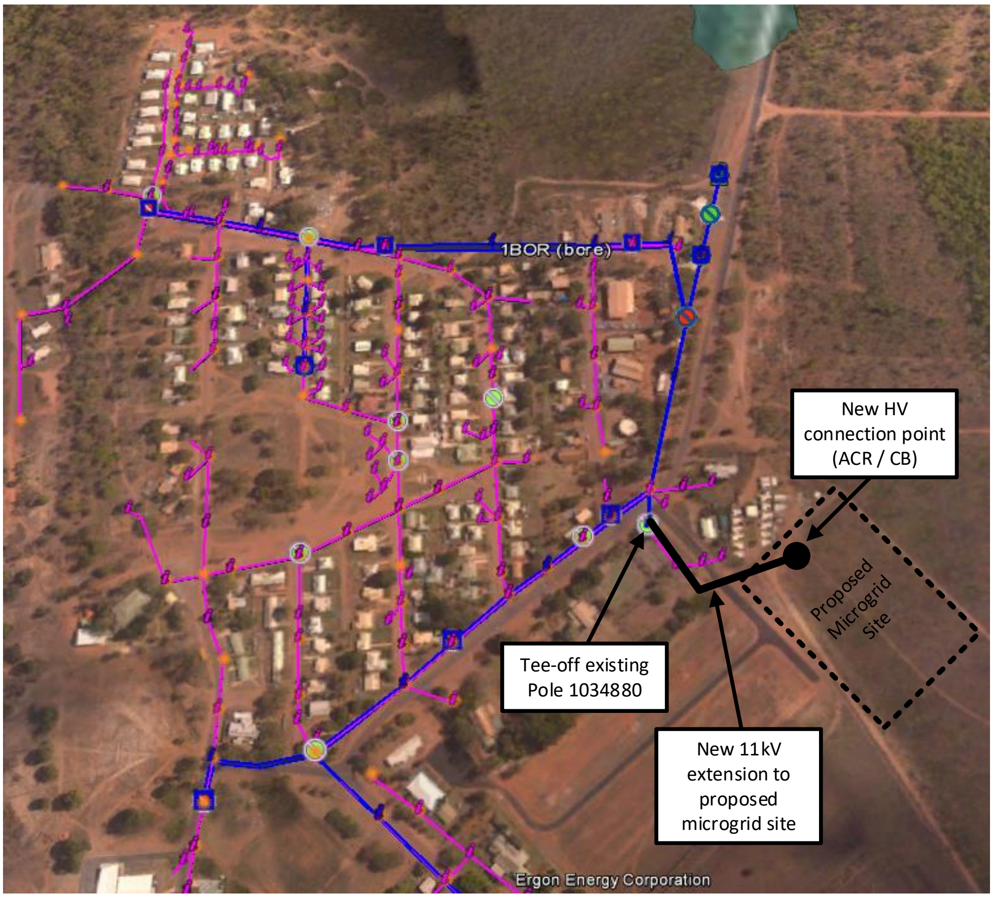


Figure 34: Proposed connection to microgrid site

9.3.3 Considerations Moving Forward

Ongoing consultation with RTA is required to better understand the impacts on the RTA power system and the level of acceptance for the proposed connection. There are a few RTA projects underway, such as the Humbug-Andoom interconnection, solar and BESS, that may affect the feasibility of the proposed microgrid, and the level of detailed studies required. This was not considered in this study.

In addition to obtaining approval for the network connection, the connecting Proponent must obtain consent from both EEN and RTA to form an island of the distribution network. They should also familiarise themselves with the extent of requirements, including legal, regulatory, technical and safety obligations, the sale of energy, and the operation and maintenance of the system.

Technical access standards for connection in the EQL Isolated Networks are not well-defined but would expect to fall under the requirements of STNW 1175. This would be in addition to RTA requirements due to the potential impacts on the power station. Although

STNW 1175 is based on NER requirements, the standard is considered the best practice for EQL Isolated Networks to ensure and uphold a reasonable level of system performance.

This study only considered steady-state load flows based on worst-case network scenarios. Detailed planning studies are required to verify feeder ratings and power station capability to understand the power transfer capabilities back to RTA.

Protection requirements have not been assessed as part of this study. This is due to the complexity of modelling short-circuit performance of inverters, particular for islanded situations. Detailed studies are required to verify protection impacts when grid-connected and during islanding to ensure the protection system is maintained.

9.4 Network Development

As outlined in section 5.3, approximately half of the outages (in terms of customer-minutes off supply) impacting Napranum in 2020 and 2021 were due to planned and unplanned outages affecting the local EQL distribution network.

The project team notes that:

- EQL has no local staff on site at Napranum and deployment of response crews from distant depots can result in delays to restoration of power supply following a fault
- whilst RTA manages the existing power generation and upstream distribution network, it is not authorised to work on the local EEN Napranum distribution assets
- the local distribution network is quite small consisting of just 1.5km of overhead 11KV network and 9 pole-mounted distribution transformers
- most critical infrastructure at Napranum has access to standby generators in the event of a sustained fault.

EnergyConnect has focused attention on the feasibility of establishing a microgrid at Napranum which can assist to address the impacts of upstream faults on the RTA network and Weipa power station.

It has not explored strategies currently in place or being considered by EQL to improve the local distribution network performance and considers that EQL would be better placed to undertake such a review if required.

EQL undertakes routine maintenance programs and monitors the network performance at its 33 remote and isolated communities, and benchmarks performance against Minimum Service Standards criteria, to prioritise investment in improvement activities in these locations.

Some opportunities have presented, in line with the establishment of a microgrid at Napranum, to contribute to future network improvement outcomes.

For example, by establishing two 11kV feeders out of the central microgrid facility, rather than a single feeder, the Napranum distribution system could be split so that half of the load is on one feeder and the other half is on the second feeder. With appropriate protection systems in place, a local distribution fault on one of the feeders may not impact customers that are connected to the other feeder, reducing overall community impact. A potential configuration is shown in Figure 35.

It may also be possible to utilise components of the microgrid control system and associated devices installed at customer premises behind-the-meter to assist EQL with remote fault-finding activities, leading to more rapid and accurate fault diagnosis, and improved response times.

Figure 35: potential 2-feeder connection into the existing Napranum network

10

Operating Model and Financial Analysis

10 Operating Model and Financial Analysis

10.1 Asset Ownership and Management

Based on feedback from community stakeholders and a preliminary assessment by the project team, a preferred ownership and operating structure has been identified for the development of a microgrid within the Napranum community. The proposed model for the microgrid generation assets is expected to include NASC (directly or through a subsidiary entity) as the key proponent responsible for designing, constructing, and owning these assets.

After consultations, it was found that a commercial O&M arrangement with a third-party operator, such as EQL, would be the preferred long-term operating structure for the microgrid generation assets, which include solar PV, diesel generator, and BESS. The energy generated from these assets would be sold via a PPA to the energy retailer and then on-sold to the community consumers.

Other ownership and operating models were also considered, such as a lease arrangement between NASC and a third-party entity, EQL (or a related entity) owning and operating the microgrid generation assets outright, or an independent third-party entity owning and operating these assets. Although all of these alternative models had potential benefits, it was concluded that the preferred option most closely aligned with the benefits sought by NASC and the Napranum community.

10.2 Funding Sources

Based on an assessment of the existing Government and non-Government programs targeted at supporting renewable energy projects and the advancement of Indigenous and remote communities, a range of potential funding options for the project were identified. While not exhaustive, the following list represents the key funding programs that may be accessed to support the development of the microgrid and related infrastructure:

- Queensland Government - Microgrid Pilot Fund (QMPF) – noting that currently this fund is only applicable for grid-connected indigenous communities
- Queensland Government - Renewable Energy and Hydrogen Jobs Fund (QREHJF)
- ARENA - First Nation’s Community Microgrid Fund
- ARENA - Community Battery for Household Solar Program
- ARENA - Regional Australia Microgrid Pilot Project (RAMPP)
- Indigenous Land and Sea Corporation - Our Country, Our Future Program
- National Indigenous Australians Agency – Indigenous Advancement Strategy
- Minderoo Foundation

Other non-Government funding sources may also be considered; however, these sources will typically mandate a level of commercial return on monies invested in capital infrastructure.

10.3 Financial Assessment

To conduct the financial assessment of the microgrid project, it is assumed that NASC will fund, construct, own, and operate the microgrid generation assets. These assets will be held in a separate legal entity, beneficially owned by NASC, and separated from the ordinary Council dealings. A dedicated project management team will support NASC, coordinating pre-construction activities, construction, commissioning, and operation of the microgrid. Furthermore, a local operations team will be engaged to manage the day-to-day operations of the microgrid assets.

The total estimated capital cost of the microgrid project is approximately $20 million, to be incurred over a 2-year period (excluding GST). For project construction funding, it is assumed that public programs will be sourced, and government funding will cover the full capital value of the project and major capital refurbishments. However, the funding mix will depend on the ownership, operating, and management structure adopted for the project and will be considered in the fullness of time.

To complete the assessment, conservative assumptions were made regarding the price at which electricity generated by the microgrid would be sold to the designated energy retailer, at $0.24/kWh. Although the current price for energy used to supply the Napranum community is not publicly available, it is expected to exceed the assumed price by two or three times the amount. As a result, there is likely significant financial upside that can be leveraged as part of commercial negotiations with the energy retailer for the cost of energy produced.

To illustrate the potential outcomes that may result for the project under varying PPA rate scenarios, and considering the impacts of the ability to obtain capital grant funding for the project, the following table provides a range of investment metrics for consideration:

Table 26: Investment metrics

	Calculation Excludes Capital Grant Revenue		**Calculation Includes Capital Grant Revenue**	
PPA Rate	NPV ($)	IRR	NPV ($)	IRR
$0.24/kWh (Base case)	(20,103,501)	-19%	2,005,613	22%
$0.30/kWh	(17,122,396)	-11%	4,986,719	43%
$0.40/kWh	(12,153,888)	-4%	9,955,226	76%
$0.60/kWh	(2,216,871)	-2%	19,892,243	132%
$0.80/kWh	7,720,145	11%	29,829,259	177%

What is highlighted in the above table is that where a PPA rate of $0.80/kWh or above can be achieved through commercial negotiations with the energy retailer, the Napranum microgrid assets would be suitable for investment without the need for any capital grant funding. For PPA rates below this amount, it is likely that some level of grant funding would be required to support the construction and future refurbishment of the microgrid assets. Conversely, where grant funding is available for the whole capital requirement for the establishment and upkeep of the microgrid, the project presents as a viable investment under all scenarios considered.

Due to the preliminary nature of the project concept, the financial assessment should be treated as indicative only. A more detailed financial assessment will be required once details regarding ownership, management, technical requirements, and commercial arrangements are refined. As such, investment decisions in relation to the project should not be made considering the outcomes of the financial assessment alone.

10.4 Ownership and Operating Model

The purpose of this section is to outline the potential ownership structures and operating models that may be adopted for the preferred microgrid solutions proposed for the Napranum community. Specifically, three potential structures have been identified for the selected microgrid options and these have been discussed in detail. Underpinning these structures are a range of assumptions regarding the flow of energy, and resulting value flows, through the four elements of the energy model.

10.4.1 Microgrid Energy Model

In developing the relevant ownership and operating models for the Napranum microgrid, certain assumptions have been made regarding the flow of energy, and resulting value, between the following four elements of the energy model:

- Generation
- Distribution
- Retail
- Consumer

The description and assumptions underpinning these elements of the overall model have been discussed below.

Generation

Energy is primarily generated from the core microgrid assets, including the solar PV, diesel generator and community BESS. This is supplemented by excess energy generated from the selected community rooftop solar PV systems located on Council owned properties. Energy generated is sold to the energy retailer in accordance with a negotiated PPA, through which the energy generator is remunerated an agreed rate or residential property owners are provided with a feed in tariff for energy fed into the network.

Distribution

The energy distribution network in Napranum is owned and operated by EEN. The generation assets will be required to connect into this network to supply energy to consumers within the community. Charges for use of the network, to distribute energy from the generation source to consumers, are typically levied on the energy retailer.

Retail

The energy retailer is responsible for the purchase of energy from generators and for the on sale of energy to consumers. EER is the existing energy retailer for the Napranum community. Energy retailers generate revenue through energy supply agreements with individual customers. The retailer is also responsible for installation and management of energy meters, card meters, billing and energy feed in from rooftop solar systems.

Consumer

The primary energy consumers within the Napranum community include domestic household customers, commercial organisations and Government organisations. Consumers enter into agreements with EER for the supply of energy to their respective premises. The retailer monitors energy usage through card or fixed meters.

Energy consumers who operate a behind the meter (BTM) solar PV system (for example, rooftop solar system) may be eligible for feed in tariffs for excess energy generated through their system that is unused by the consumer and is fed back into the grid.

An illustration of the energy flow model across the four different elements has been outlined in Figure 36 below. This model is designed to provided context to the microgrid ownership and operating model discussed further in this section.

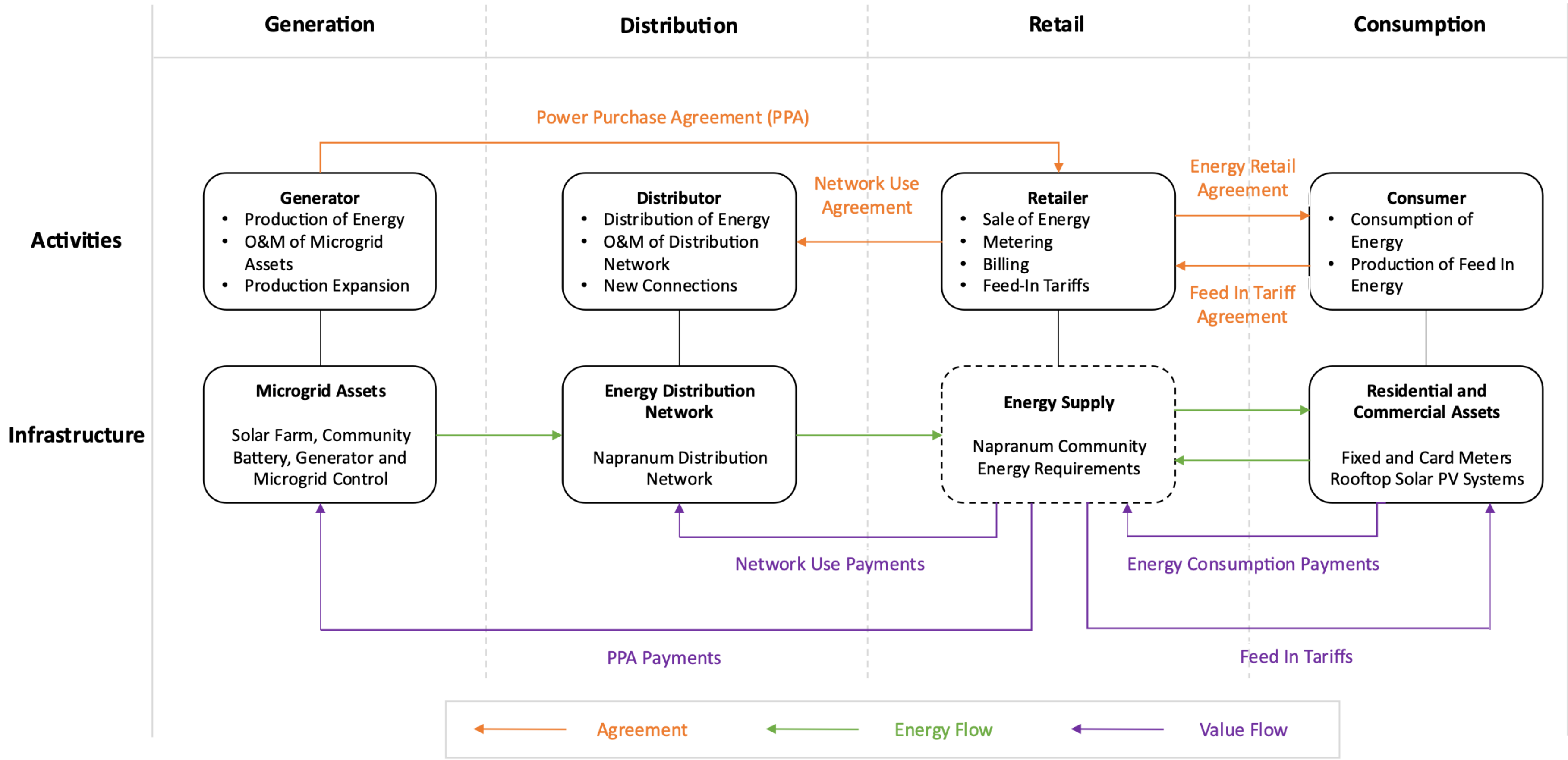


Figure 36: Energy and value flows from generation to consumption

10.5 Microgrid Ownership and Operating Models

Extensive investigations were undertaken as part of this feasibility study into possible financing / funding models for the project assets. This in turn required consideration of the potential ownership and operating structure for the project assets. While various ownership and operating models were considered, following consultations with NASC, as the key proponent for the project, and other key stakeholders, the following preferred options were identified as requiring further consideration:

- Structure 1 – NASC Owned with Contracted Operation and Maintenance
- Structure 2 – EQL Owned and Operated
- Structure 3 – Third Party Owned and Operated

These three structures have been discussed in further detail below.

10.5.1 Structure 1 – NASC Owned with Contracted Operation and Maintenance

Structure 1 includes NASC, directly or through a wholly owned subsidiary, retaining outright ownership of the core microgrid assets. Through this structure NASC would design, finance and construct the microgrid assets and would retain ownership and control of the assets post construction. NASC would also be responsible for determining the arrangements for the ongoing operation and maintenance of the infrastructure.

Following consultations with NASC, a preferred model for the ongoing operation and maintenance of the microgrid assets is expected to involve an outsourced arrangement with a third-party operator (such as EQL). While the specific terms and conditions of such an arrangement would be subject to commercial negotiation, in general terms it is expected that NASC would directly contract an operator to manage the ongoing operation of the assets. The operator would also be required to maintain the assets to an agreed standard.

In return, the operator would secure an interest or a right to energy generated by the microgrid assets and would enter arrangements with energy retailers for the sale of this energy. The return for NASC would be informed through commercial negotiations, however, the revenue mechanism is expected to be linked to the net return to the operator arising from the sale of energy. Additional returns may be sourced through Council rates and levies and access charges.

An overview of the proposed structure is provided in Figure 37 below.

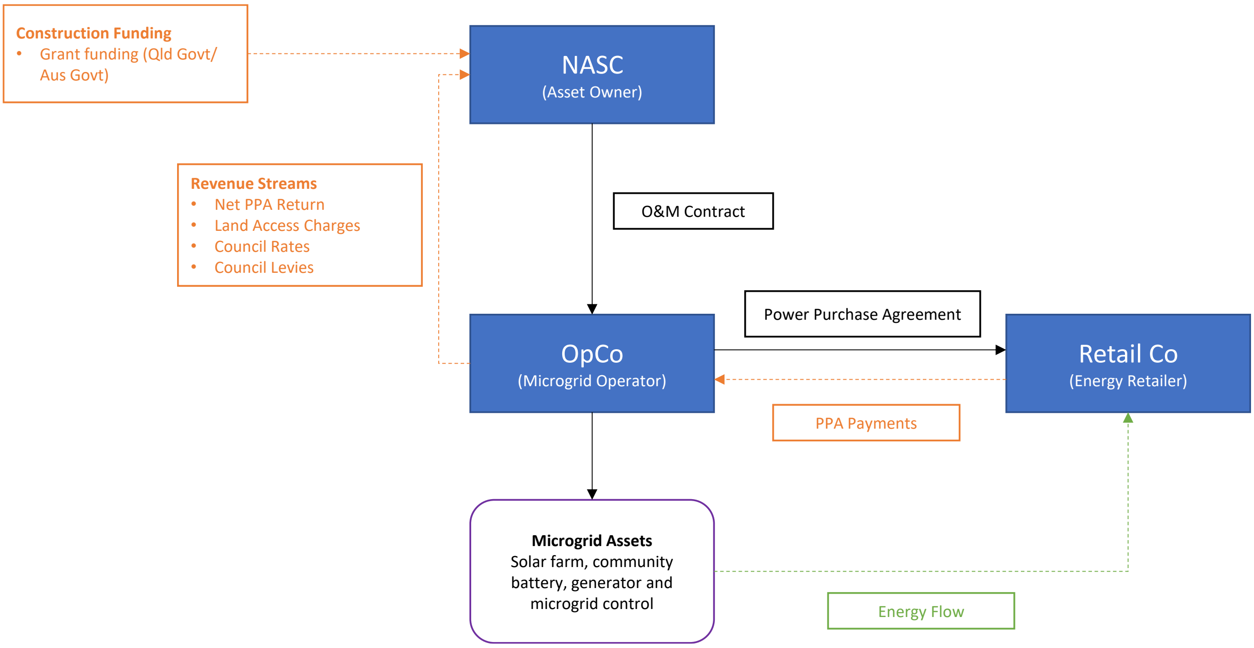


Figure 37: NASC owned with contracted third-party operator

A variation to this structure may include NASC leasing the assets directly to a third-party operator. Under this arrangement, NASC would have limited exposure to the costs and benefits of operating the assets and would receive an agreed annual payment in respect of the leased assets. The lessee (or microgrid operator) would assume full responsibility for the costs of operating the project assets and would benefit entirely from the sale of energy generated. Depending on the nature of the lease, NASC may also levy Council rates and other statutory charges. An overview of the proposed structure is provided in Figure 38 below.

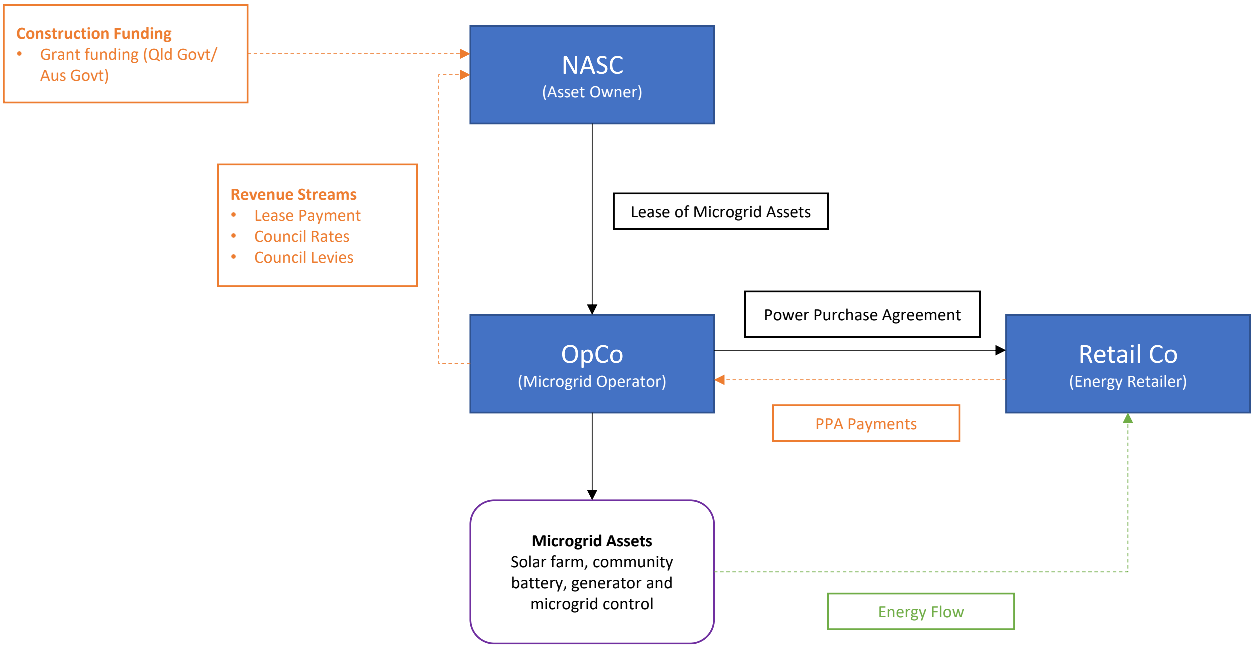


Figure 38: NASC owned with assets leased to third party operator

Under either model, with NASC retaining ownership of the assets and dictating the commercial terms pertaining to the operation of the assets, it is expected that the desired benefits of the project, in terms of the supply of reliable power and reduced energy costs, will be delivered to the Napranum community.

10.5.2 Structure 2 - EQL Generation – Owned and Operated

Structure 2 considers an ownership structure whereby EQL (or a related entity) would design, finance, construct, own and operate the core microgrid assets. The generated energy would be fed into the existing power distribution network and EQL would enter an arrangement with the retailer (EER) for the sale of the energy. As EQL is the parent GOC company for both Network and Retail activities in isolated communities like Napranum, the entity may also receive additional revenue through the Community Service Obligation (CSO) and system usage charges.

Under this arrangement, NASC would receive a lease payment for the land upon which the microgrid assets sit, in addition to potential access charges and Council rates and levies. NASC would have little to no control over the final design of the project assets or the outcomes for the community and would rely on EQL to ensure that the final infrastructure adequately meets the needs of the Napranum community. Notwithstanding, it is expected that the microgrid would generate lower cost energy into the network, with these savings being passed on to Government as a reduced CSO liability, noting that regulated electricity tariffs are available in Napranum under current Queensland Government policy. Furthermore, the proposed structure would pass all responsibility for the construction of the assets (including financing) onto EQL.

EQL would be responsible for arranging the sale of energy (i.e., a PPA) for that which is produced by the microgrid and would be responsible for engaging and managing staff to operate and maintain the assets. This model replicates the existing arrangements in other remote and isolated communities in regional Queensland where EQL is responsible for generating and distributing electricity.

An overview of the proposed structure has been outlined in Figure 39 below.

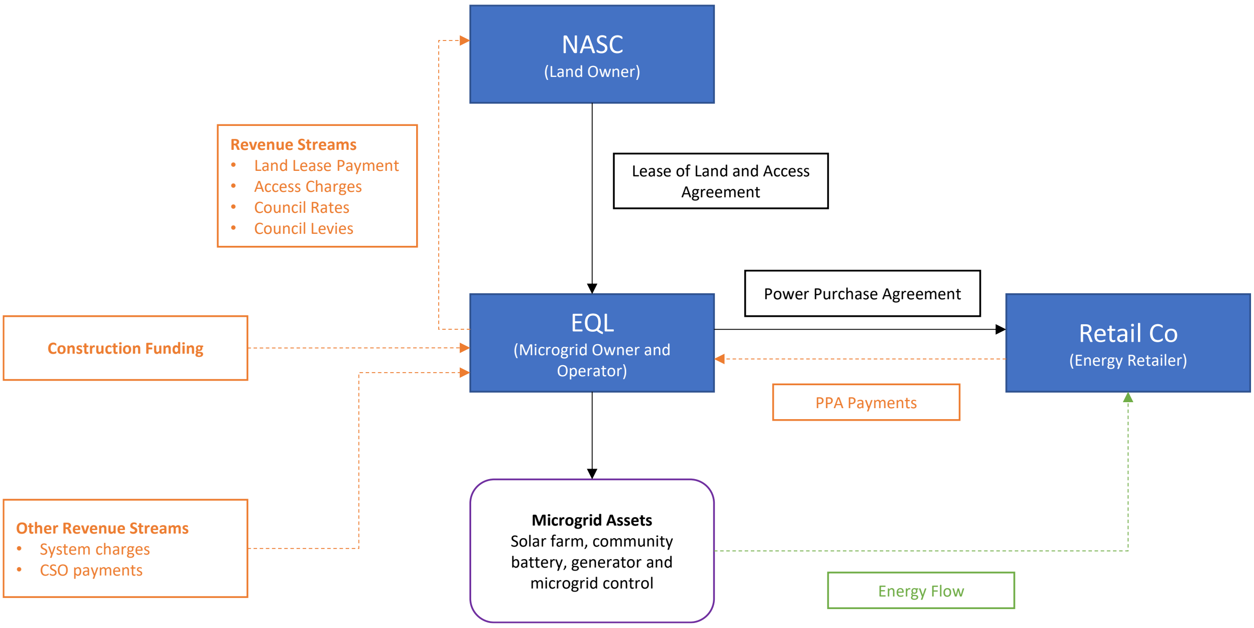


Figure 39: EQL owned and operated microgrid

10.5.3 Structure 3 – Third Party Owned and Operated

Structure 3 is similar to Structure 2, with the microgrid assets being owned and operated by a third-party entity. Under this structure, rather than the third-party entity being EQL, an independent party, likely a private sector organisation (GenCo), would establish, own, and operate the core microgrid assets. GenCo would sell any power generated by the microgrid to an energy retailer in accordance with a negotiated PPA.

Under this arrangement, NASC would receive a lease charge for the land upon which the microgrid assets sit, in addition to potential access charges and Council rates and levies. As with Structure 2, NASC would have little control over the final design of the project assets or the outcomes for the community and would rely on the GenCo to design, construct and operate a system that adequately meets the needs of the Napranum community. Notwithstanding, it is expected that the microgrid would generate lower cost energy into the network, with these savings being passed on to Government as a reduced CSO liability, noting that regulated electricity tariffs are available in Napranum under current Queensland Government policy. Furthermore, the proposed structure would pass all responsibility for the construction of the assets, such as financing, onto GenCo.

GenCo would set a commercial rate for the sale of energy aligned to company policies which may be different to the rate that EQL would set under Structure 2, given that EQL is a Government-owned Corporation. There would be a net economic benefit if the rate set by the GenCo was less than the current rate charged by RTA.

Structure 3 has been outlined below in Figure 40.

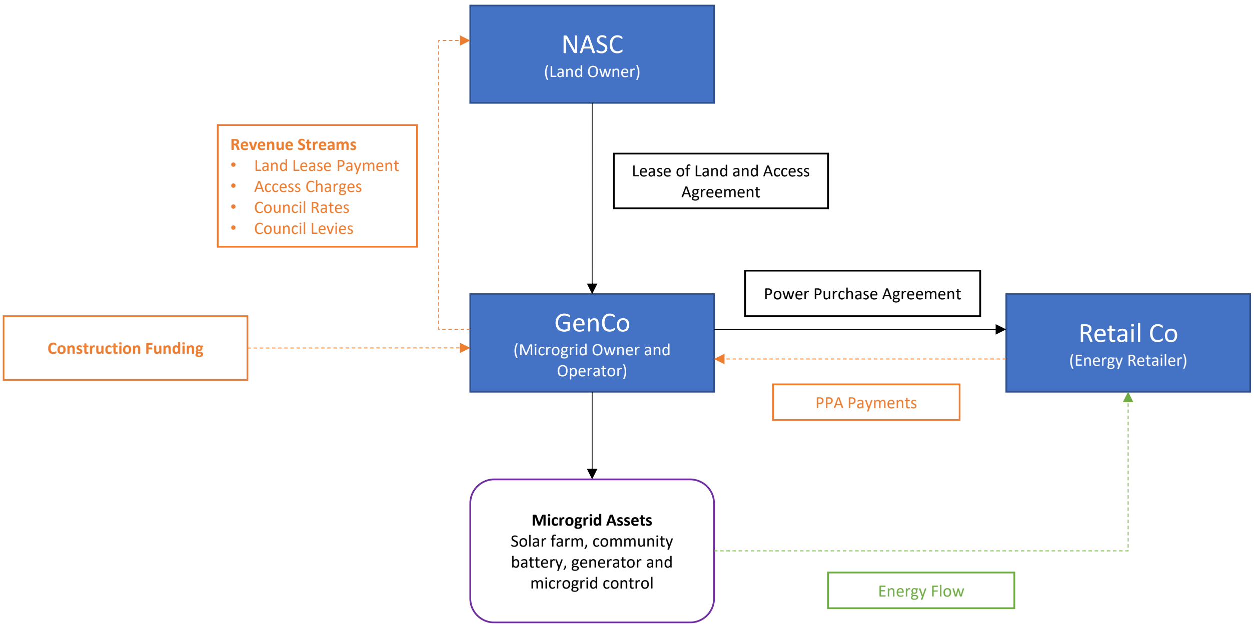


Figure 40: Third-party entity (non-EQL) owner/operator of microgrid

10.6 Summary

The energy flow model associated with the proposed microgrid solution comprises of four distinct elements: generation, distribution, retail, and consumption. Each element comprises of separate infrastructure and the activities under each are commonly managed by separate entities. In designing a potential ownership and operating structure for a microgrid for a community such as Napranum, it is important to consider the energy flow model and the value drivers for each element.

Based on consultations with NASC as the key proponent for the project, a preferred ownership and operating model includes one in which NASC retains ownership of the microgrid assets. Once constructed, it is the preference of NASC that a third-party entity is engaged to operate and maintain the assets, and to negotiate arrangements with energy retailers for the sale of energy generated.

Alternate structures may also be considered, whereby a third-party entity retains ownership and control of the microgrid assets, however, a risk exists that such an arrangement may not deliver the optimal outcome for the Napranum community in terms of delivering reliable and affordable energy.

10.7 Funding Assessment

The purpose of this section is to provide a summary of the alignment of the project with key Government policies, programs and initiatives focused on the renewable energy sector and targeted at supporting the advancement of Indigenous communities. In turn, this section seeks to present a range of potential current or past Government and non-Government funding options that may exist for the construction of the project assets.

10.7.1 Funding Options

Based on an assessment of the existing Government and non-Government programs targeted at supporting renewable energy projects and the advancement of Indigenous and remote communities, a range of potential funding options for the project were identified. The following list represents current or announced funding programs that may be accessed to support the development of the microgrid and related infrastructure. An exhaustive list of government policy, initiatives, and programs is in Appendix F.

Funding Program	Description
Queensland Microgrid Pilot Fund (QMPF)	As part of the Queensland Energy and Jobs Plan, the QMPF will invest up to $10 million over two years to boost the resilience of regional and remote communities to extreme weather events, through supporting the development and delivery of microgrids across Queensland. The QMPF provides grant funding under two streams. Stream 1 allows for between $250,000 and $750,000 to support feasibility studies into the development of microgrid projects. Stream 2 provides funding up to $5 million in relation to the construction of microgrid infrastructure and supporting assets. Grant funding is available for microgrid projects that meet the QMPF program objectives. The total funding allocated for QMPF is up to $10 million, which can at any point be reduced at the discretion of the Queensland Department of Energy and Public Works (DEPW). It is noted, however, that under the current QMPF guidelines, the funding will only apply to “grid-connected” networks. It is understood that while the Napranum network is supported by EQL, it does not currently fall into this category. Notwithstanding, there may be an opportunity for the program to be extended to encompass communities such as Napranum in due course.
Queensland Renewable Energy and Hydrogen Jobs Fund (QREHJF)	The Queensland Renewable Energy and Hydrogen Jobs Fund allows energy Government owned corporations to increase ownership of commercial renewable energy and hydrogen projects, as well as supporting infrastructure, including in partnership with the private sector. Investment proposals may be submitted for consideration and will be assessed against the following criteria: Renewable energy – development of additional renewable energy generation and storage capacity and how this contributes to the State’s renewable energy targets. Commerciality – level of commercial value demonstrated by the project Employment and Jobs – the extent to which the project creates new employment opportunities and training. Applications to the fund are assessed progressively as proposals are received.
ARENA - First Nation’s Community Microgrid Fund	As part of the 2022-23 Federal Budget, ARENA was allocated funding of up to $83.8 million for the First Nations Community Microgrids Program. While the specific details of the program are yet to be released, the objective of the program is to increase access to cheaper, cleaner and more reliable energy for the identified communities. It is expected that the funding may be used to assess, design and construct microgrid projects to support the identified communities.
ARENA – Community Battery	The Community Batteries for Household Solar Budget Measure was announced in the October 2022 Commonwealth Budget. Funding of up to

for Household Solar Program	$171 million to be administered by ARENA over 4 years (until 2025-26). The Program aims to deploy community batteries across Australia to lower bills, cut emissions and reduce pressure on the electricity grid by allowing households to store and use the excess power they produce. ARENA are currently preparing funding application materials, including funding guidelines, and are undertaking an extensive market consultation process to inform the conditions that will attach to funding program. Expressions of interest for the program are expected to open in the first half of 2023.
ARENA – Regional Australia Microgrid Pilot Project (RAMPP)	As part of the 2020-21 Federal Budget, $50 million of funding was allocated over a six-year program that aims to improve the resilience and reliability of power supply for regional and remote communities. The RAMPP builds upon the Australian Government's Regional and Remote Communities Reliability Fund (RRCRF), which funded feasibility studies for regional and remote communities to investigate deployment of local microgrid technologies. Funding under the RAMPP will be made available over two stages. Stage 1 (launched in CY22) included $30 million in funding and Stage 2 (to launch in CY23) will include $20 million in funding. Grants of between $1 million and $5 million may be provided, with projects exceeding $5 million requiring demonstration of significant and broad industry benefit. The program assesses applications across a range of criteria including alignment with program objectives, capacity and capability of the applicant, design and delivery methodology and financial viability and co-funding. In addition, all projects and applications must be supported by a robust feasibility study. Applications for funding are now open.
ILSC – Our Country, Our Future	ILSC partners with Indigenous Australians to provide economic, environmental, social and cultural benefits through acquisition of land or water rights and assistance in managing these rights. The Our Country, Our Future funding program is central to achieving this objective. Through the funding program ILSC offer direct funding, provides advisory and capability development services and facilitates connections with technical advisors to enable projects to progress. While the program does not directly focus on the development of renewable energy projects, there is clear alignment in supporting Indigenous communities to build capacity and to deliver economic growth through the creation of enabling land-based utility infrastructure. Furthermore, the development of microgrid infrastructure will progress initiatives towards preserving the environment and improving outcomes for the community. The program is currently open for expressions of interest.
NIAA – Indigenous Advancement Strategy	The National Indigenous Australians Agency (NIAA) administers the Indigenous Advancement Strategy (IAS). The IAS is the way the Australian Government funds and delivers a range of programs for Indigenous Australians. The IAS is focused on providing positive impact to Indigenous communities through improvement of education, employment, economic development and social participation, and growing healthy and safe communities. In the 2019-20 Budget, the Australian Government allocated $5.2 billion to the IAS, over four years to 2022-23, for grant funding processes and administered procurement activities that address the objectives of the IAS. Applications are assessed on their contribution to improving the lives and outcomes for Indigenous Australians against key priority areas. The program is currently open for applications.

Western Cape Communities Trust (WCCT)	The Western Cape Communities Trust (WCCT) will support and sponsor initiatives and activities of communities living within the Western Cape Communities Co-Existence Agreement (WCCCA) area that are for charitable purposes or promoting benefit to the overall welfare of the communities. Support may be offered in areas such as: • Community development • Community well being • Whitegoods acquisition While the funding is specifically for Traditional Owners groups and their communities, assistance may contribute to energy efficiency upgrades of dwellings through appliance upgrades.
Minderoo Foundation	The Minderoo Foundation was established to address tough and persistent issues in society with the objective of drive significant change in the community. As a philanthropic organisation, Minderoo directs funds to a diverse range of causes to effect change. The foundation contributes to initiatives that seek to create parity with and for Indigenous Australians and to build resilience within communities. Opportunities may exist for the Project to seek funding under these initiatives where notable advancement towards achieving the objectives of these initiatives can be demonstrated.

10.8 Financial Assessment

10.8.1 Overview

A financial assessment was completed in relation to the preferred microgrid option for the project to ascertain its financial viability, and to provide a future looking forecast of the funding requirements for the project. The purpose of this section is to provide an overview of the financial assessment conducted. The key components in this analysis include:

- General financial assumptions - outlines the methodology and input assumptions underpinning the financial assessment.
- Construction phase - presents the costs, timing and assumptions expected during the construction of the project.
- Operating phase - outlines the operating performance of the project assets, including its forecast operating costs and revenues.
- Financial analysis - presents the project's overall financial analysis in terms of forecast profit and overall sustainability.

The assumptions relied upon in preparing the model are preliminary in nature and are indicative only. It is recommended that a more detailed financial model is prepared as details regarding ownership, management, technical requirements, and commercial arrangements are refined.

10.8.2 Ownership and Operating Structure

For the purposes of the model, NASC has been assumed as the owner and operator of the project assets and will retain responsibility for the design, financing, construction, and operation of the microgrid. For modelling purposes, it has been assumed that the project assets will be held in a separate special purpose vehicle (SPV) entity incorporated and controlled by NASC.

To support NASC in designing, constructing, and operating the assets, it has been assumed that an external project management team (comprising of project management specialists) would be engaged to oversee the project through construction and into the operational phase. The team (Project Management Office) would support NASC in coordinating all preliminary works (for example technical studies, contracting, commercial negotiations etc) and would remain for the initial 3 years of operation to support in a capability building and economic development capacity. NASC would also employ two full time operational officers to operate and maintain the microgrid assets throughout the lifecycle.

Any future arrangement with a third party to operate and maintain (or lease) the assets would be subject to specific commercial negotiation and may change the outcomes of this financial assessment. As part of such negotiations the financial model would require amendment to reflect the agreed commercial terms underpinning a future proposed operating structure.

10.8.3 Assessed Microgrid Option

For the purposes of this assessment, microgrid option 2 (per section 9.1 of this report) has been assessed in detail in this section. The elements of this microgrid option are as follows:

- 2 MW solar PV array
- 900 kW backup diesel generation
- 2.7 MW 4-hour BESS
- 300 kW Rooftop Solar PV

This microgrid option is designed to generate most of the power requirements for the Napranum community, with the connection to the RTA Weipa network maintained for redundancy.

10.9 General Financial Assumptions

10.9.1 Methodology

The financial analysis for the project was undertaken considering industry standards. The project cashflows modelled in this financial analysis are based on the capital costs, operating costs, and revenues to a pre-tax level (Earnings Before Interest, Tax, Depreciation, and Amortisation (EBITDA)). These cashflows are based on the cost of the project in today's (2023) dollars and have been escalated as required for inflation or other factors.

10.9.2 Financial Assumptions

The key financial assessment assumptions that have been incorporated into the financial model, and the sources of those assumptions (as of 31 December 2022), are presented in Table 27. These include broad assumptions such as general timing and inflation which underpin the cash flow analysis. The general approach to these assumptions was confirmed with key project stakeholders.

Table 27: Key financial assumptions

Input Assumption	Description
Commencement Date of Analysis	1 July 2023
Commencement of Project Activities	1 July 2023
Commencement of Operations	Financial year immediately after completion of construction works for each Stage
End of Financial Assessment	30 June 2043
Total Assessment Period	20 Years
Inflation	1.5% per annum applied to each year of the construction and operational phases to represent the inflated price of goods and services over time
Periodic	Annual
Rounding	Rounding to the whole number

10.10 Construction Phase

A preliminary concept design cost plan for the project was prepared as part of the technical option analysis. This assessed the direct cost to construct the project assets based on industry standards. In addition to these cost estimates, other costs have been included as capital expenditure for items such as preliminary construction works, planning, program and project management, detailed studies and analyses, site assessments, tendering, contracting and related items.

The total construction cost estimates were prepared based on the following assumptions:

- All prices exclude GST.
- Costs are based on industry benchmark data from similar projects as advised by ITP.
- Costs include design, planning and approval fees, contract administration, construction costs, contingencies, contractor margins and overheads.
- Costs are presented in real 2023 terms and escalated at a rate of 1.5% per annum.
- No allowance has been made for staging or delayed construction costs.
- Consideration has been given to the additional costs associated with undertaking works in a remote location including site establishment, freight etc.

10.10.1 Capital Development Cost

A summary of the construction cost estimate for the project has been outlined below:

Table 28: Cost estimates

Capital Expenditure Summary	FY23	FY24	FY25
Program Management Office	2,950,000	-	-
Solar Farm, Battery, Generator	-	16,629,000	-
Total Capital Expenditure	**2,950,000**	**16,629,000**	**-**

Collectively, the total estimated capital cost for the project is expected to be $20.00M over a 2-year period (excluding GST). The construction of the project is assumed to be completed through a fixed price contract; therefore, no escalation has been applied to the total capital cost.

The capital cost of $2.95M allocated to the Program Management Office relates to the detailed assessments and investigations required to refine the concepts presented as part of the feasibility study and option analysis. This amount includes costs such as:

- Community consultation and engagement
- Technical specifications
- Hydrology studies
- Land and site assessments
- Detailed designs and engineering reports
- Detailed financial and commercial analyses
- Quantity surveys
- PMO establishment

An amount of $1.1M has also been included in this budget for energy efficiency audit and upgrade of certain household appliances. These preliminary works will be required to advance the project to a shovel ready state.

10.10.2 Capital Refurbishments

The costs of maintaining the project assets have been reflected as operating repairs and maintenance expenditure. The rates used for the repairs and maintenance expenditure applicable to the project assets have been determined with reference to industry benchmarks.

Major capital refurbishments for certain project assets have been reflected in the financial model. These amounts are as follows:

Table 29: Capital refurbishment costs

Refurbishment Capital Expenditure Summary	FY35	FY36	FY37	FY38
Program Management Office	-	-	-	-

Solar Farm, BESS, Generator	6,703,001	-	-	-
Total Refurbishment Capital Expenditure	**6,703,001**	**-**	**-**	**-**

Collectively, the total estimated sustaining capital cost for the project is expected to be $6.703M (excluding GST) commencing approximately 10 years after completion of project construction works. These costs have been estimated based on FY23 rates and have been escalated by annual inflation of 1.5%.

10.10.3 Capital Revenues

Due to the nature of project assets, it has been assumed that the project construction will be primarily funded through Federal and State Government contributions. As such all capital expenditure requirements have been matched with capital revenues of the same level. Target funding programs have been outlined in detail in this Report. The timing of the receipt of grant funds has been assumed to align with the financial year in which expenditure is incurred.

10.11 Operating Phase

The operating phase for each of the project stages will commence immediately after the construction phase ends. All operating revenues and costs outlined in the summary below reflect their rates in today's (2023) dollars. Operating revenues and costs have been escalated based on a nominal growth rate of 1.5% per annum (unless otherwise stated).

10.11.1 Operational Revenues

Operating revenues for the project are expected to be generated from PPA with the designated energy retailer. The table below summarises the total operating revenues generated by the project assets for the first eight years of operation.

Table 30: Operating revenue

Operating Revenue	FY26	FY27	FY28	FY29	FY30	FY31
Operating Revenue - PPA Payments	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415
Operating Revenue - Grants	-	-	-	-	-	-
Operating Revenue - Other	-	-	-	-	-	-
Total Operating Revenues	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415

Based on an assessment completed by ITP, it was determined approximately 4,500,000 kWh of energy would be generated annually by the microgrid assets. For a baseline assessment it has been assumed that NASC will enter into a PPA with EER to purchase this energy at a rate of $0.24/ kWh (and escalated by 1.5% per annum)[57]. To illustrate the impact of the chosen PPA rate on the broader financial assessment, Section 10.12.2 provides a scenario analysis of varying rates for the PPA on the EBITDA for the Project.

In addition to the PPA payments, other income streams may be sourced through Government grants directed at yielding specific social outcomes, for example employment and training. While it is expected there is a high likelihood of the project attracting such income, these revenues have not been factored into the financial assessment as these programs will require specific application as and when they open.

Furthermore, while the primary revenue stream has been assumed to include payments under a PPA, to the extent that an alternate operating model is adopted, for example third party lease of microgrid assets, we expect an equivalent "lease" payment would be returned to NASC in lieu of the PPA payment reflected in the assessment.

10.11.2 Operational Costs

This section outlines the ongoing costs associated with the operation and maintenance of the project assets.

Employment Costs (Salaries, Superannuation and On Costs)

Employment costs included in the model relate to two primary streams:

- Program Management Office staff
- Operations and Maintenance staff

Annual employment costs have been determined with reference to the relevant industrial awards and industry averages in the Napranum and surrounding communities for the specific role. The base rates are as follows:

Table 31: Base rates

Role	Base Annual Salary (Excluding On Costs)
Operations Officer	$60,000
Program Director	$150,000
Program Support Officer	$80,000

Superannuation has been included for these roles based on the following rates:

[57] The current retail price for Ergon Energy Retail Residential General Supply Tariff 11 is $0.24385 per kWh.

Table 32: Superannuation rates

Financial Year	Rate
FY23	10.5%
FY24	11.0%
FY25	11.5%
FY26 Onwards	12.0%

In addition to these costs, nominal estimates for payroll tax and workers compensation cover have been calculated for staff employed. These costs have been estimated based on the following rates:

Table 33: Tax and compensation rates

On Cost	Rate
Payroll Tax	4.75%
Workers Compensation	2.00%

The FTEs included within the model are summarised as follows:

Table 34: Model FTEs

Role Title	FTE	Duration
Program Director	1	FY24 to FY28
Program Support Officer	1	FY24 to FY28
Operations Officer	2	FY26 to FY43

Operating Costs & Overheads

Operating costs for the microgrid project have been primarily determined based on estimates provided by ITP for direct operation and maintenance costs, considering industry benchmark information. In addition to these costs, special program costs and overheads have been included as operating costs. These costs are reflected across the following categories:

- Direct Costs – O&M Expenses
- Direct Costs - Facility Expenses
- Overheads

The operating costs across each Stage of the project have been outlined below.

Program Management Office

As the project has been assumed to be established under a separate entity, the costs associated with operating the entity and supporting the employees have been included within the Program Management Office (PMO) area. These costs primarily relate to leasing and operating an office facility and supporting the corporate functions of the PMO.

Item	$/ annum
Facility Expenses	62,000
Other Overheads	49,200

Community Solar Farm, BESS, and Generator

The operating and maintenance costs associated with the community microgrid assets have been determined based on industry benchmarks.

Table 35 outlines the cost basis for direct operating costs associated with the community solar farm, BESS, and generator.

Table 35: Cost basis

Item	Rate	Unit
PV System - O&M	$30.14	$/kWh
Battery - O&M	$37.43	$/kWh
Diesel Generator - O&M	$15.66	$/kW
Microgrid Control Unit - Subscription	$50,000.00	$/annum
Microgrid Rooftop Droplet – Subscription	$10,000.00	$/ annum
Land Lease, Site Maintenance and Utilities	$170,000.00	$/annum

10.12 Financial Analysis

Table 36 outlines the summary financial assessment completed for the first eight years of the project. Detailed financial statements for the assessed life of the project have been attached in Appendix A.

Table 36: Financial assessment 2024-2031

Financial Summary	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
Profit and Loss								
Operating Revenue	-	-	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415
Capital Revenue	2,950,000	17,305,831	-	-	-	-	-	-
Total Revenue	**2,950,000**	**17,305,831**	**1,112,441**	**1,129,128**	**1,146,065**	**1,163,256**	**1,180,705**	**1,198,415**
Less: Direct Costs	(347,298)	(353,812)	(1,036,026)	(1,051,566)	(1,067,340)	(773,234)	(784,833)	(796,605)
Less: Operating Expenses	(49,200)	(49,938)	(50,687)	(51,447)	(52,219)	(53,002)	(53,797)	(54,604)
EBITDA	**2,553,502**	**16,902,082**	**25,729**	**26,115**	**26,506**	**337,020**	**342,075**	**347,206**
Less: Interest & Depreciation	(118,000)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)
Net Profit/ (Loss) Before Tax	**2,435,502**	**16,091,848**	**(784,504)**	**(784,119)**	**(783,727)**	**(473,214)**	**(468,158)**	**(463,027)**

Cashflows								
Operating Cashflows	(387,383)	(403,588)	(31,899)	25,389	25,906	336,136	341,316	346,436
Capital Grants	2,950,000	17,305,831	-	-	-	-	-	-
Capital Expenditure	(2,950,000)	(17,305,831)	-	-	-	-	-	-
Other Cash Adjustments	5,743	1,344	27,189	2,224	2,145	(6,974)	948	952
Net Cashflow	**(381,640)**	**(402,244)**	**(4,711)**	**27,613**	**28,051**	**329,163**	**342,264**	**347,388**

10.12.1 Investment Metrics

Based on a discount rate of 6% and utilising earnings before interest, tax, depreciation and amortisation (EBITDA), as an indicator of the free cashflows arising from the project, the following metrics were returned:

Financial Metrics	
Net Present Value (NPV)	(20,103,501)
Internal Rate of Return (IRR)	-19%

It is noted that these calculations have been determined excluding the assumed capital grants for the construction and future refurbishment of the microgrid assets.

Based on these metrics alone, with a negative NPV of $20.1M combined with an expected IRR of -19%, this would indicate that the project not suitable for investment in its own right and is reliant on capital grant funding for the cost of construction and future refurbishment of the assets. Conversely, where capital grants for the construction and future refurbishment of the assets are included in the calculation, the following metrics were returned:

Financial Metrics	
Net Present Value (NPV)	2,005,613
Internal Rate of Return (IRR)	22%

Under this scenario, with a positive NPV of $2.0M and IRR of 22%, the project does present as a viable investment option.

10.12.2 Alternate PPA Rates

In Section 10.11.1 it was noted that the PPA rate assumed for the base financial analysis was $0.24/kWh. As the current rate paid by EER for power generated for the Napranum community is not publicly available, it has been assumed that this rate is conservative and the potential for a higher price for the energy is likely. The following table provides an overview of the impact on the revenue and EBITDA by varying this rate across a range of upside alternative rates:

Table 37: PPA rates 2024-2031

PPA Rate	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
Base Case - $0.24/kWh								

Operating Revenue	-	-	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415
EBITDA	2,553,502	16,902,082	25,729	26,115	26,506	337,020	342,075	347,206
Alternative 1 - $0.30/kWh								
Operating Revenue	-	-	1,390,552	1,411,410	1,432,581	1,454,070	1,475,881	1,498,019
EBITDA	2,553,502	16,902,082	303,839	308,397	313,023	627,834	637,251	646,810
Alternative 2 - $0.40/kWh								
Operating Revenue	-	-	1,854,069	1,881,880	1,910,108	1,938,760	1,967,841	1,997,359
EBITDA	2,553,502	16,902,082	767,356	778,867	790,550	1,112,524	1,129,211	1,146,150
Alternative 3 - $0.60/kWh								
Operating Revenue	-	-	2,781,104	2,822,820	2,865,163	2,908,140	2,951,762	2,996,039
EBITDA	2,553,502	16,902,082	1,694,391	1,719,807	1,745,604	2,081,904	2,113,132	2,144,829
Alternative 4 - $0.80/kWh								
Operating Revenue	-	-	3,708,138	3,763,760	3,820,217	3,877,520	3,935,683	3,994,718
EBITDA	2,553,502	16,902,082	2,621,426	2,660,747	2,700,658	3,051,284	3,097,053	3,143,509

As is evidenced in the above analysis, with increasing PPA rates for the energy generated by the microgrid assets, the potential return (EBITDA) for the owner grows substantially. To the extent that a higher PPA rate can be negotiated for the energy generated by the microgrid, alternate funding and financing arrangement options may be considered.

A comparison of NPV and IRR under the five scenarios is summarised in Table 38:

Table 38: Comparison of NPV and IRR

	Calculation Excludes Capital Grant Revenue		Calculation Includes Capital Grant Revenue	
Scenario	NPV ($)	IRR	NPV ($)	IRR
Base Case - $0.24/kWh	(20,103,501)	-19%	2,005,613	22%
Alternative 1 - $0.30/kWh	(17,122,396)	-11%	4,986,719	43%
Alternative 2 - $0.40/kWh	(12,153,888)	-4%	9,955,226	76%
Alternative 3 - $0.60kWh	(2,216,871)	-2%	19,892,243	132%
Alternative 4 - $0.80kWh	7,720,145	11%	29,829,259	177%

What is highlighted in the above table is that where a PPA rate of $0.80/kWh or above can be achieved, the Napranum microgrid assets would be suitable for investment without the need for capital grant funding for construction or refurbishment. For PPA rates below this amount, it is likely that some level of grant funding would be required to support the construction and future refurbishment of the microgrid assets. Conversely, where grant funding is available for the whole capital cost, the project presents as a viable investment under all scenarios considered.

As noted, the financial assessment was prepared based on the preliminary concept ownership and management structure and defined elements of the project. Many of these elements are subject to further commercial negotiation and refinement. As such, the assumptions relied upon in preparing the financial model are preliminary in nature and are indicative only. It is recommended that a more detailed financial assessment is undertaken as details regarding ownership, management, technical requirements, and commercial arrangements are refined. The outcomes of this assessment alone should not inform a future investment decision in the project, but rather should be used to inform whether the project is suitable for further investigation.

11

Challenges and Barriers to Uptake

11 Challenges and Barriers to Uptake

11.1 Challenges

Napranum and other remote communities face many challenges in building community resilience and developing community infrastructure projects due to several factors which can be exacerbated by remoteness, lack of capacity, technological knowledge, and community preparedness to take control and implement change.

Napranum leaders have expressed their strong support and desire for a more reliable and sustainable microgrid system and recognise the broader community benefits that can be leveraged from the project.

The key considerations include:

- Meeting community expectations for improved reliability and energy cost-reductions.
- Community willingness to participate in energy efficiency programs including behavioural changes and capacity to purchase energy-efficient appliances will influence the forecast economic return to households and the community.
- The emerging Regulations for remote and isolated microgrids and how this may impact potential ownership and operational models including the roles of NASC, RTA and EQL in any reconfiguration of the supply network.
- NASC's reliance on external funding to progress the development of the microgrid and associated infrastructure and operating model[58]. The estimated cost to implement the project is $20.0 million over 2 years with a future investment of $6.7 million for refurbishment works approximately 10 years after commissioning.
- Assumptions that revenue from sale of energy and other potential revenue streams is expected to cover operating costs.
- Development of a microgrid at Napranum challenging the traditional energy supply planning and investment criteria for EQL, and the current supply arrangements with RTA.
- Existing RTA policies regarding the deployment of rooftop solar PV systems at Napranum and Weipa township.
- Future energy needs and available capacity in the Weipa area when mining operations eventually cease at Weipa and Andoom mines.
- Meeting government-stated objectives for reducing greenhouse gas emissions including at remote indigenous communities.

[58] Assumes that NASC is the asset owner and subcontracts or leases the assets to an operator/maintainer

11.2 Barriers to Uptake

11.2.1 Community Expectations

Despite the regular engagement with Napranum Council, the extent of penetration of information and knowledge about the proposed microgrid in the broader community is relatively low.

However, based on feedback received during community surveys and energy audits, it is clear to the project team that the key outcomes expected from the community are:

- An improvement in the reliability of electricity supply – less and shorter-duration outages.
- Provision of solutions that can reduce the impact of household electricity costs.
- Creation of employment opportunities for locals.
- A reduction in environmental impacts by utilising renewable energy solutions.

As part of the energy-efficiency program proposed to be delivered with the Napranum microgrid project, an ongoing engagement program will be implemented to inform, assist and educate residents. This will be particularly important for ensuring that:

- The level of energy literacy is increased to help residents make informed decisions about their energy use, tariff selection, and appliance purchase decisions.
- Residents adopt energy efficiency practices that can aid in reducing household electricity bills and contribute to reducing community energy demand.
- Community members understand the scope of work and the benefits, including improved power supply reliability outcomes and job opportunities and this will assist in securing a suitable development site for central microgrid assets.
- The cost, timeframes and technical solutions that may be feasible at Napranum, based on population, location, construction, operation, and maintenance considerations; ownership and other criteria are communicated in a timely manner.
- There is shared "ownership" of the new infrastructure including behind-the-meter components like rooftop solar panels, inverters, metering, and any fixed appliances that may be replaced as part of an energy efficiency roll-out to ensure that residents can support reliable operation of the equipment and timely maintenance and repairs.

11.2.2 Regulatory considerations

As noted in Section 5, remote and isolated communities such as Napranum are not physically connected to the national grid and are not currently subject to AER regulations applicable to generation and distribution services in the NEM. The Queensland government and QCA provide and administer an alternative regulatory framework in these locations.

Ergon Network owns and operates 33 remote and isolated power stations and associated electricity networks throughout regional Queensland and is responsible for the Napranum distribution network. It is feasible that they could also own and operate future generation facilities at Napranum in line with the current state-based regulations.

Should a third-party ownership model be preferred for the Napranum microgrid generation assets, ability to comply with the state-based regulations would be a primary requirement.

Ergon Retail currently purchases energy from RTA and provides energy retailing services at Napranum. Should a cost-effective alternative source of generation be established at Napranum, a PPA would need to be established with Ergon Retail for the purchase of the energy. The current power purchase arrangements with RTA would need to be renegotiated if Napranum remains connected to the RTA network, or terminated if a standalone system was implemented. Transitional arrangements would also need to be considered.

It will be necessary to ensure that the most appropriate ownership and operating model is established for the Napranum microgrid to ensure the safe and efficient operation of the system and compliance with regulatory requirements.

The cost of providing electricity supply in regional Queensland is currently subsidised by the government via a CSO payment to EQL. Napranum residents benefit from the CSO arrangements with access to standard tariff charges, a range of rebates and other safeguards and support mechanisms. No changes to current electricity retailing activities at Napranum are anticipated with the development of the microgrid.

This feasibility study has not assessed the impacts investing in the microgrid would have on the CSO, however, if energy could be locally produced at a lower price than currently available via RTA, this would lead to a reduced impact on the CSO for Napranum. A reduced impact on the Napranum CSO would be consistent with Queensland government and EQL long-term economic objectives.

The development of the microgrid would be subject to a range of Federal, State and Local planning instruments and legislation. It may require a project to undertake an Environmental and Social Impact Assessment at significant cost, resource and time commitment and report on its impacts and commitments over time.

Government and community agencies will have obligations to show compliance with, and progress to achieving regional, state, national and international commitments on climate change.

11.2.3 Cost and Funding Considerations

As outlined above, the estimated capital cost of the Napranum microgrid is $20.0 million with a future requirement of $6.70 million for refurbishment works after about ten years of operation. As a small Council which is reliant on government funding for its capital works and operational activities, this project is beyond the capacity of NASC to fund without external support.

Given that the microgrid project can demonstrate positive socioeconomic returns for the community, and aligns closely with many Queensland Government priorities, it is anticipated that the State government may support the implementation of this project.

Grant funding may also be available via a range of alternative programs offered by the Australian government. Alternative capital investment may be available via philanthropic sources or impact investment funds.

Potential funding sources and programs are outlined in section 10.7 of this report.

The financial analysis presented in section 10.8 identifies a range of investment outcomes that could be considered in more detail depending on the energy sale (PPA) price achievable as a result of building the microgrid.

For example, if energy was available at $0.30/kWh from the microgrid, government funding would be necessary to develop the infrastructure. However, if the price was $0.80/kWh then the project may represent a viable investment opportunity for a commercial enterprise.

Realising an energy sale price from the microgrid assets that reduces the current government CSO payment to Ergon Retail may create an incentive for government or EQL investment in the project.

The costs of providing affordable housing in remote indigenous communities are significant, and this has resulted in past practice of providing a basic level of housing based on generic designs with no provision for facilities such as rooftop solar PV systems and energy-efficient heat pump hot water systems.

It is recommended in this study that consideration be given to providing more energy-efficient housing designs that can contribute to reduced household energy costs for occupants and provide a contribution to the Napranum microgrid via rooftop solar PV systems. This would need to be considered in budget forecasts by the relevant government departments.

Many households at Napranum are living below the poverty line and there is a low level of individual home ownership. This could limit individual capacity to purchase and install energy efficient appliances or renewable energy technologies without subsidies or financial support. The Western Cape Communities Trust provides financial support for some members of the community that meet the Trust's criteria to assist with the purchase of energy efficient appliances.

The provision of 'behind the meter' renewable energy solutions such as rooftop solar PV and raising energy literacy could contribute to reducing the impacts of energy costs on household budgets over time.

11.2.4 Tenure – DOGIT & Native Title

As outlined in section 2, in many indigenous communities, land for infrastructure development is in limited supply, competing with other important requirements like the development of local housing stock.

Sufficient lead times need to be allowed for consultation with landholders and Native Title holders to address property issues like ownership, access, and operational requirements associated with implementing and maintaining microgrid infrastructure.

Whilst a potential development site has been identified in consultation with NASC, it is understood that most vacant land in the Napranum area is gazetted as Deed of Grant in Trust (DOGIT). NASC, Traditional Owners and the Mokwiri Aboriginal Corporation Registered Native Title Body Corporate (RNTBC) will be key stakeholders to engage early in the decision-making process to identify tenure of potential development sites and to assist in addressing access and other tenure issues.

11.2.5 Technology-based

It is imperative to ensure that the microgrid is designed to integrate seamlessly with the RTA Weipa network and to operate in island mode when the network is unavailable.

It may also be necessary to limit export of excess generated energy from the Napranum microgrid to the RTA network to avoid interference with mining operations.

This proposed configuration may add complexity to the final design but is not considered to be a significant barrier to implementation.

Operational protocols and/or automation will be essential to ensure the safe and reliable operation of the system and compliance with RTA and EQL Network Operating Standards.

It will be necessary to ensure that specifications for key plant items to be used in the microgrid consider the local environmental conditions, including their suitability for operating in a tropical environment with hot temperatures, humidity, rainfall, and coastal saline conditions.

11.2.6 Local policies and constraints

RTA currently applies a “no rooftop solar PV” policy at Weipa and Napranum. The company is developing centralised solar and BESS facilities at Weipa to offset diesel consumption. Therefore, NSCA is unable to install rooftop solar systems on council-owned houses to reduce their tenants’ energy bills.

Developing rooftop solar at Napranum as part of the microgrid solution is likely to introduce disparities between the two neighbouring communities.

Control systems would need to be established to ensure that energy generated within the Napranum community could not be exported to the wider RTA network, under the current constraints.

11.2.7 Future Weipa requirements

It is understood that the existing Weipa and Andoom mining operations have a finite life expectancy which may impact the broader energy requirements in the area over the next 5 to 10-year horizon.

There may be an opportunity for the Napranum microgrid to provide additional renewable energy or BESS capacity to support the Weipa town area in future when mining operations cease.

Detailed studies of the Weipa network would be required to establish future requirements.

This is beyond the scope of the current feasibility study.

12

Recommendations

12 Recommendations

This study has identified that the development of a microgrid at Napranum has the potential to address a range of Queensland government priorities for isolated indigenous communities, whilst addressing social and economic barriers currently faced by Napranum residents.

This report recommends progressing pre-implementation activities to advance the concepts developed in the feasibility study to test the assumptions made, and to confirm technical and commercial feasibility, before proceeding to develop the most appropriate and sustainable microgrid solution for the Napranum community.

Pre-implementation activities will require further close engagement with community and key stakeholders, whilst taking into consideration potential impacts on, and current constraints of, the existing Rio Tinto electricity supply infrastructure and operational arrangements.

Recommendation 1 – Community and Stakeholder Engagement

A formal Community and Stakeholder Engagement Plan be developed to ensure effective communication and consultation throughout the pre-implementation phase and beyond.

This plan should provide transparency of the project purpose and objectives, ensuring that Traditional Owners, community leaders and the broader community are informed, engaged, and have the opportunity to provide input to guide outcomes that will benefit the whole of the Napranum community.

Key stakeholders including NASC, Rio Tinto and Energy Queensland must be fully engaged to ensure the most efficient and effective operational model and technical solutions are implemented.

Additionally, other key stakeholders including government agencies and potential project funders should be engaged throughout this phase to progress implementation of energy efficiency programs, rooftop solar deployment, development of the energy efficient housing program, and to ensure funding is in place for the microgrid deployment program.

Recommendation 2 – Pre-implementation Partnership

In partnership, EQL and EnergyConnect undertake pre-implementation activities to develop the Napranum microgrid business case.

This would include knowledge sharing of learnings from the feasibility studies completed to date and working together to develop the most appropriate ownership and operating model, in consultation with NASC.

Additionally, a detailed review of potential commercial, environmental and social benefits associated with developing a sustainable microgrid solution would be prepared, identifying specific opportunities for EQL and the Queensland Department of Energy and Public Works to realise a number of the objectives of the Queensland Energy and Jobs Plan, potentially improving long-term financial returns to EQL and the Queensland Government through CSO reduction.

A cost-benefit assessment would also consider other factors including net greenhouse gas reduction and creation of local employment opportunities.

Recommendation 3 – Program Management Office

Subject to the outcomes of pre-implementation activities as per Recommendation 1, establish a Program Management Office (PMO). It is envisaged that initially this would entail allocating office space, equipment, and the engagement of a Program Director and Program Support Officer.

The PMO would initially be responsible for developing and managing the implementation works plan, coordinating funding applications, the stakeholder and community engagement program, preliminary activities associated with microgrid site identification and acquisition, and coordinating technical and commercial studies, as well as all other associated project management activities within a defined timeframe.

Recommendation 4 – Detailed Technical Studies

Undertake detailed technical studies for preferred option(s).

This may entail more detailed network modelling of both the EQL and RTA networks to assess the interaction between the microgrid and upstream power systems under various operating scenarios. It would be necessary to consider load flows, fault studies, protection and microgrid control system requirements.

Build on network modelling activities undertaken by EQL MIST team for the Napranum reticulation as part of this feasibility study.

These studies will inform the final technical design requirements for the microgrid.

Recommendation 5 – Rooftop Solar PV

Liaise with NASC and relevant government departments to undertake detailed assessment of Napranum rooftops to establish a list of properties suitable for hosting rooftop solar PV systems that would form part of the distributed energy resource component of the microgrid.

Prepare specifications for the deployment of rooftop solar PV systems and any associated building remediation works that may be required.

Note that there is currently a Rio Tinto ban on connection of rooftop solar PV systems in Napranum and Weipa, and it would be necessary to address all technical and other requirements to satisfy Rio Tinto's requirements before any rooftop solar can be deployed as part of the project implementation works.

Undertake metering alteration requirements to support the implementation of rooftop solar systems.

Recommendation 6 – Energy Efficiency and Education Program

Develop and deliver a community-wide energy efficiency program, including provision of energy efficiency advice to households. Local people could be trained to deliver and provide on-going support for this program.

Scope requirements for a program targeting replacement of inefficient appliances including air-conditioners and hot water systems and liaise with relevant government departments to ensure deployment of energy efficient appliances in new homes and during retrofit and refurbishment programs.

Liaise with government agencies to develop energy efficient housing design standards for social housing that reduce energy costs for tenants and can support the deployment of renewable energy-based microgrids.

13

Implementation Approach

13 Implementation Approach

13.1 The Opportunity for Napranum

The development of a microgrid could provide local employment during the development and on-going operation of the system as well as generating revenue for Council and addressing energy affordability issues for residents.

Implementing a standalone power supply system at Napranum could also address some of the current restrictions on the development of embedded generation like rooftop solar PV systems, which is currently not permitted by RTA due to potential impacts on mining operations at Weipa.

There is currently limited economic development opportunity at Napranum from agriculture, industry, tourism or other commercial activities, that can create jobs for residents and generate income for households and the community. The main employment streams at Napranum are associated with local government activities and government services like health and aged care.

In addition to community benefits, development of the microgrid could present an opportunity for EQL to develop the "renewable energy remote power station of the future." i.e., EQL could lead the design and development of a power station that has solar PV and BESS at its core. There are also broader opportunities to integrate distributed energy and smart control systems throughout Napranum. This is a different approach to address the current challenges faced by EQL in retrofitting diesel-based power stations at its 33 isolated locations around regional Queensland with renewables, to reduce diesel consumption and greenhouse gas emissions.

There is also a potential economic benefit or EQL and the Queensland Government by developing a lower-cost alternative to the current power purchase arrangements with RTA. Reducing the power purchase price via local renewable energy generation can contribute to a reduction in the CSO payment currently provided by government and paid to EQL to support the uniform tariff policy.

13.2 Queensland Government Priorities

The development of a microgrid at Napranum meets the objectives of numerous Queensland Government priorities including:

- Local Thriving Communities – establish greater decision-making authority in service delivery and economic development
- Tracks to Treaty – a new way of working
- Queensland Plan
    - Nobody gets left behind
    - Regional development and delivery reflects the needs of that region

    - We invest in and adopt sustainable and renewable solutions.
- Queensland Reconciliation Action Plan 2018-2021
    - Maintain and leverage mutually beneficial relationships with ATSI peoples, communities and organisations to support positive outcomes
- State Infrastructure Strategy 2022
    - Encourage jobs, growth and productivity
    - Enhance sustainability and resilience
    - Develop regions, places and precincts
    - Adopt smarter approaches
- Queensland Energy and Jobs Plan
    - 50% renewable energy by 2030; 70% by 2032; 80% by 2035
    - Invest in more batteries and storage
    - Support households to manage their energy use and save on electricity bills
    - Continuing to implement the uniform tariff policy,
    - Supporting the deployment of more rooftop solar
    - Decarbonising remote communities
    - Deliver real and lasting benefits for regional communities – strategic planning and community engagement

13.3 Proposed Solutions

In assessing suitable alternatives for improving the resilience of the Napranum community via a microgrid, and in addition to meeting the required technical standards, EnergyConnect sought solutions that were consistent with the principles of:

- Self-determination – by empowering the community via decision-making and asset ownership and operating models.
- Economic opportunity – revenue generation.
- Reliable local energy supply.
- Building community resilience and transition from a position of vulnerability.
- Creating long-term and on-going employment opportunities for locals.
- Reducing reliance on fossil fuels.
- Creating a social enterprise business model, not just a technical business case.
- High demonstration value for other remote and rural communities.

It is intended that the Napranum microgrid would be designed and operated as an "islandable microgrid" which will retain a connection to the RTA Weipa network. Napranum would primarily be supplied from its own local generation system and be able to draw additional capacity from the RTA network on an as-required basis for battery charging during extended periods of inclement weather, to meet peak demand requirements, or on occasions when the local generation plant is not available.

Additionally, if the upstream RTA network was not available, the Napranum microgrid can operate as a standalone system (Island mode).

Technical and economic optimisation modelling using the min-E simulation tool resulted in a preferred solution consisting of the following elements:

- A centralised solar farm (2,000 kW) and BESS (2,700 kW / 10,800 kWh) supported by a Standby Generator (1,000 kW).
- Rooftop solar PV systems installed on approximately 60 dwellings (300 kW)[59].
- An energy efficiency program to target demand reduction via education, behavioural change and the replacement of inefficient air-conditioners and hot water systems.
- A microgrid control system to optimise DER orchestration and integration with the RTA network.

Figure 41 below shows the proposed configuration of the Napranum microgrid.

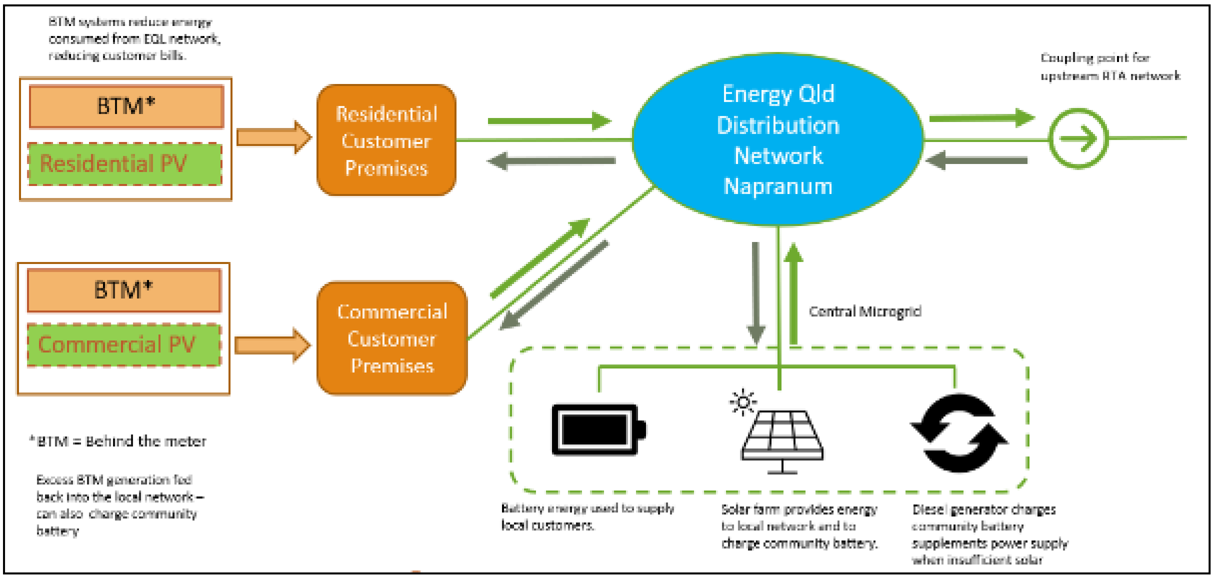


Figure 41: Proposed configuration of the Napranum microgrid

Rooftop solar PV systems proposed in this microgrid solution have several benefits including:

- Solar is the most economical and suitable technology for renewable energy generation at Napranum.
- The use of available rooftop real estate reduces the land area needed for the central solar farm.
- Behind-the-meter rooftop solar systems will provide electricity bill relief to residents, and this can represent a significant saving in large households.

[59] There may be opportunity to provide additional rooftop solar on Council buildings and other commercial properties in Napranum which can offset the required solar farm capacity

Modelling for the standby generator was based on using diesel fuel, however the use of biofuels or other fuel substitutes could be considered in the final design.

The standby generator would be required to operate for approximately 266 hours for the year under normal microgrid operating conditions (excluding disaster events).

It is also assumed that approximately 25,000kWh of energy would be supplied via the RTA network with the preferred configuration.

13.4 Microgrid Implementation Plan

It is anticipated that the Napranum microgrid would be implemented in three stages as described below: -

13.4.1 Stage 1 - Pre-implementation

- Implement a comprehensive community and stakeholder engagement program.
- Confirm ownership and operating model and business case with EQL and NASC.
- Confirm the funding strategy and secure project funding.
- Detailed design.
- Modelling and operational studies of the RTA network.
- Energy efficiency programs.
- Scope rooftop solar and negotiate rooftop access arrangements.
- Site assessment for central microgrid assets.
- Establish a program management office.

In Stage 1, activities shall be undertaken to refine the concepts developed during the feasibility study and option analysis in consultation with the Napranum community, Traditional Owners, community leaders and key stakeholders. It is proposed that the project development team, EnergyConnect, would work closely with EQL and NASC to develop the concepts presented in this report.

This includes defining the most appropriate ownership and operating model for the Napranum microgrid, which in turn will assist with the development of the funding strategy for the key infrastructure. It is assumed that funding for Stage 1 works can initially be secured via appropriate government grants.

Pre-implementation activities include site assessment and selection and associated technical studies and developing detailed designs and refining financial analyses and budgets.

A focused energy efficiency program will be delivered in a community-wide program, including provision of energy efficiency advice to households. Local people can be trained to deliver and support these programs.

A program targeting replacement of inefficient appliances including air-conditioners and hot water systems would be delivered and energy efficiency principles would be developed to support and guide Council, residents and government agencies for future residential developments at Napranum.

At the end of this stage it is expected that the microgrid project would be shovel-ready.

13.4.2 Stage 2 – Rooftop solar

- Confirm funding
- Prepare specifications
- Tendering and contract award
- Contract delivery and administration
- Metering and tariff alterations
- Operating and maintenance program

Stage 2 targets the works required to implement the residential rooftop solar PV systems.

Rooftop solar PV systems would be deployed to approximately 60 Council-owned dwellings as the initial deployment of renewable energy infrastructure to Napranum, providing immediate electricity bill relief to occupants of those residences.

This stage would also entail establishing administrative arrangements for managing feed in tariffs for COMs.

Where appropriate, additional rooftop solar may also be deployed to Council and commercial buildings which will serve to reduce the overall size of the central solar farm.

13.4.3 Stage 3 - Central microgrid

- Confirm funding and partnership arrangements
- Prepare specifications
- Tendering and contract award
- Contract delivery and administration
- Implement commercial arrangements
- Operating and maintenance program
- Microgrid control systems and operating protocols

Stage 3 works will focus on the establishment of the centralised microgrid facilities, including solar farm, community BESS, and standby generation.

Pre-construction activities such as detailed technical design of microgrid components and control systems, site assessment and acquisition, and preparing specifications, will be completed in Stage 1.

Preparing tender documentation and coordinating tendering processes, including awarding of tenders and quality and delivery management would be undertaken in Stage 3.

13.4.4 Implementation Model

Section 10 outlines in detail the proposed asset ownership and operating models for the Napranum microgrid. The final approved model would be established during Stage 1 Implementation activities in consultation with key stakeholders including NASC, EQL, the Queensland Department of Energy and Public Works, and RTA.

A community-own and operate model is preferred with Napranum Aboriginal Shire Council being the Asset Owner with specific positions established within the Program Office to manage all implementation and on-going operational activities.

The Program Office would be responsible for all aspects of delivery of the microgrid program of works and its future operation, including program delivery and budget management, employment and training of personnel and consultants, project administration, and contract management.

The establishment of the Program Office is considered a priority activity to progress the implementation of the Napranum microgrid project.

Appendices

Appendix A. Ergon Energy network outages at Napranum

Upstream outages affecting all customers (Ergon Energy)

Customers Affected	Date	Duration (hours)	Outage Type	Event Trigger (Unplanned)
260	30/10/2020	21.7	Unplanned	LV-Unassisted failure (Apparent defect)
260	31/07/2020	6.5	Unplanned	Animal impact
259	24/10/2021	5.7	Planned	
259	30/10/2021	3.1	Unplanned	Customer Installation Fault
260	21/07/2020	3.1	Unplanned	Non EE Transmission fault
260	21/09/2020	3.0	Unplanned	Generation failure - Isolated
259	28/11/2021	2.8	Unplanned	Lightning
256	16/01/2020	2.4	Unplanned	Generation failure - Isolated
260	29/07/2021	2.3	Unplanned	Trip & Manual Reclose - 15 Mins or more No Trigger Found
259	30/10/2021	2.1	Unplanned	Customer Installation Fault
260	7/08/2020	2.1	Unplanned	Generation failure - Isolated
260	5/08/2020	1.7	Unplanned	Generation failure - Isolated
260	27/07/2020	1.5	Unplanned	Non EE Transmission fault

258	5/11/2020	1.5	Unplanned	Generation failure - Isolated
260	6/08/2020	1.5	Unplanned	Generation failure - Isolated
258	13/02/2021	1.3	Unplanned	Generation failure - Isolated
260	25/07/2020	1.2	Unplanned	Non EE Transmission fault
258	26/03/2021	0.7	Unplanned	Generation failure - Isolated

All 2020-21 outages (Ergon Energy)

Outage ID	Customers Affected	Date	Duration (hours)	Outage Type	Event Trigger (Unplanned)	Standard Reason (Forced / Planned)	Outage Classification
19FN14626	4	15/01/2020	0.1	PLN	NA	Coordinated M'tce e.g. lines & subs	SUSTAINED
20FN0779	256	16/01/2020	2.4	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN1111	1	19/01/2020	21.4	UNPLN	Severe Weather	NA	SUSTAINED
20FN1125	1	20/01/2020	3.0	UNPLN	Severe Weather	NA	SUSTAINED
20FN1127	1	20/01/2020	1.2	UNPLN	Service Asset Fault	NA	SUSTAINED
20FN1618	1	23/01/2020	17.7	UNPLN	Overload	NA	SUSTAINED
20FN1997	1	28/01/2020	26.6	UNPLN	Overload	NA	SUSTAINED
20FN3149	1	10/02/2020	195.6	UNPLN	Service Asset Fault	NA	SUSTAINED
20FN3146	1	10/02/2020	188.3	UNPLN	Service Asset Fault	NA	SUSTAINED
20FN3150	1	10/02/2020	188.6	UNPLN	Service Asset Fault	NA	SUSTAINED

20FN10691	260	21/07/2020	3.1	UNPLN	Non EE Transmission fault	NA	SUSTAINED
20FN10907	260	25/07/2020	1.2	UNPLN	Non EE Transmission fault	NA	SUSTAINED
20FN11047	260	27/07/2020	1.5	UNPLN	Non EE Transmission fault	NA	SUSTAINED
20FN11342	260	31/07/2020	6.5	UNPLN	Animal impact	NA	SUSTAINED
20FN11584	260	5/08/2020	1.7	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN11586	260	6/08/2020	1.5	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN11692	260	7/08/2020	2.1	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN14012	260	21/09/2020	3.0	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN15819	260	30/10/2020	21.7	UNPLN	LV-Unassisted failure (Apparent defect)	NA	SUSTAINED
20FN16063	258	5/11/2020	1.5	UNPLN	Generation failure - Isolated	NA	SUSTAINED
20FN16163	55	9/11/2020	0.6	FORCD	NA	Lines Emergency Maintenance	SUSTAINED
20FN16587	41	16/11/2020	3.9	UNPLN	Service Asset Fault	NA	SUSTAINED
21FN1984	258	13/02/2021	1.3	UNPLN	Generation failure - Isolated	NA	SUSTAINED
21FN2704	1	1/03/2021	22.7	UNPLN	Lightning	NA	SUSTAINED
21FN2708	1	1/03/2021	20.7	UNPLN	Lightning	NA	SUSTAINED

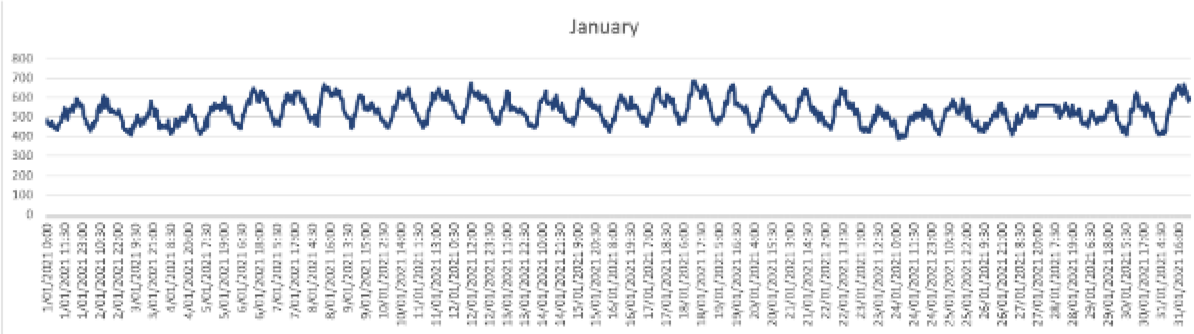
21FN2713	1	1/03/2021	20.8	UNPLN	Lightning	NA	SUSTAINED
21FN2691	258	2/03/2021	0.0	UNPLN	Trip & Auto Reclose - No Trigger Found	NA	MOMENTARY
21FN2728	1	2/03/2021	3.4	UNPLN	Lightning	NA	SUSTAINED
21FN2722	41	2/03/2021	2.3	UNPLN	Lightning	NA	SUSTAINED
21FN2730	1	2/03/2021	2.0	UNPLN	Lightning	NA	SUSTAINED
21FN2861	41	3/03/2021	3.3	UNPLN	Lightning	NA	SUSTAINED
21FN2989	1	4/03/2021	2.2	UNPLN	Lightning	NA	SUSTAINED
21FN3530	1	16/03/2021	1.4	UNPLN	Lightning	NA	SUSTAINED
21FN3938	258	26/03/2021	0.7	UNPLN	Generation failure - Isolated	NA	SUSTAINED
21FN4576	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN4579	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN4580	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN4581	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN4582	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN4583	1	8/04/2021	0.3	PLN	NA	Corp initiated line works	SUSTAINED
21FN5882	1	21/05/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED
21FN5883	1	21/05/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED

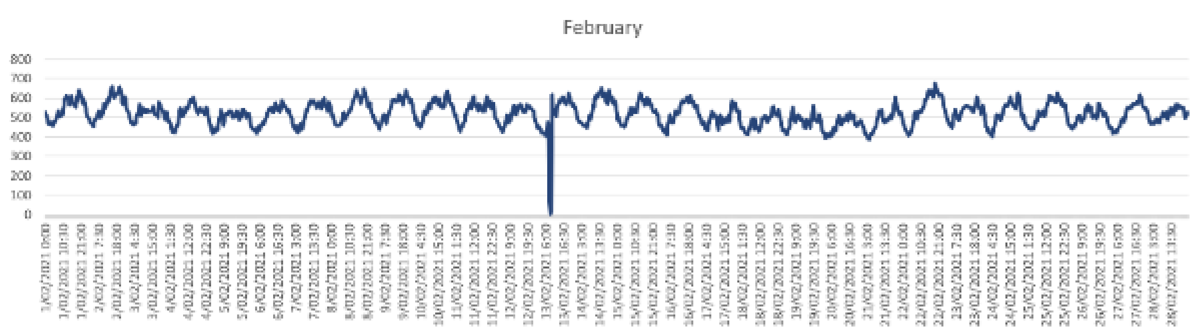
21FN6455	1	13/06/2021	0.5	FORCD	NA	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	SUSTAINED
21FN7824	260	29/07/2021	2.3	UNPLN	Trip & Manual Reclose - 15 Mins or more No Trigger Found	NA	SUSTAINED
21FN9543	34	10/09/2021	6.7	UNPLN	Fire (External)	NA	SUSTAINED
21FN10007	34	23/09/2021	0.3	FORCD	NA	Lines Emergency Maintenance	SUSTAINED
21FN8037	34	22/10/2021	1.8	PLN	NA	P2 Lines Works	SUSTAINED
21FN11271	41	22/10/2021	17.7	UNPLN	Vibration	NA	SUSTAINED
21FN8039	259	24/10/2021	5.7	PLN	NA	P2 Lines Works	SUSTAINED
21FN11608	259	30/10/2021	3.1	UNPLN	Customer Installation Fault	NA	SUSTAINED
21FN11610	259	30/10/2021	2.1	UNPLN	Customer Installation Fault	NA	SUSTAINED
21FN11788	1	2/11/2021	4.9	UNPLN	Service Fuse Blown	NA	SUSTAINED
21FN12833	1	13/11/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED
21FN12834	1	13/11/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED
21FN12835	1	13/11/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED

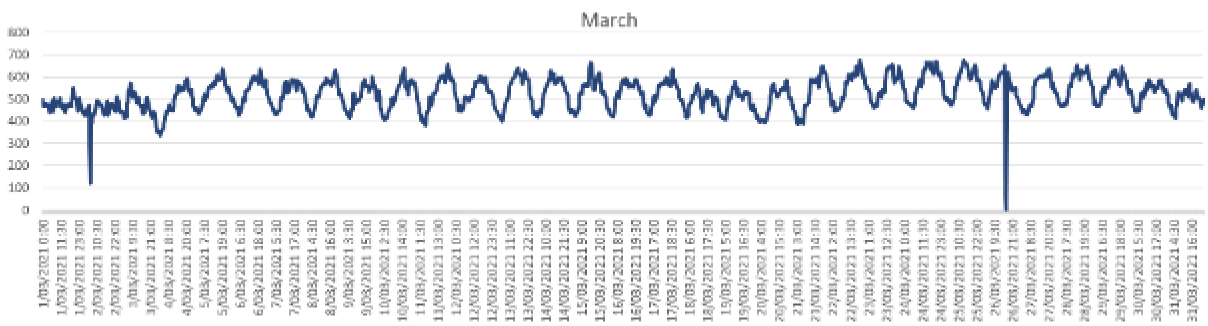
21FN12945	1	16/11/2021	0.5	PLN	NA	Corp initiated line works	SUSTAINED
21FN13057	259	28/11/2021	2.8	UNPLN	Lightning	NA	SUSTAINED
21FN14287	25	29/12/2021	53.1	UNPLN	Severe Weather	NA	SUSTAINED
21FN14382	41	30/12/2021	20.8	UNPLN	Severe Weather	NA	SUSTAINED

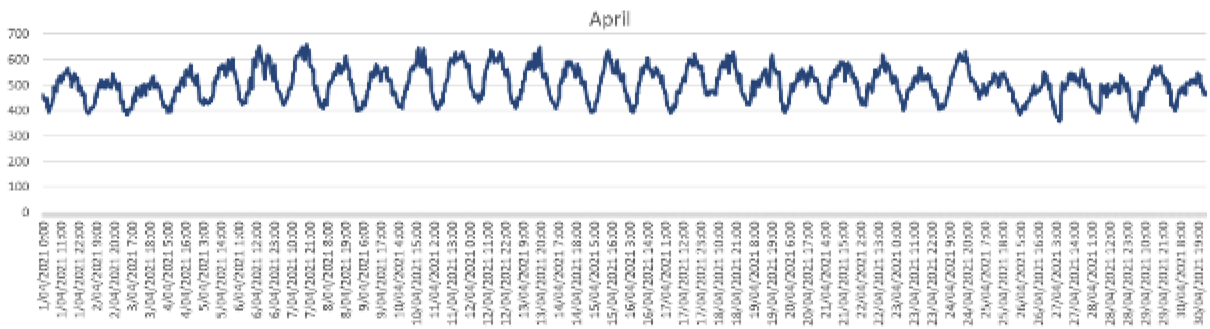
Appendix B. Detailed load profiles

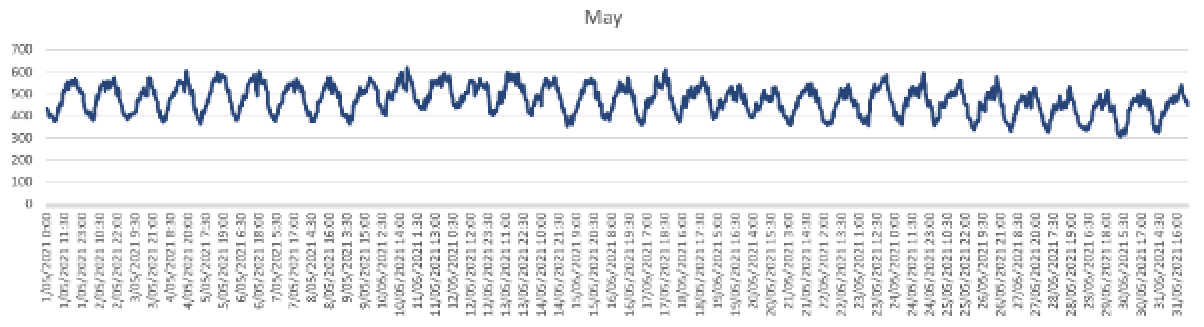
The following load profiles are for the 2021 calendar year, in kVA.

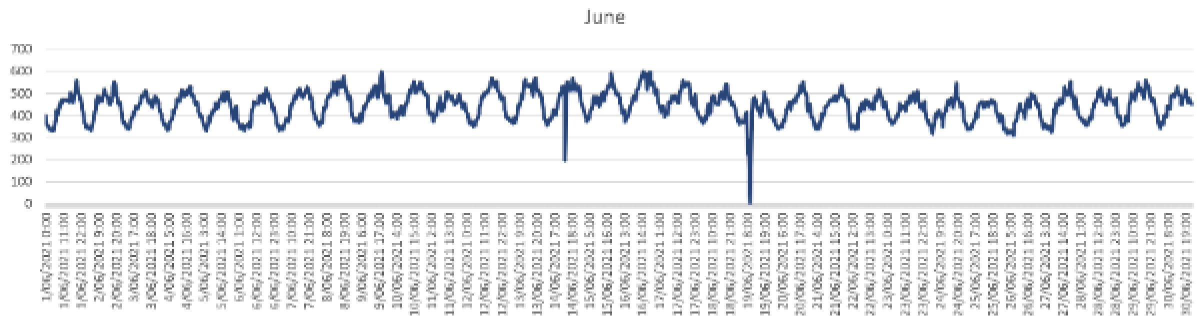


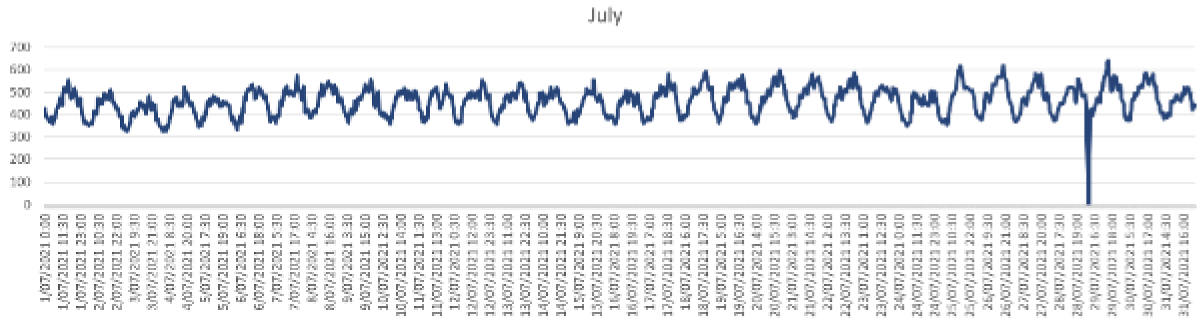


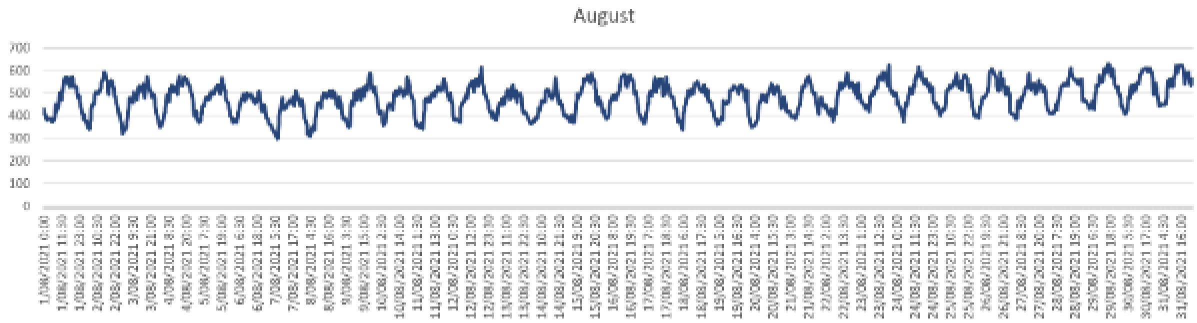


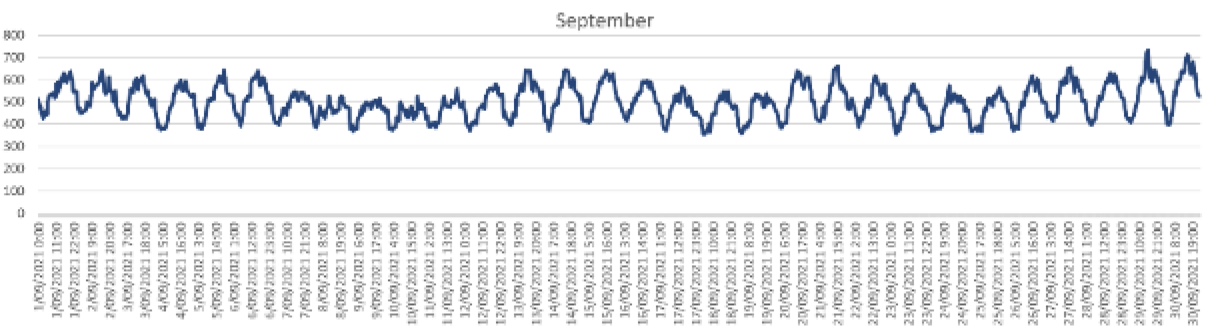


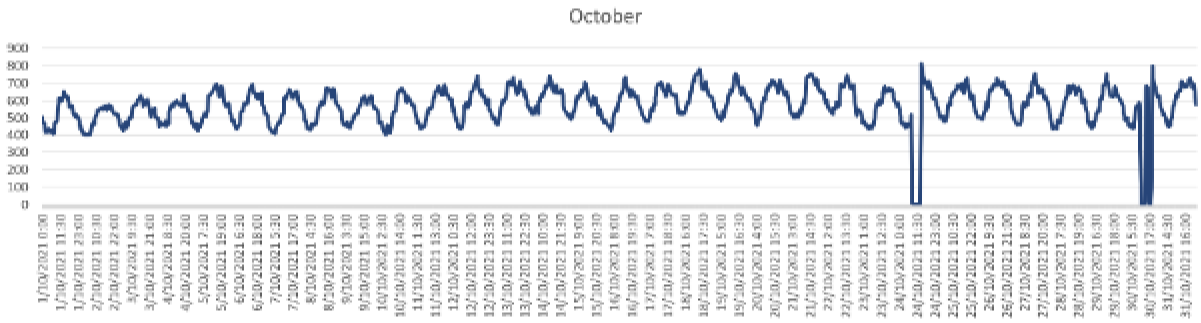

May

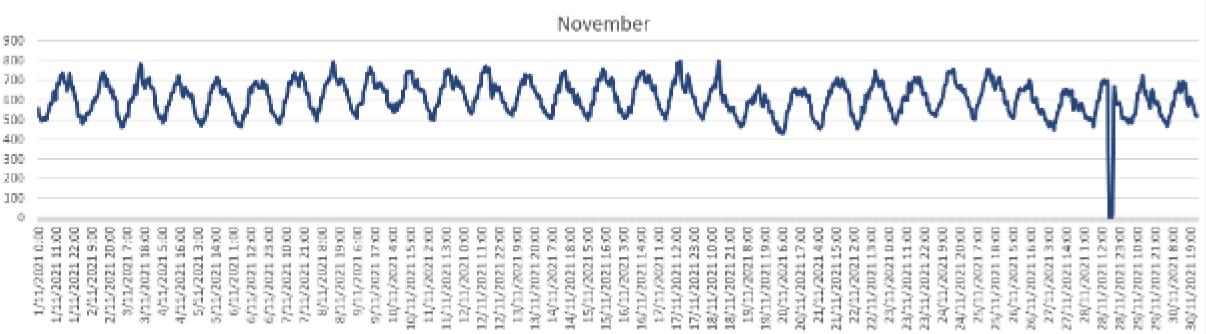

June

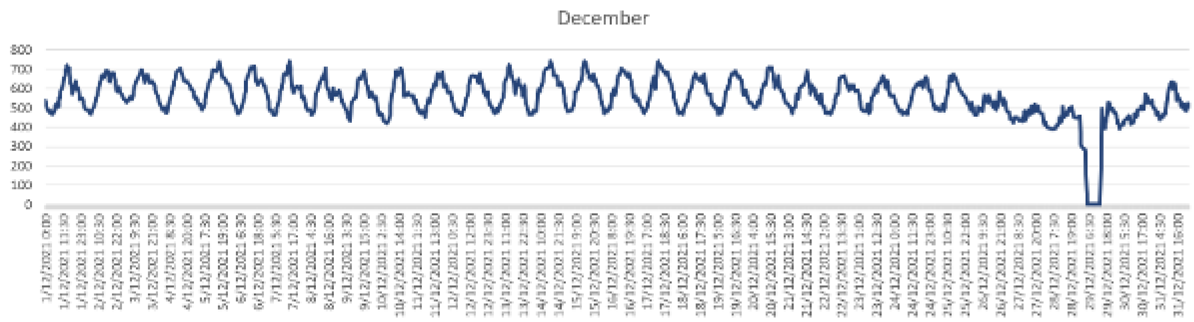

July


August


September


October
900
800
700
600
500
400
300
200
100
0


November
900
800
700
600
500
400
300
200
100
0


December
800
700
600
500
400
300
200
100
0

Appendix C. Renewable energy technologies

C1. Solar

The processes for converting sunlight into useful energy to generate electricity and heat water are outlined below.

C.1.1 Photovoltaic

Solar photovoltaic (PV) cells are semi-conductors that create a direct current (DC) voltage when exposed to light within a certain wavelength range. This wavelength range is broadly similar to the spectrum that is visible to the human eye. Hence, a solar cell can be assumed to create a voltage when exposed to visible light.

Solar PV cells are connected in series within PV modules (also called panels), which allow sunlight to reach the cell surface, but otherwise protect the cells from direct exposure to the environment. PV modules can be connected together in an array. The PV array is connected to an inverter, which draws the optimum DC current from the PV array and converts it to AC current at an appropriate voltage for use by the customer or export to the grid.

A PV system's power output is dependent on the instantaneous intensity of the solar radiation incident on the plane of the array and the system efficiency. The solar radiation hitting the PV array can fluctuate rapidly throughout the day due to passing cloud and shading by nearby trees. It also varies more slowly over the course of a day and year owing to the changing sunlight hours and the angle of the sun relative to the PV array.

Higher PV cell temperatures reduce efficiency slightly. Typically, good solar resources tend to correlate with high ambient temperatures. Nevertheless, annual PV system output correlates well with increasing annual radiation.

Ground mount PV can be fixed, single or dual axis tracking. Tracking increases annual output with an increase in maintenance costs. Tracking is not suitable for areas within cyclone regions.

PV systems can be cost-effective at small-scale as well as large-scale. It can be used in grid-connected systems that feed power into the electricity network at domestic, commercial and larger, utility scale applications. PV can also be used in isolated power systems to supply power at various scales, from fuel-saving designs (low annual contribution) to more complex systems that include energy storage to achieve fossil fuel free-off operation (high annual contribution).

Solar PV is exceptionally reliable with minimal maintenance requirements. A PV array can be expected to operate for 25 years or more. Typically, the inverter does not last that long and inverter replacements every 10 or so years are factored into financial analysis. Otherwise, there are minimal maintenance costs for fixed PV systems arising from washing panels, checking cabling and isolators.

C.1.2 Solar Thermal

Solar thermal systems are technically proven for most ranges of temperature use. Lower temperatures for residential and commercial hot water are available from simple flat plate and evacuated tube collectors. More complex, concentrating solar collectors that track the sun are needed for higher temperatures, such as the generation of steam.

The performance of solar thermal systems is strongly linked to the average level of direct normal irradiation (DNI) at a site. The fluids heated by solar thermal systems provide a form of energy storage. For example, an insulated, residential water tank can hold its heat for many cloudy days, if the hot water is not discharged.

Flat plate collectors consist of a metal sheet with passages for fluid flow, mounted in an insulated case with a glass cover sheet. They can heat fluid to 85˚C, making them suitable for heating water (for example domestic hot water systems), but can also be connected in large arrays for commercial and industrial use.

Evacuated tube collectors consist of a series of individual tubes mounted together in panels. An evacuated space between two concentric tubes minimises heat loss and allows the inner surface to reach higher temperatures and then exchange heat to a fluid. Evacuated tubes can heat fluid to between 50˚C and 150˚C and are a suitable for domestic and commercial solar hot water, especially in cooler climates. Addition of an appropriately curved mirror behind an evacuated tube collector can boost the energy absorbed allowing higher temperatures (up to 200˚C) and more efficient operation.

Commercial concentrating solar technologies include:

- Parabolic trough collectors – a curved reflective surface in the shape of a parabola that tracks the sun along one axis throughout the day. This focuses the sun's rays into a tubular receiver that contains a heat transfer fluid, such as synthetic oil, which can be heated to 100°C to 450°C to generate steam for process heat or power generation.
- Linear Fresnel systems – long mirror strips laid out in parallel rows that are each tracked independently to focus direct beam radiation onto the receiver. This provides heat over a similar temperature range to parabolic trough collectors.

Commercial solar thermal systems have a size-dependent capital cost that makes larger systems progressively more cost-effective. Also impacting on capital cost are site-specific aspects, such as the amount of energy storage needed, integration costs and the quality of solar resource available. Concentrating solar systems require clear sky days because clouds result in diffuse radiation that cannot be focused onto the receiver. The design of solar thermal systems also needs to factor in the seasonal nature of the resource and the loads it would be supplying.

Larger-scale solar thermal technologies may be an alternative to gas used for process heat or industrial processes, depending on gas prices, temperatures required, quality of solar resources at the site and space to host an installation. Rigorous economic evaluation is very site and process specific. Predicting the performance can be more complex process than it is for other technology options. Flat plate and evacuated tube technologies are off-the-shelf technologies and may be attractive for sites where there is a requirement for hot water or steam for process heat.

Typically, residential electric heat pump hot water systems have a co-efficient of performance of between 3 and 4.5. Thus, their peak electric power draw for boosting is, usually, significantly less than electric boosted, solar hot water systems. This makes heat pumps more suitable for islandable microgrids than electric boosted solar hot water systems. Heat pump hot water systems also generally come with built in timers which can be used to maximise self-consumption from rooftop PV systems.

C2. Wind

Wind turbines operate when wind turns blades around a rotor, and the rotational force is then used to turn a generator to create electricity, or in the case of windmills mechanically turn a water pump. Depending on the type of wind turbine used, electrical output from the generator may require conditioning by power electronics to obtain the correct frequency and voltage before it can be exported to the grid.

The most common form of wind turbine has the rotor spinning around a horizontal axis and three blades. Vertical axis wind turbines also exist but they have a very small proportion of the wind turbine market.

C.2.1 Horizontal

Wind turbine technologies are available at small and large scale. In both instances, the quality of the wind resource is critical to viability. The wind resource (i.e. annual wind speed distribution, wind shear) is highly site-specific and a thorough assessment is required to ensure turbine performance and lifetime will be sufficient to warrant the investment.

Wind speed increases with height and wind turbulence increases maintenance costs, hence the preference for high nacelle heights to minimise ground terrain effects.

Small wind turbines can be sized to meet a range of annual energy contributions for stand-alone power systems. Typically, they are installed at remote homes and farms along with batteries and a diesel generator. These wind turbines are significantly smaller than those used in large-scale wind farms.

All wind turbines have a cut-in, rated and cut-out wind speed as shown in Figure 42. In very high winds, wind turbines use various protection mechanisms which means no power is produced.

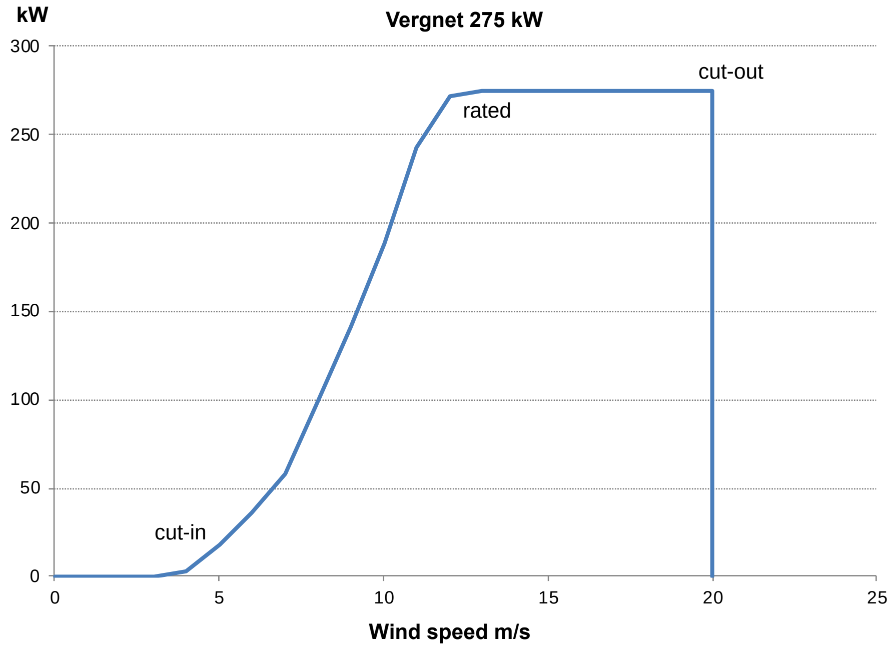


Figure 42: Wind Turbine Power Curve

It is worth noting that a 2 MW wind turbine designed for central desert conditions will have a different rated wind speed to a 2 MW turbine designed for an island in the Bass Strait. A wind turbine will generate less than its rated power output when the wind speed is below its rated wind speed. It only generates its rated power output when the wind is between the rated and cut-out wind speed.

Small scale wind turbines are available in various designs and sizes. Typically, a stand-alone power system for a home in a windy area would use a wind turbine in the 2 to 10 kW range. Very small, wind turbines can be rated as low as 50 Watts. These are often used for auxiliary power for small, recreational boats.

Typically, small-scale wind turbines achieve lower capacity factors than large wind turbines due to the lower height of the tower. The physics for wind generation mean the potential power available is proportional to the swept circular area of the rotor's blades and the cube of the wind speed.

Historically, large-scale wind turbines have been the dominant form of large-scale renewable generation deployed worldwide. Wind turbine generation benefits from economies of scale, so developments in turbine and blade size as well as technology continues. Typically, the output of multiple wind turbines is aggregated through a central connection point to the electricity grid.

Wind farm projects also experience strong economies of scale. Typically, cost-effectiveness increases rapidly with increasing turbine size and the number of turbines, up to the power limit of the grid-connection point. New onshore projects can use turbine capacities of more than 3 MW, blades around 50 to 60 metres in length and tower heights of more than 110 metres. New offshore projects use larger turbines of around 6 MW or more, with blade lengths over 80 metres. In 2021, the largest offshore wind turbine being built has a blade length of 108 metres. As such, the logistics of construction (i.e. materials and container handling, locally-available cranes) are critical considerations for large wind projects.

In most parts of Australia, large wind projects typically generate more power in winter than summer and generation is higher overnight than during the day. Maximum, instantaneous wind turbine power output can occur at any time of the day. Project developers usually select sites with the highest average wind speeds. Recent advances in designs however mean lower speed wind resources can also be used for generation. Typically, this would have higher overall costs per kWh generated.

Owing to the harsh operating conditions in which wind turbines operate, maintenance requirements are higher and more critical than for solar PV. Nevertheless, where a suitable wind resource exists, and where maintenance requirements are adhered to, wind turbines can deliver clean energy at low cost, and can operate outside of sunshine hours.

C.2.2 Vertical

Typically, vertical axis wind turbines require more maintenance due to wind shear effects and the potential for vibration issues to arise. They are a specialised technology, not widely deployed and have unique design approaches to attempting to survive cyclones. Some vertical axis turbines have a maximum survival speed of 60 m/s, which is 216 kilometres per hour. Wind speed gusts above this can occur in Category 4 cyclones.

The power curve for vertical axis wind turbines can have a gradual reduction in power output in very high winds which declines to zero at the cut-out wind speed.

Typically, detailed wind monitoring is undertaken before deciding on the optimal wind turbine for a particular location. The costs of grid-connecting small wind turbines will also affect the economic viability.

C3. Bioenergy

Bioenergy refers to the potential energy stored within biomass that can be converted to thermal energy. Biomass is organic matter originally derived from plants and animals, (not fossilised such as coal), and can be used to provide heat, electricity, transportation fuels or as a chemical feedstock.

Biomass feedstocks, their components and moisture content are varied. The specific feedstock will affect efficiency as well as the type of technology used to extract useful energy. Feedstocks can be solid or liquid, and include wood, bark, bagasse, agricultural crops (e.g. straw and rice husk), energy crops (e.g. mallee), and waste products (e.g. wood or paper waste, black liquor, sewage sludge). Biomass can be combusted, gasified, pyrolised or digested to make biogas.

Owing to the complexity of efficiently converting thermal energy to electrical energy, it is assumed that small locations such as Yarrabah would use internal combustion engines driving synchronous alternators for generation. This is because the working principles and maintenance requirements of internal combustion engines are widely understood, and because such systems can be cost-efficient at some scales.

Internal combustion engines can run on liquid or gaseous fuels, with only minor differences from the common diesel generator. Hence, provided sufficient biomass feedstock is available and can be secured long term, electricity can be generated on demand from processed biofuels.

Most of the risk with a bioenergy solution lies with the biomass supply and delivered cost. Relative to the purchase cost, biomass resources are expensive to transport. Thus, the lowest cost biomass resources are those local to the user. Bioenergy capital costs are strongly dependent on system size, with large systems being progressively more cost effective.

C.3.1 Biogas

Biogas is produced when bacteria break down organic matter in suitably controlled conditions in the absence of oxygen in a process called anaerobic digestion. The biogas is mainly composed of methane with some carbon dioxide and other trace gases. Feedstocks to produce biogas include livestock effluents and meat processing waste, the organic components of landfills and any other source of 'wet waste' biomass (e.g. wastewater treatment sludge or food and beverage industry wastes). This biogas can be combusted for process heat or used in engines or, with extra investment, purified and in principle used for chemical feedstock or sensitive combustion applications.

Biogas can be produced at small-scale using simple materials, with larger, more sophisticated digesters used for production at large scale. Digesters can be:

- Covered effluent ponds for liquid waste, where biogas accumulates under an impermeable cover and is piped for processing, or
- Digestion tanks where semi-liquid wastes are mixed and the digestion process can be controlled by temperature, or by adding bacteria to enhance the process.

Solids which settle at the base of the digester are a by-product from biogas production and can be used as fertilizer.

Anaerobic digestion is often selected as a waste treatment option for wet wastes, to be installed where the waste occurs. For example, where large-scale sewage treatment is anaerobic, the installation of capture and generation equipment is almost always cost-effective, and the electricity is generally used entirely on site. Anaerobic digesters can be used to treat waste streams in a wide range of industries, from food and beverage to livestock.

Anaerobic digestion occurs in landfill sites, where methane is produced from the organic element of the waste and requires control to prevent explosion. In this case energy generation is the alternative to flaring the gas. However, anaerobic digesters are more commonly an active waste management strategy. The digester element may require little additional expenditure, for example it may only require fitting a cover to an existing waste treatment lagoon to capture gas or may require the installation of a purpose made tank where digestion and gas capture occurs. Anaerobic digestion may also be used at a central waste processing site for liquid wastes, such as slurries from livestock or food and drink industries.

C.3.2 Ethanol

Renewable ethanol is produced from biomass feedstocks that contain large amount of sugar (sugar cane, sugar beet and molasses) or from materials that can be converted into sugar such as starch (corn, wheat, grains) or from cellulose (crop residues and wood). The main steps in the production of ethanol are extraction of glucose (sugars) from feedstocks, fermentation, distillation and dehydration. Where conversion to glucose is necessary, pre-treatment and pre-processing of the feedstock is required before fermentation and distillation.

Ethanol transport fuel blends range from 5% (E5) to 100% pure ethanol. E10 is the most widely used around the world. Where ethanol is produced from waste products, it does not interfere with food production. Commercialisation efforts continue with the development of other feedstocks, such as algae, cellulosic biomass, trees and grasses.

Ethanol is produced where abundant supply of feedstocks exist. (e.g. in the US, ethanol is mainly made from corn, and the ethanol plants are concentrated in areas where corn is farmed, in Australia, ethanol is produced near sugarcane mills). The availability of land for farming of suitable feedstocks affects the opportunity for local production of ethanol.

C.3.3 Biomass boilers

Direct combustion involves burning a fuel (such as wood pellets or bagasse) and using the heat to drive a steam turbine. Combustion systems can be configured in various ways and are primarily used for steam and hot water production. The biomass must be progressively fed to a grate where combustion takes place or in smaller particles to a fluidised bed. In either case, fan systems introduce air and automated feed systems are incorporated. Heat is extracted usually via water/steam passing through boiler tubes that surround the combustion region.

An established supply chain for biomass material such as wood pellets is important to project viability.

Combustion may also be used for mixed waste streams, such as municipal solid waste. In this case the capital expenditure will be dominated by waste handling and treatment, as the waste requires sorting to extract the organics, may require some material diversion for recycling, and the plant will require considerable effort on the flue gas treatment, which is more complex with a mixed feedstock. Gate fees for the waste treatment are likely to be required to make the project financially viable.

C4. Hydropower

The use of large dams for power generation is widely used in areas with suitable geography and reliable rainfall. These systems can be cost-effective due to the predictability and consistency of their dispatchable output as well as the long design life of the assets. The systems involve major civil works primarily made of concrete that do not degrade and have a useful life of around 50 years. They also benefit from significant economies of scale and are relatively more land intensive.

Small hydro generation turbines are also commercially available. There is no widely used definition for the distinction between large and small hydro generators. For the purposes of this study, an indicative size range for small hydro is around 5 MW to 30 MW.

Hydro generators below 5 MW are often described as mini hydro. The term micro hydro is also used for even smaller systems, usually in the kilowatt range.

Appendix D. Energy storage

A range of energy storage technologies are utilised for various applications around the world. These include various battery chemistries, pumped hydro, compressed air, thermal, flywheels and hydrogen.

Electricity storage can be broadly categorised into two major types:

- Short-term energy storage and
- Bulk energy storage.

The primary purpose of short-term energy storage is generation ramp rate control, so relatively high instantaneous power outputs are required for short periods. Thus only a relatively small amount of energy is required to be stored. The primary purpose of bulk energy storage is to store large amounts of VRE generation, to be used later, when there is no or limited output from VRE generation.

The parameters for energy storage will depend on its designed role. This can vary widely as requirements can be different depending on function, other generators and whether it is an isolated or an islandable microgrid.

For isolated microgrids:

- Short-term storage can be used to maintain power quality by smoothing VRE output to keep power ramp rates within certain bands, and
- Bulk storage can be used to power loads when there is no output from the VRE source (e.g. At night for PV, during periods of no wind for wind turbines).

D1. Short-term Energy Storage

The primary purpose of short-term storage in an isolated microgrid is to store relatively small amounts of energy to be able to deliver sufficient amounts of power to smooth out fluctuations in output from a VRE generation. Examples of short-term storage technologies include flywheels, ultracapacitors, lithium-ion, lead acid and other batteries with high MW output capacity and low MWh storage duration. These systems are designed for a high power-to-energy ratio, as fluctuations are generally short in nature.

The system design manages any prolonged increase/decrease in power output from the VRE source by changing the power output from the diesel[60] generators. Smoothing out VRE power output can manage rapid voltage sag/rise on the network to acceptable limits and provide a smoother load profile with manageable ramp rates for diesel generators to follow.

[60] Isolated microgrids can also use gas engines or turbines, bioenergy and/or hydro power with diesel generators or instead of diesel generators. However, diesel generators are the most common for isolated microgrids.

Given the relatively small amount of energy stored, short-term energy storage alone cannot be used where there are high amounts of VRE annual contribution, although it can allow for instantaneous power proportions above 30% of total supply.

Short-term energy storage can absorb limited amounts of VRE overproduction; beyond a certain point, dumping is required (e.g. limiting production from the VRE system or diverting surplus energy to a deferrable or dump load). Underproduction by the VRE system is met in the short-term (a few seconds to several minutes) by the short-term energy storage system, and in the long-term, by diesel generation.

All these systems require inverters to control their power output/input, and as such the network protection equipment must be designed with the inverter's limited current delivery in mind.

D2. Bulk Energy Storage

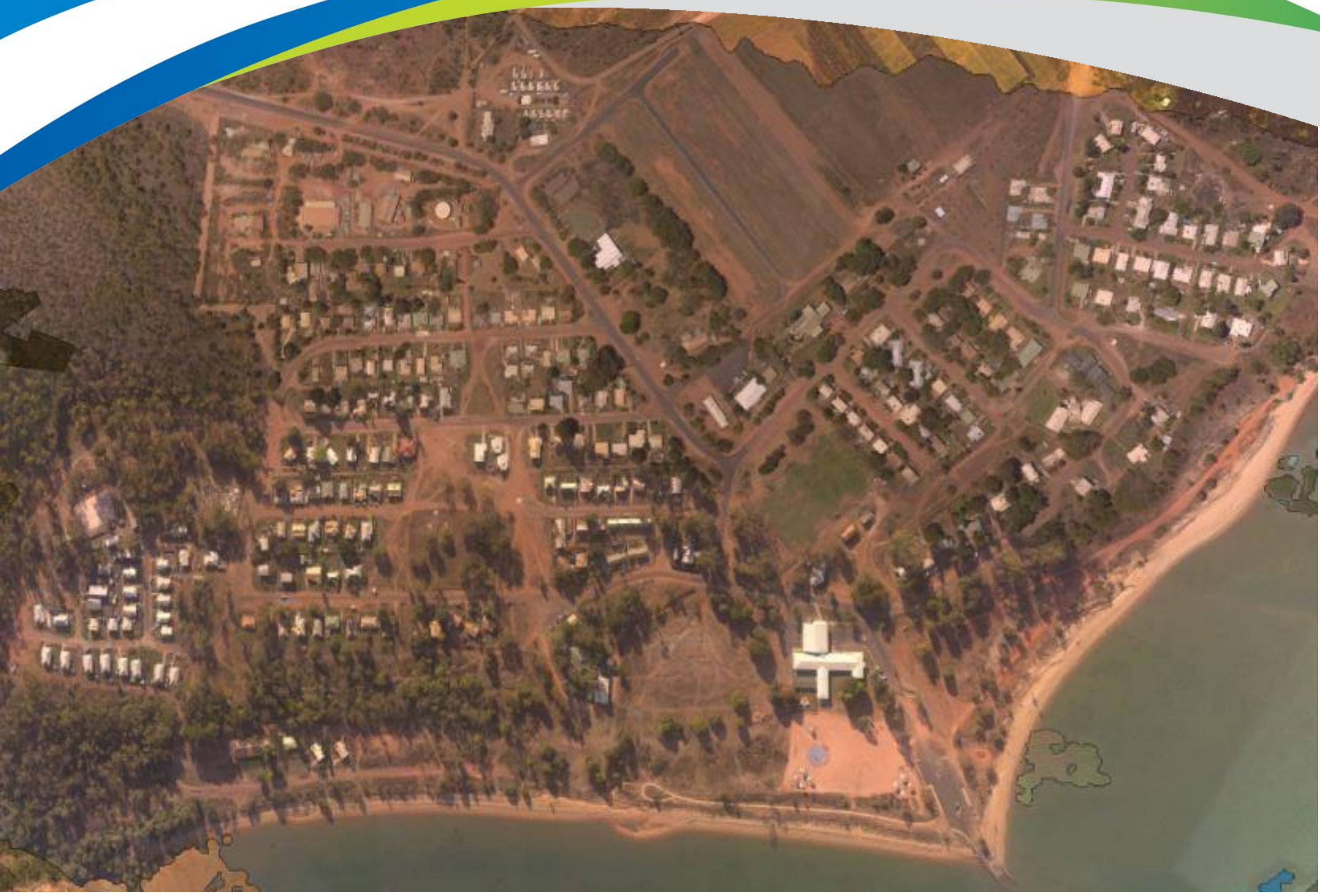
For isolated microgrids, if the VRE instantaneous power proportion and annual energy contribution is to be increased beyond what short-term energy storage and the associated diesel generation can support, bulk energy storage is required. Bulk storage is used to capture any excess electricity generated to use it later when the VRE generation has decreased.

Examples of bulk electricity storage include pumped hydro, compressed air, thermal, hydrogen and a variety of battery technologies including lithium-ion, flow and lead-acid. Bulk electricity storage technologies become economical when the cost of curtailed or dumped (i.e. wasted) electricity from the VRE generators exceeds the cost of storing it.

Depending on the scale of the bulk electricity storage required, there may be potential for larger systems that achieve economies of scale (e.g. pumped hydro). Careful dispatching of this stored electricity will affect the economics of the system. Where diesel generators are used, electricity should be released from the bulk energy storage such that the diesel generators are loaded to operate at their peak efficiency (roughly 80% loading), or not operating at all (diesel-off mode). Operating in only these two regimes is not always possible, but it should be aimed for.

The efficiency of a bulk energy storage system is important, especially on an isolated microgrid where the marginal cost of electricity used by customers is the cost of diesel-fired electricity (which is generally quite high). This is because losses are made up at the marginal cost. Where space is limited, storage technologies offering a high energy density are required.

Appendix E. Ergon Energy MIST Report



Napranum Microgrid

Pre-connection Feasibility Study

20 April 2023

Part of Energy Queensland

DOCUMENT CONTROL

Version Control			
Version	**Description of Changes**	**Revised By**	**Date**
0.1	Initial Draft	A. Louis	28/10/22
0.2	Revised draft based on comments from EnergyConnect	A. Louis	10/11/22

Document Approval				
Version	**Name**	**Title**	**Function**	**Date**

DISCLAIMER

This report is intended as general advice for incorporation into a pre-connection feasibility study to assist the Customer in determining whether to proceed with the proposed connection. This report does not constitute connection advice or requirements as part of a formal connection process.

In preparing this report:

- Ergon Energy Network has assumed that the information provided is reliable, accurate and complete;
- Ergon Energy Network has assumed that the records used by it in the preparation of this report are an accurate record of the relevant portion of Ergon Energy's distribution network;
- Ergon Energy Network has based the information on a "desktop" assessment of the proposed project and has not carried out detailed site-based or Customer-focused investigations to confirm the presence or absence of any factor that might be of interest to an entity considering whether or not to proceed with the project;
- Ergon Energy Network has exercised judgement as to the information that it considers that a Customer wishing to proceed with the project would be interested in;
- That Ergon Energy Network has made an assumption does not mean that Ergon Energy Network has made any enquiry to verify any such assumption;
- Subject to the constraints listed above, Ergon Energy Network has used due care in selecting and including information, and Ergon Energy Network is not aware of any circumstance that would affect the correctness of any such information; and
- Ergon Energy Network makes no claim of the accuracy and validity of information and connection requirements to the specific Rio Tinto network and power station, which may significantly affect the outcome of the feasibility of the project.

Accordingly, this report should be viewed as containing preliminary information only, current only at the date of this report, and may only be used by the Customer for a feasibility study. Ergon Energy Network does not make any claim as to the accuracy or authenticity of the content of this report. Accordingly, Ergon Energy Network does not accept any responsibility for any loss or damage, however caused, which any person or entity may suffer in connection with the information contained in this report.

CONTENTS

Napranum Microgrid Pre-Connection Feasibility

EXECUTIVE SUMMARY

This report outlines the pre-connection technical feasibility study of a proposed microgrid system for the Napranum 11kV distribution network owned by Ergon Energy Network (EEN), and supplied by the East Weipa power station, owned by Rio Tinto Australia (RTA). This work is part of a broader program through the Regional and Remote Communities Reliability Fund (RRCRF) to investigate microgrid solutions to enable a more reliable, secure and cost-effective energy supply for regional and remote communities in Australia. EEN was engaged by Ener-G on behalf of the EnergyConnect project team to prepare the network model and undertake network studies to inform the microgrid feasibility study for Napranum.

The Napranum township is supplied by a 5km 11kV feeder from the power station to an EEN-owned recloser at the EEN/RTA connection point. The EEN 11kV distribution network is comparatively very short, consisting of only 2.4km[1] of 11kV distribution network. However, the Napranum township is highly susceptible to large disturbing loads as part of the RTA mining operations. The nature of this connection inherently suits the objective of the microgrid solution and conceptually aligns with the microgrid philosophy for reliability improvement and energy independence.

This report covers the load flow studies, design considerations and preliminary technical assessment for the proposed connection. The outcomes of this report should be read in conjunction with the assumptions and exclusions, as per Section 1.3. At the time of writing, the project is only at a feasibility stage, and no formal connection application has been lodged. Microgrid connections with grid-forming inverters are still immature in Australia, and connection standards are yet to be updated. As such, this report is only a preliminary assessment based on existing standards and best practices, some of which are based on the National Electricity Rules (NER).

See Section 1.2 for details of the microgrid scenarios. The studies are only considered based on the EEN connection point to the RTA network, and there are no considerations of impact on the upstream RTA network or power station or protection systems.

Table 1 shows the summary of the technical feasibility of each microgrid scenario based on this preliminary assessment. The study considered the steady-state criteria based on worst-case loading and generation in both grid-connected and islanding modes. The summary of scenarios is as follows:

- Scenario 1 grid-connected is feasible based on voltage levels and power flow, assuming no limitation of power transfer back to the RTA network.
- Scenario 2 grid-connected is marginally feasible due to the potential for increased loading from BESS charge and the high generation back onto the RTA network. There is likely conductor limitation on both EEN and RTA networks. The worst-case voltage step is high buy marginal (~5%), which would need to be assessed further.
- Scenario 4 grid-connected is extreme and not feasible unless there is major network augmentation, such as reconductoring or building new feeder circuits. This is due to the extreme power transfer back to RTA and the very large voltage steps (>7%). There are likely extensive studies required to understand the full impacts on the RTA power system.
- During islanding, all scenarios seemed feasible to manage voltage and supply loads with minimal curtailment (except Scenario 4) of renewable resources.

[1] *Excludes the RTA owned network*

Table 1 – Summary of microgrid scenarios

Scenario	Description	Grid-Connected		Islanded		Feasible without Major Network Augmentation ?
		Voltage Levels	Power Flow within Limits	Voltage Levels	Power Flow within Limits	
1	Primarily grid-connected, and only island during RTA outage	✓	✓*	✓	✓	Yes
2	Primarily islanded with RTA as a backup during microgrid outage	✓	✓*	✓	✓**	Yes*
3	Fully standalone, with no connection to RTA	-	-	✓	✓	Yes
4	Fully standalone, with future expansion to supply RTA	×	×	✓	✓**	No

A summary of considerations moving forward are:

- Ongoing consultation with RTA is required to understand better the impacts on the RTA power system and the level of acceptance for the proposed connection. In addition, a few RTA projects are underway, such as the Humbug/Andoom interconnection, solar and BESS, that may affect the feasibility of the proposed microgrid and the level of detailed studies required. These RTA projects are **not considered** in this study.
- In addition to obtaining approval for the network connection, the connecting Proponent must obtain consent from both EEN & RTA to form an island of the distribution network. They should also familiarise themselves with the extent of requirements, including legal/regulatory, technical and safety obligations, the sale of energy, and the operation and maintenance of the system.
- The technical access standards for connection in the Isolated Networks are not well-defined but would expect to fall under the requirements of STNW 1175. This would be in addition to RTA requirements due to the potential impacts on the power station. Although STNW 1175 is based on NER requirements, the standard is considered the best practice for Isolated Networks to ensure and uphold a reasonable level of system performance.
- This study only considered steady-state load flows based on worst-case network scenarios. Detailed planning studies are required to verify feeder ratings and power station capability to understand the power transfer capabilities back to RTA.
- The protection requirements have not been assessed as part of this study. This is due to the complexity of modelling short-circuit performance of inverters, particularly for islanded situations. Detailed studies are required to verify protection impacts when grid-connected and during islanding to ensure the protection system is maintained.

DEFINITIONS, ABBREVIATIONS AND ACRONYMS

CP	Connection point
DRM	Demand response mode
EEN	Ergon Energy Network (Distributor of the Napranum 11kV network)
EMT	Electro-magnetic transient (type of detailed computer simulation)
IBR	Inverter based resources
ITP	ITP Australia
MIST	Microgrid and Isolated Test Facility
NEM	National Electricity Market
NER	National Electricity Rules
PLL	Phase Locked Loop
RRCRF	Regional and Remote Communities Reliability Fund
RTA	Rio Tinto Australia (Owner/operator the Weipa power system)
SCR	Short Circuit Ratio

REFERENCES

Energy Queensland Documents

Document	Version	Description
STNW1174	18/12/2021	Standard for Low Voltage Embedded Generating Connections
STNW1175	18/12/2021	Standard for High Voltage Embedded Generating Connections

External Documents

Document	Description
Queensland Electricity Connection Manual	Applies to all electrical installations that are connected, or are to be connected, to the respective supply network
Queensland Electricity Metering Manual	Applies to all premises connected to Energex and Ergon Networks, including all premises connected to an Isolated Power System, or part of the Mt Isa supply network.
AS/NZS 3000:2018	Electrical installations (Australian/New Zealand Wiring Rules), Standards Australia.
AS/NZS 4777.2:2020	Grid connection of energy systems via inverters, Part 2: Inverter requirements, Standards Australia.
IEEE 2030-7:2017	IEEE Standard for the Specification of Microgrid Controllers
IEEE 2030-8:2018	IEEE Standard for the Testing of Microgrid Controllers
IEEE 2030-9:2019	IEEE Recommended Practice for the Planning and Design of the Microgrid

Napranum Microgrid Pre-Connection Feasibility

1 INTRODUCTION

This document outlines the pre-connection technical feasibility study of a proposed microgrid solution for the Napranum 11kV distribution network. The distribution network at Napranum is owned by Ergon Energy Network (EEN) and supplied by the East Weipa power station which is owned by Rio Tinto Australia (RTA). This work is part of a broader project by Ener-G through the Regional and Remote Communities Reliability Fund (RRCRF) to undertake feasibility studies into more reliable, secure and cost-effective energy supply for regional and remote communities in Australia.

The scope of this study consists of power system modelling, distribution studies and connection advice related to the pre-connection technical feasibility of microgrid solutions for the 11kV Napranum distribution network. At the time of writing, the project is only at the feasibility stage, and **no formal connection application** has been lodged.

The study considers a number of microgrid scenarios, as described in Section 1.2, which were formulated by EnergyConnect. This scope does not cover economic analysis related to microgrid component sizing (i.e. inverter/battery, generator size, PV capacity, etc.) Technical assessment includes aspects such as:

- Reviewing available network data (schematics, load profiles, engineering reports, etc.) as provided by the Customer
- Modification and validation of the Powerfactory model based on available information
- Establishing load flow study case and boundary conditions for each scenario
- General network connection advice and access requirements for the EEN distribution network, based on STNW 1175
- General advice on impacts on the Isolated Network
- Validation of microgrid operating scenarios and proposed sizing is fit for purpose.
- Steady-state assessment of the power system under various scenarios and boundary conditions
- Perform fault studies and consider high-level protection impacts of the microgrid.

1.1 System Overview

The Rio Tinto Australia (RTA) northern facilities at Weipa consist of operations at East Weipa and Andoom, which supply the Weipa township and the port facility at Lorim Point. The Weipa distribution network is supplied from the Humbug power station, which consists of 6 x 5.45MVA MAN diesel generators and a 1.6MW solar PV farm. The Andoom network is supplied by 7 x 1.75MW CAT diesel generations. Although there is a 22kV interconnector between Humbug and Andoom, the two networks are typically operated separately due to operating constraints. However, at the time of writing, there were studies underway for a potential upgrade of the network to allow for the interconnection of two networks to provide some power transfer capability.

This study focuses on the Napranum township, which is supplied by the 11kV East Bore Line feeder from East Weipa power station (Humbug), as shown in Figure 1. This 11kV feeder also supplies other RTA loads such as the Lorim Port port, bore field, Weipa airport, 55ML dam and Evan's landing area.

Figure 1 – Geographic overview of 11kV Bore Line feeder from Humbug power station

Napranum Microgrid Pre-Connection Feasibility

Figure 2 shows an overview of the Napranum 11kV (▬) and LV (▬) distribution network. The Napranum network is comparatively short compared with the RTA upstream network but consists of reasonably high community loads. The Napranum township power supply is susceptible to any large disturbing loads on the upstream RTA network, primarily from mining operations. The nature of this arrangement inherently suits the objective of the microgrid application to improve reliability and increase energy independence from the upstream RTA network. Conceptually, this aligns with the philosophy of the proposed microgrid application for reliability improvement.

Figure 2 – Geographic and electrical overview of the Napranum distribution network

1.2 Microgrid Scenarios

This technical study considers the following microgrid scenarios:

1. Operate primarily grid-connected but can be islanded and self-sufficient as required during contingency or for network support.
2. Operate primarily islanded microgrid that is self-sufficient but uses the RTA network as backup supply during contingency
3. Operate a fully standalone self-sufficient microgrid with no connection to the RTA network.
4. Operate a fully standalone self-sufficient microgrid with no connection to the Weipa grid but allow for expansion to supply the Weipa township.

Since scenario 3 assumes no connection to the RTA network, only the EEN distribution network impacts are considered. Table 2 shows the assumed sizing for the technical study developed in collaboration with EnergyConnect.

Scenario 4 is considered a conceptual exercise as the total size of the centralised solar is very significant compared with the existing distribution network. As such, any modelling results regarding Scenario 4 should be viewed with caution.

Table 2 – Summary of sizing of energy resources for the study

Scenario	Description	BESS Capacity (MVA)	BESS Storage (MWh)	Centralised Solar (MW)	Small Wind (MW)	Total Rooftop Solar (MW)	Total IBR Connected Capacity (MW)
1	Primarily grid-connected, and only island during RTA outage	1	3	0.5	0.35	0.3	2.2
2	Primarily islanded with RTA as a backup during microgrid outage	2.7	10**	2	0.0	0.0	4.7
3	Fully standalone, with no connection to RTA	2.7	10**	5	0.35	0.3	8.4
4	Fully standalone, with future expansion to supply RTA	2.7	10**	10	0.35	0.3	13.4

*Note ** - Preliminary value and not used in this study.*

1.3 Assumptions and Exclusions

- This study **<u>does not consider the economic feasibility</u>** of the proposed microgrid connection.
- Only steady-state studies are considered. Dynamic studies are not considered in scope, since it depends on the availability of RTA dynamic models (i.e. generators AVR/governor, solar PV, BESS, etc.).
- All microgrid configurations, including BESS inverter sizing, energy storage capacity, diesel generation, solar PV, location, etc., are provided by the Customer.
- Economic sizing or life cycle of the microgrid solution is not assessed, but EEN will consider the technical feasibility of the microgrid connection based on distribution planning criteria, existing connection standards and any agreed RTA Connection Point (CP) connection agreements that can be provided by the Customer. In the absence of any RTA CP technical agreements or operating protocols, assumptions can be made by EEN to test the microgrid connection against industry standards or best practices.
- No microgrid operating philosophies are considered. While this can be achieved through quasi-dynamic simulation with relative ease in the future, there needs to be additional consultation with the Customer, as it is linked to economic sizing.
- DigSilent Powerfactory 2021 was used as the simulation package for technical studies.
- The impact assessment of the microgrid on the RTA Weipa power station was only preliminary and high-level since there was limited information on the RTA network and power station.
- There was no consideration for the planned upgrade of the interconnection between the Humbug and Andoom power stations and the impact of the solar farms or BESS.
- There was no consideration of costs or timing in regard to the EEN connection process and formal technical assessment requirements.

2 PROPOSED MICROGRID CONNECTION

Figure 3 shows the preliminary concept plan of the proposed microgrid site located within the Napranum township. The proposed site includes the following:

- HV connection point (11kV) with automatic circuit recloser or high voltage CB
- The power transformer(s) with a total capacity are dependent on the microgrid scenarios. This may consist of multiple transformers depending on detailed design considerations (flicker, fault levels, redundancy)
- Grid-forming battery energy storage system (BESS)
- Centralised solar PV and wind turbine (depending on wind resources)
- Backup diesel generators (not grid coupled) and fuel tanks

Although not located at the new site, there may be additional rooftop solar PV to be installed at premises across the Napranum community.

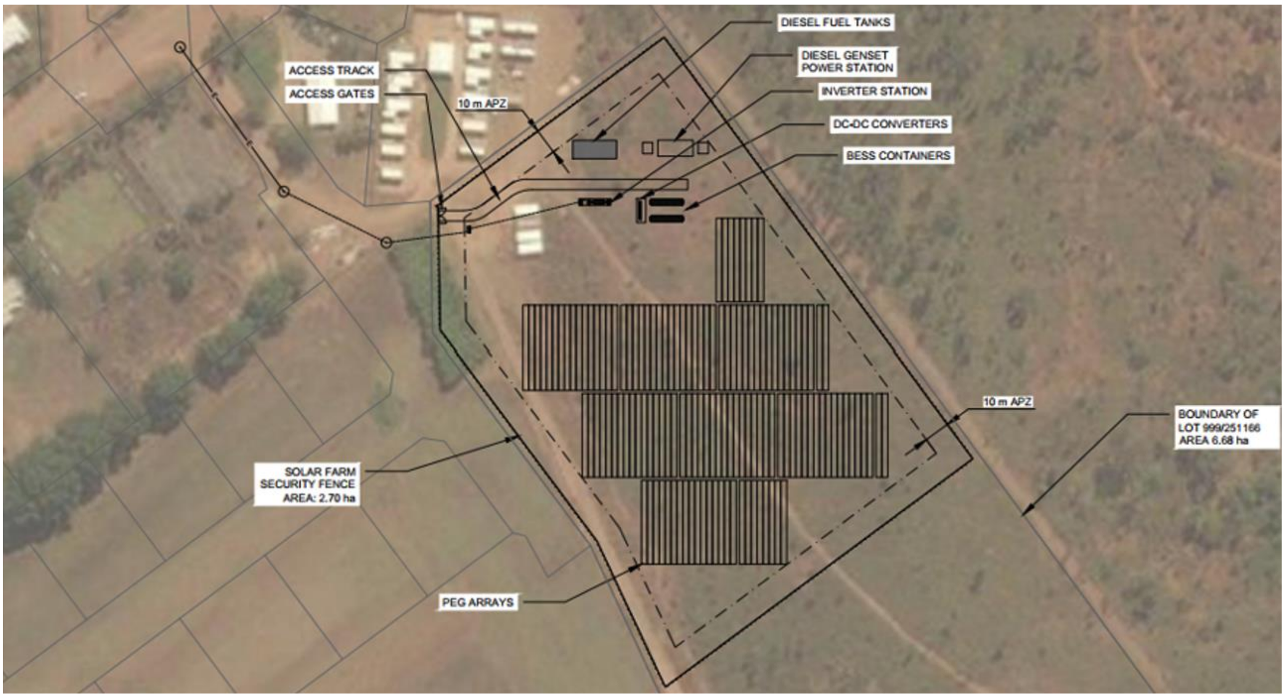


Figure 3 – Preliminary site arrangement

The connection to the microgrid site is shown in Figure 4. The preliminary scope of works for connection into the distribution network includes:

- Tee-off from existing HV term pole 1034880 (potential for alternative tee-off points)
- Construct approximately 200m extension of 11kV overhead from pole 10344880 to the customer site
- Establish a new 11 kV connection point with ACR or HV CB at the customer connection point
- Depending on a detailed analysis of conductor ratings, additional reconducting from pole 1034880 to the Napranum recloser may be required to maximise power transfer to the RTA network.

- Install HV metering point upstream of the Napranum recloser to provide HV voltage sensing back to the microgrid site. RTA-side HV voltage sensing is required for synchronising to seamlessly transition back from islanding to grid-connect operation.
- Direct communication from the microgrid site to the Napranum recloser for control and status indication.
- Communications to the Weipa power station for control and indication by RTA. This may include telemetry back to RTA, issuing runback or curtailment commands, and protection intertrip.
- Install a power quality analyser at the microgrid HV connection point for commissioning and ongoing performance monitoring and validation.
- Provision for upgrading the existing Napranum recloser to allow for additional protection requirements such as sync check.

The feasibility of this scope of work can only be confirmed after a detailed connection assessment and through consultation with RTA. Further activities will also impact option feasibility, including assessment of thermal feeder limits, load/generator rejection studies, and fault analysis. This will occur during the detailed technical assessment.

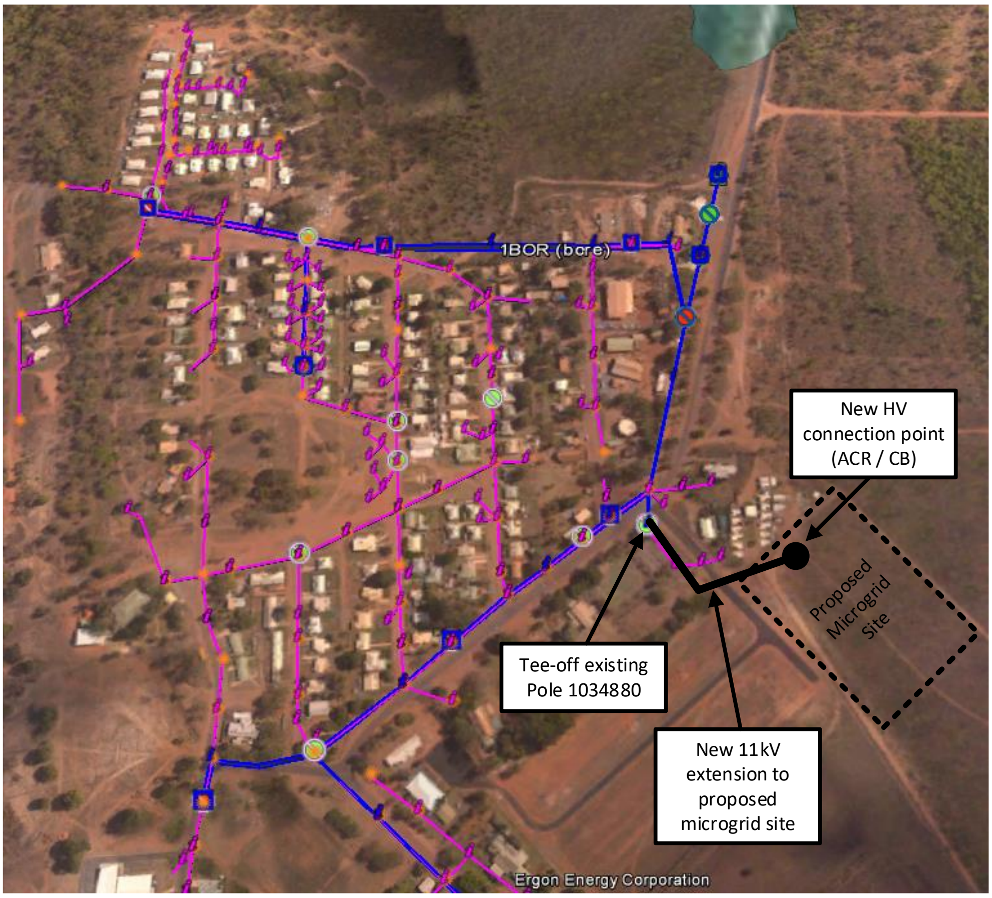


Figure 4 – Proposed connection to microgrid site

3 POWER SYSTEM MODELLING

3.1 Load Profile

The load and voltage profile at the Napranum connection point was obtained from the recloser (RC804669) and the HV metering unit, which are both nearby to each other. Figure 5 and Figure 6 shows the load profile from the Napranum recloser in 15min intervals. At the time of the study, only four months of data were stored locally on the device, and an historian does not poll the recloser.

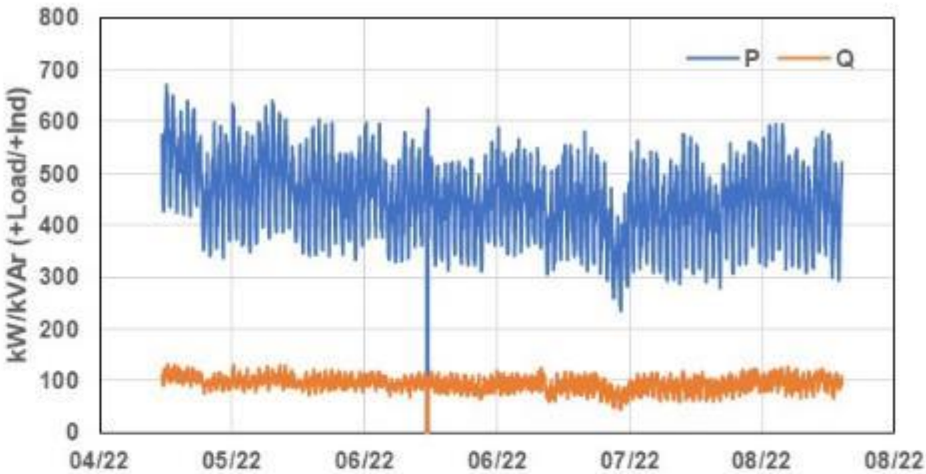


Figure 5 – Napranum recloser load profile

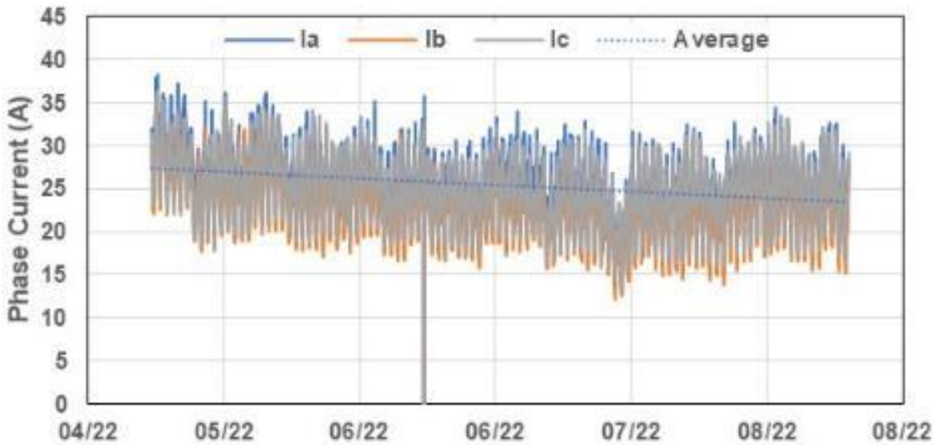


Figure 6 – Napranum recloser phase current

Due to the limited recloser information, additional data was obtained from the HV metering unit, as shown in Figure 7. This shows a peak demand of about 800kW in Nov 2021 and a minimum demand of around 300kW over the last few years. Figure 8 shows the power factor of the load, which seems to be improving closer to unity since 2019.

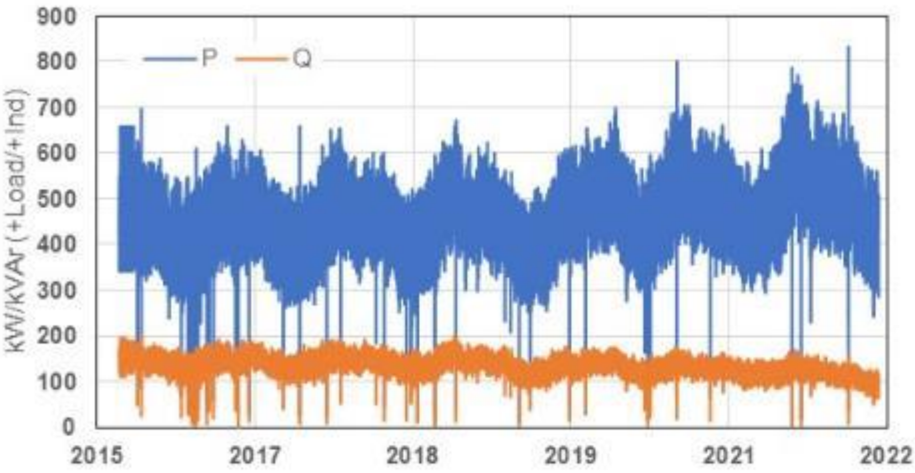


Figure 7 – Napranum HV metering unit load profile

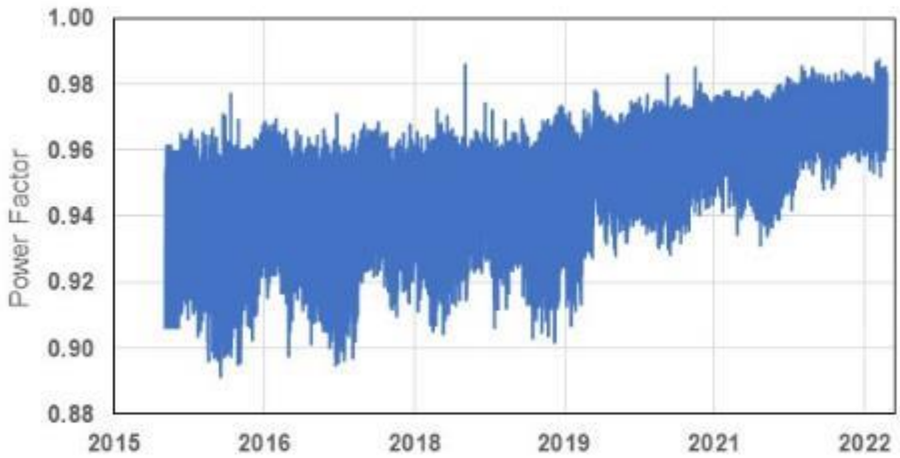


Figure 8 – Napranum HV metering unit load power factor

Figure 9 shows the load profile based on the time of day to determine the boundary cases for the proposed microgrid connection. Since no generation profiles were provided, assumptions were made for these boundary cases. Two time periods (2015-2022 and 2020 to 2022) were chosen to see the long-term and recent trends in the time-of-day load profile. This clearly shows two load peaks, one after midday at 15:30 and the evening peak at 20:00. The minimum demand period occurs consistently in the early morning, around 06:00.

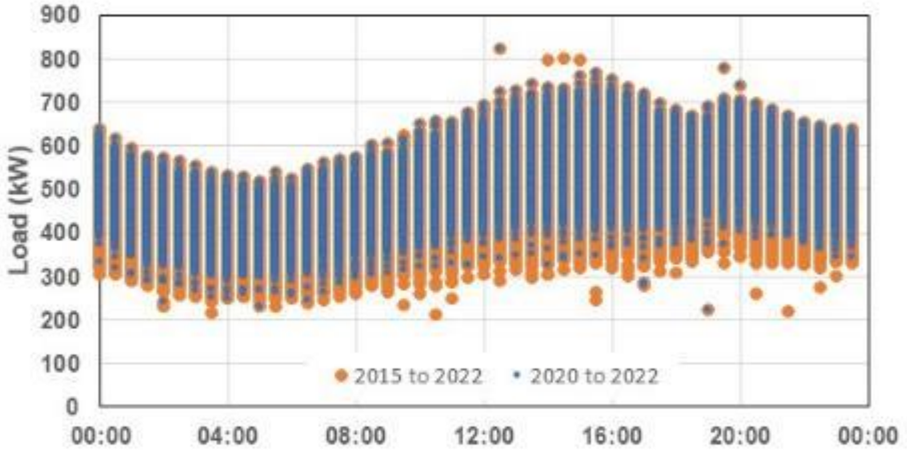


Figure 9 – Load profile with time of day (2015 to 2022)

3.2 Voltage Profile

The only source of voltage data at Napranum was from the recloser, which was limited to 4 months.

Figure 10 shows the 11kV is held relatively constant throughout this period, despite the Napranum loads. This is likely due to the relatively low load on the 11kV Bore Line feeder, relative to the conductor sizing. Most conductors are Mink 6/1/.144" ACSR and Cherry 6/4.75+1/1.6, which can handle 217A and 891A, respectively, based on Far North region, 75C summer day conditions. The voltage data also show many spikes, likely due to large disturbing loads on the RTA network.

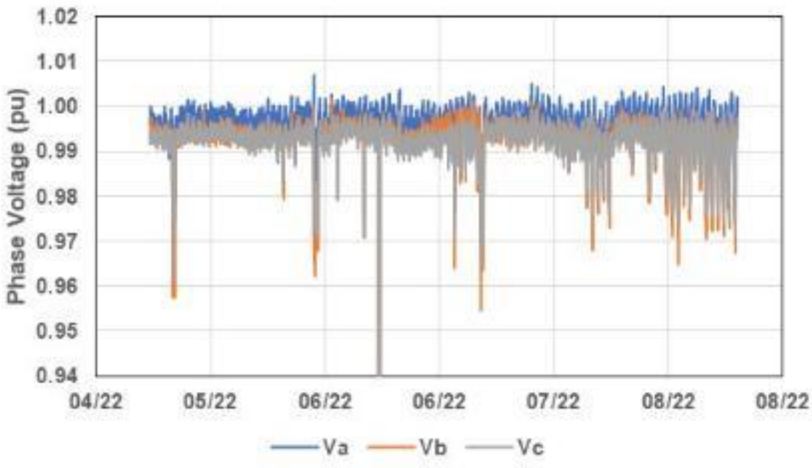


Figure 10 – Napranum recloser voltage profile

Figure 11 shows the variability of voltage based on the Napranum loads. Voltage is mostly constant at 0.99pu to 1.0pu, with some periods of slight reduction to 0.97pu. The lower voltage is likely due to station operation and intermittent large disturbing loads, as seen in the spikes in Figure 10. Also, there is no evidence of high voltage or swells. This is likely due to the short distribution networks, which have minimal capacitive line effects. Line capacitance typically leads to higher voltages during low load periods.

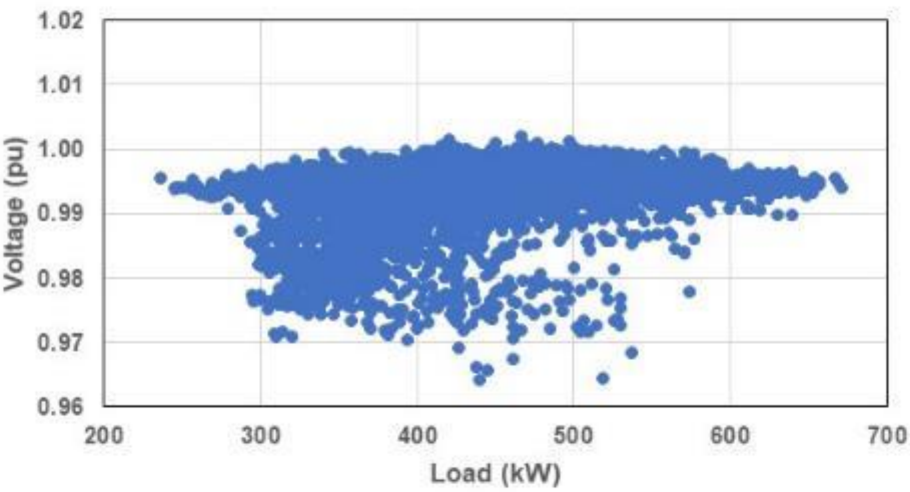


Figure 11 – Comparison of Napranum voltage with load

3.3 Load and Generation Scenarios

Based on the previous information, two worst-case network scenarios are:

- Case A considers the worst-case loading, which is based on peak load (during late afternoon/early evening)
  - For grid-connected – This tests the boundary case of peak load on the RTA network with no large renewable generation, and BESS is charging.
  - For islanded – This tests the boundary case of peak load on the islanded microgrid, and peak load needs to be supplied by the BESS, with no large renewable generation.
- Case B considers the worst-case generation, which is based on minimum demand (during the early morning)
  - For grid-connected – This tests the boundary case of minimum load on the RTA network with maximum renewable generation and export to the RTA network.
  - For islanded – This tests the boundary case of minimum load on the islanded microgrid with maximum renewable generation, and the BESS needs to absorb excess generation.

There is no consideration for energy usage/generation or BESS state of charge (SOC) management, which depends on generation profiles and microgrid operating philosophies (which were not provided).

Table 3 – Network Boundary Cases

Case	Scenario Description	Load (MW)	Load PF	Recloser Voltage (pu)	BESS (MW)	Central PV (MW)	Wind (MW)	Rooftop PV (MW)	Grid-Connect Mode	Island Mode
A	Afternoon Peak Demand with Max Charge	0.80	0.96	0.99	Max Charge	OFF	OFF	ON	Worst case RTA loading	Worst case peak load on microgrid with no renewable source
B	Morning Minimum Demand with Max Generation	0.30	0.96	0.99	Max Generation	ON	ON	ON	Worst case generation/export into RTA	Worst case excess generation during minimum demand

3.4 Load and Solar Allocation Methodology

This section describes the load and solar allocation process for the study. Napranum has a total of 10 LV distribution transformers supplying about 259 NMI customers, with approximately 87% made up of domestic customers and 13% commercial customers, as shown in Table 4. There are also some industrial loads, such as the water treatment plant.

The load study is based on static load and generation scenarios from historical performance profiles and the proposed microgrid scenarios. The load allocation of the Napranum 11kV network was based on a typical method of using energy consumption data, as shown in Table 4. The HV metering transformer was excluded since the load contribution is negligible.

The solar was evenly allocated based on the load classification of the transformers and those primarily domestic customers. This equates to 50kW being allocated to six transformers for 300kW of rooftop solar PV.

Table 4 – Distribution transformers on the 11kV Napranum network

No.	Name	Rating (MVA)	Customers	Domestic (%)	Commercial/ Industrial (%)	Annual Consumption 2016	Load Allocation	Solar Allocation
SS10050	NAPRANUM WATER TOWER	315	3	0%	100%	170,289	4.7%	0%
SS10051	GOBUNG STREET	200	32	88%	12%	331,392	9.2%	16.7%
SS10052	WA-TYNE STREET	315	64	82%	18%	880,332	24.4%	16.7%
SS10054	BEE NING STREET	315	43	96%	4%	809,723	22.5%	16.7%
SS781364	SS781364	100	0	0%	0%	0	0.0%	0%
SS7914	WEIPA SOUTH NO 3	300	43	94%	6%	590,696	16.4%	16.7%
SS7915	BLOCK PLANT	300	9	27%	73%	314,492	8.7%	0%
SS7916	WEIPA SOUTH NO 1	300	56	96%	4%	482,881	13.4%	16.7%
SS7917	WEIPA SOUTH NO 2	300	9	88%	13%	24,295	0.7%	16.7%
SS596212	WEIPA SOUTH HV METERING	10	0	0%	0%	0	0.0%	0%
	Total Capacity	**2445**	**259**	**87%**	**13%**	**3,604,100**	**100%**	**100%**

3.5 Distribution Model

The distribution network was modelled using DigSilent Powerfactory 2021, as shown in Figure 12. The model consists of:

- External grid with equivalent fault levels to the Humbug power station (discussed further below)
- Approximately 5km of 11kV distribution from the power station to the Napranum CP
- Approximately 2.4km of 11kV distribution from the Napranum CP to the various 11/0.415kV distribution transformers

The Napranum 11kV network is based on the best available EEN network information, whereas the upstream RTA 11kV network is based on historically provided information from RTA to EEN for previous protection studies.

The model **does not** include:

- Any LV distribution network
- Upstream transformers or load allocation on the 11kV RTA network

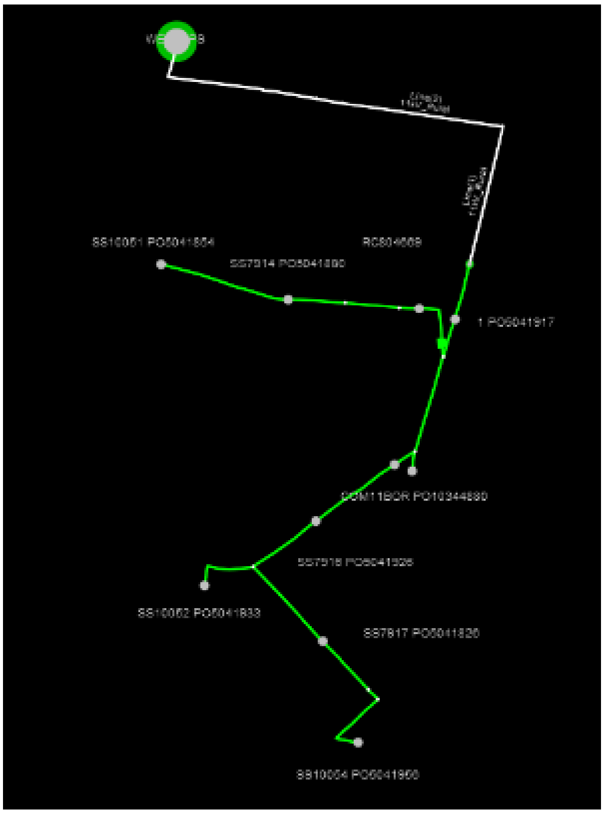


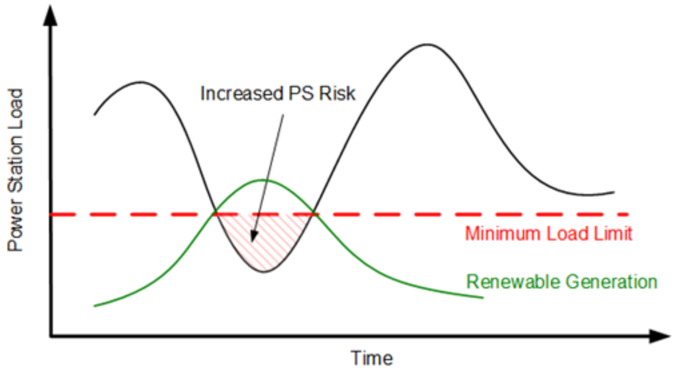
Figure 12 – PowerFactory Model of Napranum EE Distribution Network

4 DESIGN CONSIDERATIONS

4.1 Challenges with Isolated Networks

This section outlines some of the typical high-level challenges with renewable integration into primarily diesel-supplied isolated networks. The challenges of renewable integration in isolated networks are different compared with National Electricity Market (NEM) connected networks. This is due to fundamental differences in the system strength and inertia of the power system. The NEM consists of hundreds of synchronous generators providing a very stiff network, whereas the Isolated networks are comparatively weak since only a handful of generators supply the loads. The challenges are focused on power station management due to displacement of load and renewable resource intermittency. In general, the two key issues surrounding the integration of renewable energy in isolated networks are:

1. **Stability** – The inherent intermittency of renewable generation may cause stability issues with the gensets, as well as potential reverse power issues:
   a. Insufficient spinning reserve - Generators are rotating plant that has a limited active power output rating. Sudden variations in active power demand onto the power station can overload the gensets and cause under-frequency and load-shed events.
   b. Limited dynamic response capability of the gensets - Sudden variations to load or generation cause disturbances to the frequency and voltage, which can impact power quality and cause other connected inverter systems to trip. Large step loads may cause significant large frequency and voltage excursions and may cause genset protection to operate, resulting in outages. Understanding the step response of the power station is important in assessing the response to disturbances such as step loads, faults and renewable energy intermittency.
   c. Reverse power – In the event of a negative active power load on the generator (i.e. from high renewable generation), the genset protection may operate, resulting in an outage to the community.
2. **Minimum Loading** – High levels of renewable energy may displace the load such that the engines operate below the recommended minimum loading over extended periods of time, which can reduce engine performance, increase maintenance requirements and reduce the life of the asset. The actual minimum load limits vary depending on the manufacturer guidelines, and the engine's capability to run at low loads.



The management of both minimum loading and stability is essential in ensuring renewable energy can be reliably integrated. Depending on the penetration level of renewable energy, there are varying solutions to manage renewable connections.

Based on this, the following impacts of the proposed microgrid system on the RTA power station and RTA network should include:

- Impact of the microgrid when grid-connected.
  - There is a potential for the BESS to charge from the RTA network, which could increase power station loading.
  - Generation export from the microgrid into the RTA network, which can de-load the power station below the generator minimum load and increase the risk to the power station and the overall connected loads.
  - Power quality impacts such as flicker and increased harmonics (from converters) and variable renewable generation.
- Napranum is islanded and seeking to transition seamlessly back on the grid. The microgrid would need to manage the transition back to RTA in a seamless manner in terms of impact to the Napranum customers, but also the impact to the power station.

When grid-connected, the microgrid system needs to mitigate the risk of inrush and steps on the RTA power station, such as from motor starts (i.e. from BESS auxiliaries), CB operation, unintended trips of the plant (i.e. BESS/Solar CB) and transformer energisation.

As a result, there need to be detailed studies regarding the impact of the microgrid on the RTA power station performance through a consultation process. Depending on RTA connection requirements, the microgrid can be designed to mitigate impacts which should include the following:

- Detailed electromagnetic transient (EMT) studies of inverter-based resources (IBR) under low system strength scenarios and fault ride-through (when grid-connected)
- Transient stability studies during seamless islanding transitions (synchronising and deloading sequences)
- Transformer energisation studies
- Ramp-rate and curtailment controls for aspects such as power station minimum load constraints, network loading constraints and renewable intermittency.

4.2 Management of Network Voltages

EEN is required to maintain system voltages in accordance with the Queensland Electricity Legislation, of low-voltage supply of 230V +10%/-6%. As such, voltage management forms a key part of the network management. The EEN HV connection agreement onto the RTA network impacts the capability of the EEN distribution system to maintain legislated requirements. There needs to be a means to maintain customer supply voltages, under all operating modes of the Napranum microgrid, including:

- Grid-connected to the RTA Network
- Islanded from the RTA Network and N-1 contingency scenarios

4.2.1 Grid-Connected

When grid-connected to the RTA network, the effect of real power injection from embedded generation (solar PV, BESS or wind) must be considered. Typically, any generation system will either be in fixed power factor mode or in voltage control mode to keep the voltage within acceptable limits. This study considers voltage droop control at the microgrid CP, which is discussed in Section 5.6. Technical requirements with EEN and RTA will determine the specific control mode during the connection application. Rooftop PV is assumed to be compliant with AS4777.2:2020 and would operate in volt/var and volt/watt control modes.

4.2.2 Islanding

During islanding from the RTA Network, the proposed microgrid shall maintain network voltage and frequency through grid-forming modes and shall operate in V/F control, either isochronous or droop. For this study, voltage droop control and isochronous (fixed frequency) is considered. The voltage droop settings are kept the same as in grid-connected mode. This will be verified and explored further should the project proceed to a technical assessment stage.

4.3 Feeder Capacity

The EEN 11kV network consists primarily of Mink conductor, with minor sections of Helium and Libra. The conductor ratings are shown in Table 5, which assumes Far North, summer day and 75°C conditions. Based on the limited information, the upstream RTA network consists of a combination of Cherry, Mink, 185mm^2 Cu and 185mm^2 Al. However, the feeder rating of the RTA supply to Napranum needs to be confirmed through detailed studies.

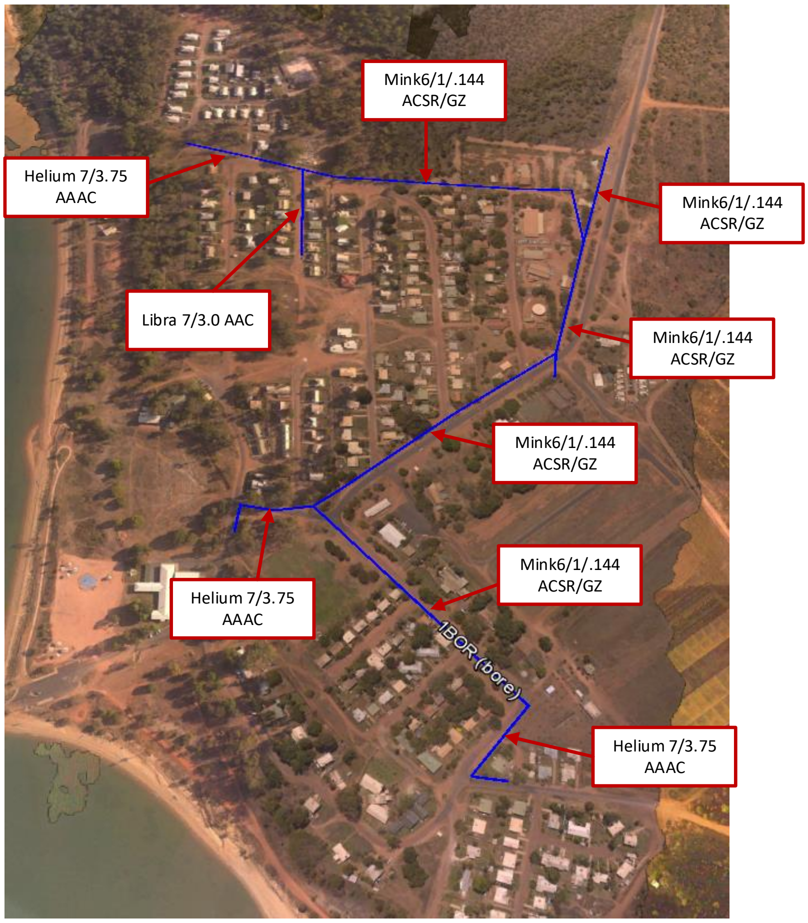


Table 5 – Conductor ratings

Conductor	kV	Amps	MVA	Deg	Region	Time
Mink 6/1/.144" ACSR/GZ 1350	11	217	4.1	75C	Far North	Summer Day
Helium 7/3.75 AAAC 1120	11	252	4.8	75C	Far North	Summer Day
Libra 7/3.00 AAC 1350	11	194	3.7	75C	Far North	Summer Day
Cherry 6/4.75+7/1.60 ACSR/GZ 1350	11	291	5.5	75C	Far North	Summer Day

4.4 Power System Stability

Power system stability is a general term that defines the ability of an electric power system to achieve a steady-state operating equilibrium following an electrical disturbance to the system. The objective is to ensure the power system parameters (e.g. voltage and frequency) remain within operating bounds, such that the power system remains intact. On the NEM there are clear AEMO published guidelines on system stability requirements[2], which are exhaustive in the design and validation of acceptable impacts on system stability by registered generators.

In recent years, there has been extensive published documentation[3] on system strength, particularly around the impact of low system strength on IBR stability and the deterioration of system strength by increasing IBR penetration. Although much of the literature is focused on large power systems (like the NEM), this system strength phenomena are even more relevant to Isolated Networks due to the sole reliance of diesel generating sets to provide fault levels and inertia. This can be more challenging due to the bespoke nature of the power station and power system and the inherently weaker nature of primarily diesel generation systems with lower mechanical inertia (relative to the loads and the NEM). Although diesel generators are synchronous machines, the rotation mass of the diesel engine actually provides a relatively small amount of inertia to the Isolated Network. One reason is that diesel generators are optimally sized to provide prime power to the network with as minimal spinning reserve as possible to save run hours and ensure efficient generator loading. This is also apparent through typical diesel generator step response tests and the comparatively low system inertia and slow response times of diesel governors.

Recently, the increased penetration of inverter-based resources (IBR) has raised concerns about the impact of system stability on grid-following IBR based on a phase-locked loop (PLL). PLL is known for unstable operation for weak grids, which is the reason for preliminary checks of short-circuit ratio (SCR) to determine the extent of analysis and validation needed for IBR connections.

Consequently, changes have been made to the NER to address this issue and maintain the stability of the power system going forward. The connecting entity should be familiar with the obligations that these changes are imposing on the generating systems. Despite this, the impacts of IBR on isolated networks with primarily diesel generation are not fully understood, which may require in-depth modelling considering the RTA power station dynamics. In order to ensure system stability in the EEN/RTA network, models of the microgrid system may be required based on the STNW1175 connection standard.

Although the proposed microgrid is not connected to the NEM, the typical EEN connection process would likely follow a similar NEM connection process for technical assessment as a best practice approach.

[2] *https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/2016/power-system-stability-guidelines.pdf*

[3] *https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf*
https://e-cigre.org/publication/rp3151-system-strength

4.5 Resilience and Seamless Islanding Transitions

The typical requirement for generation units with island capability is the provision of break-before-make connections. This means the generation units electrically isolate from the grid prior to re-establishing power supply to the loads in the island. Where a facility includes break-before-make generating units, these are included in the aggregation of generation systems to determine system classification. This is because these generators do not, at any stage, interconnect to the grid.

These arrangements are not seamless, which is in conflict with the requirements of microgrid systems under the definition of IEEE2030 standards. Under IEEE2030-7, a seamless transition is defined as the *"The connection and disconnection of a microgrid to and from the larger grid accomplished without voltage and frequency transients that exceed the specifications of the microgrid design and the interconnection requirements."*

A key objective of the microgrid system is to provide resilience and reliability to the power system. The IEEE2030 standard details the provision of microgrid services (in this case, the Napranum community), and define seamless islanding as the minimum requirement for reliability improvement. This also includes the following microgrid services:

1. Resilience
    a. Minimum requirements: Backup power during extreme, infrequent, and long-duration outage events—Basic considerations: i) Metrics: system uptime; ii) Providing backup power for critical loads (if such loads exist); iii) Black start of the microgrid in islanded mode (if the equipment capability exists within the microgrid)
    b. Additional services: Backup power for priority/critical loads, Load shedding, Optimising islanding duration, Minimising load not served, Providing time for controlled shutdown of loads following a distribution system outage
2. Reliability
    a. Minimum requirements: Uninterrupted power/seamless islanding (a minimum requirement for some customers)
    b. Additional services: Backup power during regular, frequent outages; Improvement of SAIDI, SAIFI, and CAIFI numbers, Uninterrupted power and/or seamless islanding
3. "Downstream" power quality
    a. Mitigation of voltage/frequency sags and surges, Mitigation of harmonics (voltage and/or current, if required)

Microgrid applications covering reliability improvement (such as this connection) need to consider grid-forming inverters which are coupled to the network and run parallel with the network. This is to enable a seamless transition should there be an outage or disturbance to the upstream network.

At the time of writing, there are limited standards on grid-forming inverters and grid connection requirements. Therefore a connection application involving grid-forming inverters will likely need to go through a detailed EMT modelling process.

4.6 Ramp Rate and Curtailment Schemes

All grid export to the RTA network shall be managed through defined ramp rates to prevent any renewable intermittency from affecting the power station operation.

The microgrid system shall be designed to minimise the steps on the RTA network due to contingency events or plant switching (such as transformer energisation, CB switching, contingencies)

Scope of work for curtailment schemes may include:

- Installation of run back / back-stop scheme to provide immediate curtailment of renewable generation. This provides a backup measure for the grid-connected scenario to RTA network in the event of network contingency and also for an islanded scenario to curtail excess generation.
- For centralised solar PV and wind this is recommended to be via fast communications such as direct fibre
- For rooftop PV, Ergon Energy has implemented an active PV control scheme via a third-party aggregator. This consists of a heartbeat to continuously monitor the connection to the PV every 5 seconds. In the event of a failed heartbeat, an inverter system must ramp down to 0kW. An alternative option should be to manage the grid frequency to curtail solar PV, or use demand response mode (DRM) signalling (see AS/NZS 4755-2007)

5 TECHNICAL ASSESSMENT

5.1 Overview

The connection into the EEN distribution network would be governed (to an extent) by STNW1175[4], which is the connection standard for high voltage EG connections less than 5MVA. This covers both inverter-based resources (IBR) and rotating machines. However, at the time of writing, STNW1175 does not cover grid-forming IBR, so additional requirements may be imposed. The typical step in the connection process is to carry out further analysis to provide a technical assessment of the proposed connection. Due to the expected size of this system, the technical assessment should include:

- Determine the system class as described under STNW1175. See section 5.3 for discussion.
- Undertake analysis of constraints potentially resulting from the proposed microgrid
- Determine the impact to network voltages and power quality as a result of the proposed microgrid
- Determine the appropriate operational mode for the system
- Analyse the distribution system and RTA interconnection. This study includes a preliminary assessment of this.

However, due to the additional complexity of the RTA network impacts, the technical assessment may include additional requirements and consultation with RTA, such as:

- Full detailed dynamic studies, including the RTA power station, solar and BESS connections, and considering large disturbing loads.
- Consideration of the Humbug Andoom inter-connector works that are currently proposed and potential interactions with the existing 1.6MW solar farm and the proposed 4MW/4MWh BESS.

Other relevant microgrid standards which cover specifications, design and testing include:

- IEEE Std 2030-7:2017 – IEEE Standard for the Specification of Microgrid Controllers
- IEEE Std 2030-8:2017 – IEEE Standard for the Testing of Microgrid Controllers
- IEEE Std 2030-9:2017 – IEEE Recommended Practice for the Planning and Design of the Microgrid

Although these standards are not imposed, they should be considered best practise for design of the microgrid system, in conjunction with the relevant EEN/RTA connection requirements.

[4] *https://www.energex.com.au/__data/assets/pdf_file/0007/671830/STNW1175-Standard-for-HV-EG-Connections.pdf*

5.2 Typical Information Required during Connection Process

Should a connection application be submitted, the following information may be required to ensure efficiency of the technical assessment by the EEN connection team:

A. Details of your hybrid generating system, as follows:
   a. Number, size and type of inverters;
   b. Certification to AS/NZS4777.2:2020 shall be required where LV inverters are to be used
   c. Battery system specifications (nominal power, efficiency, rated voltage, rated current, short circuit current, open circuit voltage and battery chemistry);
   d. Total number of battery modules and aggregate battery module capacity;
   e. Short-circuit performance of the system
   f. Wind turbines and solar PV details

B. Single line diagrams for protection and operation;

C. Annual half-hour profile of power output (in .csv or .xlsx format);

D. BESS charging and discharge rates and duty cycle times, preferably 1 minute profile data in .csv or .xlsx format;

E. General arrangement of the site, including the preferred location for connection assets as relevant;

F. Anticipated required maximum and minimum demand;

G. Details of any disturbing plant/loads, such as motors or pumps, including starting current and anticipated starting frequency;

H. Survey plan of land lot/s showing the general arrangement of the site;

I. Transformer details (required for fault calculations);

J. If relevant, schematics and switching sheet/table demonstrating that any break-before-make generating systems can be treated as off-grid.

K. Grid-forming details of parallel operation with the grid or islanded operation, including inertia and virtual synchronous machine performance

5.3 Fault Levels and SCR Assessment

The fault levels at Napranum have implications for not only the protection systems but also the system strength and stability of inverter-based resources (IBR). The short circuit ratio (SCR) is the accepted screening measure for system strength. Based on STNW1175, this determines the Class of the connection and the modelling requirements. SCR is calculated with the following formula:

$$SCR = \frac{S_{CMVA}}{P_{max}}$$

Where S_{CMVA} is the minimum fault contribution in MVA at the connection point bus and P_{max} is proposed aggregate AC coupled nameplate inverter capacity at unity power factor. This SCR will determine the Class of the system, as per Table 6

Table 6 – System Classification in STNW1175

Generation Capacity	Short Circuit Ratio	Connection Category
<= 1.5 MVA	All SCR	Class A1
> 1.5 MVA but < 5 MVA	SCR > 5	Class A2
> 1.5 MVA but < 5 MVA	SCR <= 5	Class B

For the purpose of the classifications in Table 6, generation capacity is the aggregate AC coupled nameplate inverter capacity of the system and does not consider operational de-rating of connection transformers at the nominal tap, applicable power factor, ambient temperature or application of any control system setting to limit the active power output of the generating unit.

The fault levels on the Napranum network are primarily determined by the number of sets online at the Humbug power station, which consist of six 5.454MVA MAN 9L diesel generators. However there is also the interconnector works underway, which will tie in seven 1.75MVA CAT generators at Andoom through a 22kV interconnector. In addition, the fault levels will be affected by the 1.6MW Weipa solar farm (Solar Phase 1) and 4MW/4MWh BESS (Solar Phase 2).

For the purposes of minimum fault levels for a preliminary system strength assessment, we assume:

- Weipa network is islanded from Andoom
- 1.6MW solar and 4MW/4MWh BESS are offline
- No contributions from mine inductor motors

RTA provided 1 hour sampled loading data for the Humbug power station from Jan 2019 to Aug 2022. Figure 13 shows the number of Humbug generators online which is primarily between 2 and 5 sets, making up 99.97% of the time. This is in line with the Aurecon June 2022 protection study report (Ref: 510659), which advised the minimum fault level configurations of 2 sets online for Weipa.

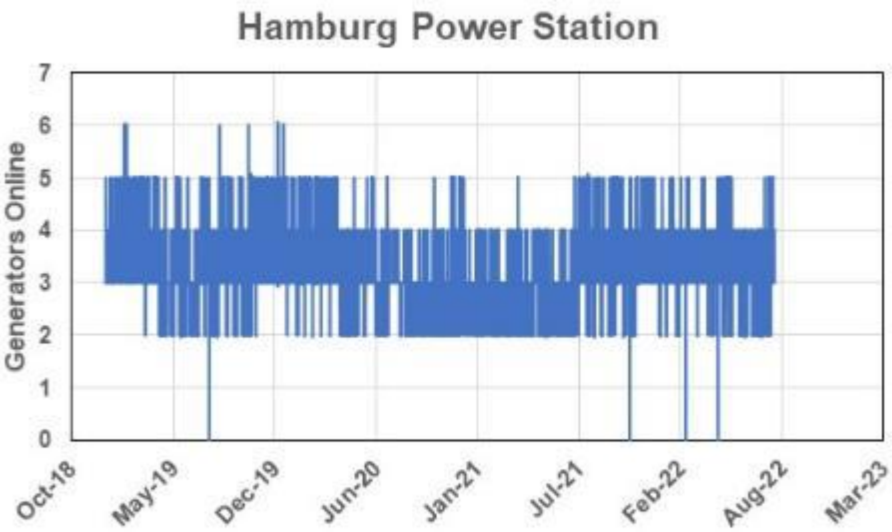


Figure 13 – Humbug station generators online

Based on the alternator datasheet, the sub-transient fault level (I_k") for a single set is 2.74kA. For two sets online, the sub-transient fault level at Napranum recloser is about 2kA (39MVA) and 1.8kA (35MVA) at the microgrid CP. Table 7 shows the preliminary assessment of SCR based on the microgrid scenarios and fault levels.

Table 7 – Assessment of SCR

Scenario	Description	BESS (MW)	Central Solar (MW)	Small Wind (MW)	Total IBR Capacity (MW)	Minimum Sub-Transient Fault Levels (MVA)	SCR	STNW 1175 Class
1	Primarily grid-connected, and only island during RTA outage	1.0	0.5	0.35	1.9	35.0	18.9	A2
2	Primarily islanded with RTA as a backup during microgrid outage	2.7	2.0	0.00	4.7	35.0	7.4	A2
3	Fully standalone, with no connection to RTA	2.7	5.0	0.35	8.1	N/A	N/A	N/A
4	Fully standalone, with future expansion to supply RTA	2.7	10.0	0.35	13.1	35.0	2.7	B

Note: the total IBR capacity does not consider the distributed rooftop solar PV.

Based on this, Scenarios 1 and 2 will be **Class A2, and Scenario 4 will be Class B.** This is only a preliminary assessment, and additional requirements may be imposed due to the complexity of the connection and the power station impacts.

Scenario 3 is not assessed since the microgrid is not connected to an existing grid. However, since the microgrid will be back-energising the existing EEN distribution network, there are other considerations, such as regulatory and quality of supply requirements.

Ergon Energy Corporation Limited ABN 50 087 646 062 | Energy Queensland Limited ABN 96 612 535 583 | Energex Limited ABN 40 078 849 055

5.4 Access Standards for Grid Connection

This section sets out the access standards that may be relevant to the proposed microgrid connection. These technical requirements are referenced in the Schedules of Chapter 5 of the NER as per Table 8. Note that this is based on NEM connection requirements, and the access standard may differ depending on connection studies and negotiations with EEN and RTA.

However, the typical expectation of generator system performance (which would include microgrid systems in Isolated Networks) is the automatic access standards, as per Chapter 5 of NER would be the minimum performance requirements to uphold a level of system performance. These automatic access standards are considered best practise for power system performance.

Table 8 – Access standards

Technical Requirement	Access Standard	NER Schedule 5.2 Equivalent
Reactive Power Capability	This ensures a level of reactive power capability to manage voltage at the connection point. Transformer details may need to be included to determine the reactive contribution of the generator	S5.2.5.1
Quality of electricity generated	Harmonic and flicker allocation will be conducted during the technical assessment	S5.2.5.2
Generating response to disturbances	Fault ride-through functionality of the inverter must be enabled; it is expected that the generator can tolerate voltage, frequency and power quality disturbances	S.5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6
Protection systems that impact on power system security	Protection system designed so as to not cause a material impact on power system security or power quality to others	S5.2.5.8, S5.2.5.9
Protection to trip plant for unstable operation	Protection to trip plant for unstable operation, such as pole-slip for rotating machines, or emission of unstable voltage, reactive power or active power.	S5.2.5.10
Frequency control	Respond to system frequency events	S5.2.5.11
Voltage and reactive power control	Voltage and reactive power control requirements will be determined as part of the technical assessment.	S5.2.5.13
Active power control	Respond to active power signalling as defined by the curtailment scheme(s) as determined in the technical assessment	S5.2.5.14
Remote monitoring and control	As required by Class in STNW1175	S5.2.6.1 and 4.11.1

5.5 Ownership and Network Regulations

This study assumes the microgrid connection is third-party-owned. The microgrid system must obtain consent from both EEN and RTA to form an island of the distribution network. The decision to allow islanding will be based on both technical validation of performance and any regulatory/legal impacts of third parties energising the EEN-owned distribution network. EEN has published a fact sheet regarding microgrids, including information on ownership models and regulatory implications for third-party-owned systems. This can be found at Microgrid Factsheet (ergon.com.au)

The connecting applicant should familiarise themselves with the extent of requirements, including regulatory, technical and safety obligations, the sale of energy, and the operation and maintenance of the system.

5.6 Voltage Droop Control when Grid-Connected

During grid-connected operation, it is recommended that the microgrid system control the voltage to within 0.5% of its set point at the connection point (CP). This is to ensure the microgrid system can achieve rated generation (i.e. BESS discharge and renewable generation) and loading (i.e. BESS charge) at the CP with minimal impact on the voltage. The microgrid system must possess adequate reactive power capability to ensure that the voltage at the connection point is kept within a specified voltage set-point determined by EEN and RTA.

Based on the NER automatic access standard, the microgrid CP should have a minimum of 0.395 times the MW capability. This is assumed to be allocated across the BESS, centralised solar and wind turbine, as per Table 9. Although Scenario 3 is not grid-connected, this is included for completeness. Note this reactive capability is the recommended minimum and higher reactive power may be required, which is demonstrated in Scenario 4 studies.

Table 9 – Reactive power capability of energy resources for purposes of the study

Scenario	Description	BESS (MW)	Central Solar (MW)	Small Wind (MW)	BESS (MVAr)	Central Solar (MVAr)	Small Wind (MVAr)	Total CP (MVAr)
1	Primarily grid-connected, and only island during RTA outage	1.0	0.5	0.35	0.40	0.20	0.14	0.7
2	Primarily islanded with RTA as a backup during microgrid outage	2.7	2.0	0.00	1.07	0.79	0.00	1.9
3	Fully standalone, with no connection to RTA	2.7	5.0	0.35	1.07	1.98	0.14	3.2
4	Fully standalone, with future expansion to supply RTA	2.7	10.0	0.35	1.07	3.95	0.14	5.2

For study purposes, the voltage is controlled at the CP based on the total CP reactive power capability and droop settings. Fixed power factor mode may be an option, however it would need to consider how the voltage control will operate between grid-connected and island operation.

Table 10 shows the voltage droop settings used in the study and the allocation among the energy resources. For ease of comparison of study results, the same droop settings were used (i.e. 1pu and 5% droop based on the scenario specific reactive power rating at the CP).

Table 10 – Voltage droop settings for load study

Scenario	Vset (pu)	Droop	Rated Q (MVAr)	Allocation at CP		
				BESS (MVAr)	Central Solar (MVAr)	Small Wind (MVAr)
1	1.00	5%	**0.7**	54%	27%	19%
2	1.00	5%	**1.9**	57%	43%	0%
4	1.00	5%	**5.2**	16%	81%	3%

Note that the droop settings in the study are only preliminary, and droop settings will need to be tuned based on detailed connection studies. All parties will need to develop and agree upon a voltage control strategy. Additional studies may be required to determine the optimal operating level. It must also be noted that network changes occur from time to time and the set point may be adjusted to ensure compliance.

A droop coordination study would typically require:

- Determining reactive power requirements at the connection point based on EEN/RTA voltage requirements, expected plant capability, system losses, acceptable voltage swing, etc.
- Tuning and coordination with RTA power station voltage control and other voltage regulating devices based on steady-state studies.
- Consideration of transient studies if there is a risk of voltage control interaction between the microgrid and the RTA power station. This may require tuning of any voltage control loops (in addition to voltage droop settings)
- Consideration of voltage response (speed or recovery and stability) of the grid-connected and islanded system.
- Consideration of a power plant controller (or part of microgrid controller) that would be required to coordinate reactive power among multiple IBR (i.e. BESS, solar, etc.)

5.7 Voltage/Frequency Control During Islanding

During islanding, the microgrid system is responsible for the voltage and frequency control of the 11kV distribution network through grid-forming capabilities. In grid-forming mode, the microgrid shall be capable of providing independent voltage and frequency control at the connection point and shall include both voltage droop and frequency droop, including capability such as:

- Voltage droop based on CP power rating;
- Isochronous and/or frequency droop

The voltage and frequency supply quality will need to be agreed upon with EEN as part of the connection application.

For reference purposes, in the EEN Isolated Networks, the voltage supply requirements are based on the Queensland Electricity Act 1994 and the AS 60038 Standard Voltages, as per Table 11. The values table assumes a 10-minute aggregated value and allows for ±1% of values to be outside the threshold. This should be considered a **minimum standard** for which the islanded microgrid system will operate the voltage supply at.

Table 11 – Voltage supply quality in EEN isolated networks

Nominal Voltage		Voltage Supply Quality
Phase-to-Neutral (V)	Phase-to-Phase (V)	
240	415	+6%, -6%
230	460	+10%, -6%
400	690	
1000	-	
-	11 000	Approximately ± 5%
-	22 000	Approximately ± 10%
-	33 000	
12 700	-	The voltage range for SWER systems will vary depending on the supply and earthing conditions.
19 100	-	

Note: Table is not updated with QLD statutory voltages +10/-6% 230V.

The frequency supply quality is based on the Frequency Operating Standards for the Tasmanian Power System from the Tasmanian Energy Regulator, as per Table 12. This should be considered a **minimum standard** for which the islanded microgrid system will operate frequency at.

Table 12 – Frequency supply quality

Condition	Frequency Range	
Normal Operating Frequency Band	49.0 to 51.0 Hz	
Operational Frequency Tolerance Band eg. Load or Network Event	47.5 to 53 Hz for a duration no longer than 5 minutes	
Extreme Frequency Excursion Limit eg. Contingency Event	46 to 60 Hz for a duration no longer than 2 minutes	47.5 to 53 Hz for a total excursion duration no longer than 10 minutes

For the study, the same voltage droop settings were used for simplicity, however in practise the voltage droop could be tightened in islanding operation.

6 MODELLING RESULTS

6.1 Base Case

The base case results of peak demand and minimum demand load flows are shown in Table 13. This is based on the load study methodology described in section 3.4. The results show little difference between the peak load and minimum load case due to the stiff upstream network and short 11kV distribution distances. This is despite no upstream voltage regulators or forms of network voltage support.

Table 13 – Load flow results of base case (no rooftop PV) at peak and minimum demand

Bus	Base - Peak Demand				Base - Minimum Demand			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.985	800	234	44.4	0.995	300	100	17
SS10050	0.983	38	12	2.1	0.994	14	6	1
SS10051	0.984	73	21	4.1	0.994	28	9	2
SS10052	0.983	195	55	10.8	0.993	73	21	4
SS10054	0.982	179	50	9.9	0.993	67	19	4
SS781364	0.984	0	1	0.1	0.994	0	1	0
SS7914	0.984	131	37	7.2	0.994	49	15	3
SS7915	0.984	70	21	3.9	0.994	26	10	1
SS7916	0.983	107	31	5.9	0.994	40	13	2
SS7917	0.982	6	6	0.4	0.993	3	5	0

Table 14 shows the comparison of bus voltage at each distribution transformer with 300kW rooftop solar installed. The 300kW was disseminated on various transformers in equal 50kW lots, as shown in the table. The location of the solar was based on the classification of the distribution transformer loads and focussed on transformers with primarily domestic and commercial customers who are likely to have available roof space. The results show a minimal change in HV voltage due to the increased solar injection due to the short distribution network. This does not consider LV distribution.

Table 14 – Comparison of system voltage with additional 300kV rooftop solar

Bus Location	Peak Demand		Minimum Demand		Difference	
	Base	Rooftop PV	Base	Rooftop PV	Peak Demand	Minimum Demand
Recloser	0.985	0.992	0.995	1.001	0.64%	0.64%
SS10050	0.983	0.991	0.994	1.001	0.71%	0.69%
SS10051	0.984	0.991	0.994	1.001	0.71%	0.69%
SS10052	0.983	0.990	0.993	1.001	0.76%	0.73%
SS10054	0.982	0.990	0.993	1.001	0.78%	0.75%
SS781364	0.984	0.991	0.994	1.001	0.71%	0.68%
SS7914	0.984	0.991	0.994	1.001	0.71%	0.68%
SS7915	0.984	0.991	0.994	1.001	0.69%	0.66%
SS7916	0.983	0.990	0.994	1.001	0.74%	0.71%
SS7917	0.982	0.990	0.993	1.001	0.77%	0.74%
Microgrid TF	0.984	0.991	0.994	1.001	0.71%	0.68%

Table 15 shows the load flow results including the 300kW of rooftop solar PV. During minimum demand, the additional rooftop solar PV will result in zero power flow from RTA power station.

Table 15 – Load flow results of base case (including rooftop PV) at peak and minimum demand

Bus	Base - Peak Demand				Base - Minimum Demand			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.992	498	80	26.7	1.001	0	-46	2.4
SS10050	0.991	38	12	2.1	1.001	14	6	0.8
SS10051	0.991	23	-4	1.2	1.001	-22	-15	1.4
SS10052	0.990	144	28	7.8	1.001	23	-4	1.2
SS10054	0.990	129	24	6.9	1.001	17	-5	0.9
SS781364	0.991	0	1	0.1	1.001	0	1	0.1
SS7914	0.991	80	11	4.3	1.001	-1	-9	0.5
SS7915	0.991	70	21	3.9	1.001	26	10	1.5
SS7916	0.990	57	5	3.0	1.001	-10	-11	0.8
SS7917	0.990	-44	-18	2.5	1.001	-47	-19	2.7

6.2 Scenario 1 – Grid-connected

Table 16 shows the load flow results for Scenario 1 and assumes the microgrid is grid-connected. Based on these cases, there is a potential power swing of about 3.3MW, resulting in a voltage change of about 0.04pu. Case A is a worst-case scenario where the Napranum load is at peak demand, and the microgrid system is charging the BESS also from the grid. Case B is a worst-case scenario of a generation back into the RTA network.

The connection to the 11kV Napranum network seems feasible based on voltage levels and power capacity. However, a detailed analysis of power flows and conductor ratings on both the EEN and RTA would be required to verify this.

Table 16 – Scenario 1 load flow results (grid-connected)

Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.98	1503	262	81.7	1.02	-1840	370	96
SS10050	0.98	37.8	12.0	2.1	1.03	14	6	1
SS10051	0.98	23.2	-4.0	1.3	1.02	-22.4	-15.1	1.4
SS10052	0.98	144	28.8	7.9	1.03	22.7	-3.7	1.2
SS10054	0.98	129	24.5	7.0	1.03	16.9	-4.9	0.9
SS781364	0.98	0.2	1.4	0.1	1.02	0.2	1.6	0.1
SS7914	0.98	80.4	11.8	4.4	1.02	-1.0	-8.8	0.5
SS7915	0.98	69.7	21.5	3.9	1.02	26.4	10.6	1.5
SS7916	0.98	56.6	5.8	3.1	1.03	-9.9	-10.7	0.7
SS7917	0.98	-44.1	-18.1	2.6	1.03	-47.4	-18.5	2.6
Microgrid TF	0.98	1000	-348	56.9	1.03	-1850.0	407.2	96.7
BESS	0.98	-1000	194	1501	1.02	1000	-202	1438
Central PV	0.98	0.0	97.2	143.2	1.02	500	-101	719
Wind	0.98	0.0	68.4	100.7	1.02	350	-71	503
SS10050_PV	0.97	0.0	0.0	0.0	1.03	0.0	0.0	0.0
SS10051_PV	0.98	50.0	24.2	81.9	1.03	50.0	24.2	77.8
SS10052_PV	0.97	50.0	24.2	82.6	1.03	50.0	24.2	78.0
SS10054_PV	0.97	50.0	24.2	82.5	1.03	50.0	24.2	78.0
SS781364_PV	0.98	0.0	0.0	0.0	1.03	0.0	0.0	0.0
SS7914_PV	0.98	50.0	24.2	82.2	1.03	50.0	24.2	78.1
SS7915_PV	0.98	0.0	0.0	0.0	1.02	0.0	0.0	0.0
SS7916_PV	0.98	50.0	24.2	82.1	1.03	50.0	24.2	77.9
SS7917_PV	0.98	50.0	24.2	81.7	1.03	50.0	24.2	77.8

6.3 Scenario 2 – Grid-connected

Table 17 shows the load flow results for Scenario 2, assuming the microgrid is grid connected. Compared with Scenario 1, the BESS is increased to 2.7MW, and the centralised PV is 2MW. The results show a worst-case power swing from 2.7MW load to 4.7MW generation between Case A and Case B. Under the worst case, there is an increased load and generation on the RTA Network of 211A and 241A, respectively. The connection to the 11kV Napranum network seems feasible based on voltage levels and typical reactive power capability, however feeder capacity would likely need to be upgraded to facilitate maximum power transfer. Detailed analysis of power flows, and conductor ratings on both the EEN and RTA would be required to verify this.

Table 17 – Scenario 2 load flow results

HV Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.958	**3540**	**-1503**	**211**	1.040	**-4333**	**1984**	**241**
SS10050	0.955	37.8	11.9	2.2	1.045	14.4	6.3	0.8
SS10051	0.956	73.4	21.1	4.2	1.042	27.6	9.2	1.5
SS10052	0.954	195	55.5	11.2	1.044	72.8	21.3	3.8
SS10054	0.953	179	51.0	10.3	1.044	67.0	19.9	3.5
SS781364	0.956	0.2	1.4	0.1	1.042	0.2	1.6	0.1
SS7914	0.956	130.7	37.4	7.5	1.042	49.1	15.8	2.6
SS7915	0.956	69.7	21.3	4.0	1.042	26.4	10.7	1.4
SS7916	0.954	106.9	31.0	6.1	1.045	40.2	13.8	2.1
SS7917	0.953	5.8	5.5	0.4	1.044	2.6	5.5	0.3
Microgrid TF	0.952	2700	-1768	177.8	1.049	-4700	1835	252
BESS	0.971	-2700	1073	4317	1.033	2700	-914	3984
Central PV	0.971	0.0	809	1203	1.033	2000	-690	2956
Wind	0.000	0.0	0	0	0.000	0	0	0
SS10050_PV	0.952	0.0	0.0	0.0	1.045	0.0	0.0	0.0
SS10051_PV	0.949	0.0	0.0	0.0	1.041	0.0	0.0	0.0
SS10052_PV	0.943	0.0	0.0	0.0	1.042	0.0	0.0	0.0
SS10054_PV	0.943	0.0	0.0	0.0	1.042	0.0	0.0	0.0
SS781364_PV	0.957	0.0	0.0	0.0	1.043	0.0	0.0	0.0
SS7914_PV	0.949	0.0	0.0	0.0	1.041	0.0	0.0	0.0
SS7915_PV	0.953	0.0	0.0	0.0	1.042	0.0	0.0	0.0
SS7916_PV	0.949	0.0	0.0	0.0	1.044	0.0	0.0	0.0
SS7917_PV	0.954	0.0	0.0	0.0	1.045	0.0	0.0	0.0

6.4 Scenario 4 – Grid-connected

Table 18 shows the load flow results for Scenario 4, which shows extreme voltage swings and power levels. There is significant power transfer back to RTA, which needs to be carefully considered in terms of feeder ratings and impact on the power station. It is likely that significant reconductoring and building of new feeder circuits would be required on both EEN and RTA distribution networks.

The network voltage is controlled since the microgrid connection is set as voltage droop however, it should be noted there is significant reactive power required (exceeding the minimum reactive power capability at the CP, as discussed in Section 5.6). This scenario is not feasible unless there is significant network augmentation.

Table 18 –Scenario 4 load flow results

HV Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.976	3249	2692	227	1.059	12440	8560	748
SS10050	0.974	37.8	12.0	2.1	1.069	14.4	6.4	0.8
SS10051	0.975	23.2	-4.0	1.3	1.064	-22.4	-14.8	1.3
SS10052	0.974	144	28.8	7.9	1.069	22.7	-3.3	1.1
SS10054	0.973	129	24.5	7.1	1.069	16.9	-4.5	0.9
SS781364	0.975	0.2	1.4	0.1	1.064	0.3	1.7	0.1
SS7914	0.975	80.4	11.8	4.4	1.064	-1.0	-8.5	0.4
SS7915	0.975	69.7	21.5	3.9	1.064	26.4	10.9	1.4
SS7916	0.974	56.6	5.7	3.1	1.069	-9.8	-10.3	0.7
SS7917	0.974	-44.1	-18.2	2.6	1.069	-47.3	-18.1	2.5
Microgrid TF 1	0.973	900	-937	70	1.079	-4350	2726	250
Microgrid TF 2	0.973	900	-937	70	1.079	-4350	2726	250
Microgrid TF 3	0.973	900	-937	70	1.079	-4350	2726	250
BESS	0.983	-2700	596	4061	0.000	2700	-1559	4269
Central PV	0.983	0.0	2184	3208	0.000	10000	-5716	15772
Wind	0.983	0.0	85	125	1.054	350	-223	568
SS10050_PV	0.971	0.0	0.0	0.0	1.069	0.0	0.0	0.0
SS10051_PV	0.976	50.0	24.2	82.2	1.069	50.0	24.2	75.0
SS10052_PV	0.968	50.0	24.2	82.9	1.071	50.0	24.2	74.9
SS10054_PV	0.968	50.0	24.2	82.8	1.071	50.0	24.2	74.9
SS781364_PV	0.976	0.0	0.0	0.0	1.065	0.0	0.0	0.0
SS7914_PV	0.973	50.0	24.2	82.4	1.067	50.0	24.2	75.2
SS7915_PV	0.972	0.0	0.0	0.0	1.064	0.0	0.0	0.0
SS7916_PV	0.973	50.0	24.2	82.4	1.072	50.0	24.2	74.8
SS7917_PV	0.979	50.0	24.2	81.9	1.074	50.0	24.2	74.6

6.5 Scenario 1 – Islanded

Table 19 shows the load flow results for Scenario 1 during islanding. This assumes the 11kV recloser is open and the BESS is providing the voltage reference. The centralised PV and wind are assumed to be zero output, and the peak load is being supplied solely by the BESS. In both cases, the BESS is able to supply the Napranum load and manage voltage. There is no curtailment of renewable energy, as there is sufficient capacity in the BESS inverter to handle excess solar generation (depending on energy management). This scenario seems feasible to supply loads and manage voltage during islanding.

Table 19 – Scenario 1 load flow results (island)

Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0	0	0	0	0	0	0	0
SS10050	0.99	37.8	12.1	2.1	1.00	14	6	1
SS10051	0.99	23.2	-3.9	1.2	1.00	-22.5	-15.2	1.4
SS10052	0.99	144	28.8	7.8	1.00	22.7	-3.9	1.2
SS10054	0.99	129	24.6	6.9	1.00	16.9	-5.2	0.9
SS781364	0.99	0.2	1.5	0.1	1.00	0.2	1.5	0.1
SS7914	0.99	80.4	11.9	4.3	1.00	-1.0	-9.1	0.5
SS7915	0.99	69.7	21.6	3.9	1.00	26.3	10.3	1.5
SS7916	0.99	56.7	5.9	3.0	1.00	-9.9	-11.0	0.8
SS7917	0.99	-44.1	-18.0	2.5	1.00	-47.4	-18.7	2.7
Microgrid TF	0.99	-498	-84	26.6	1.00	-8.5	9.4	0.7
BESS	1.00	498	47	725	1.00	-841	-5	1214
Central PV	1.00	0.0	23.3	33.8	1.00	500	-3	721
Wind	1.00	0.0	16.4	23.8	1.00	350	-2	505
SS10050_PV	0.99	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS10051_PV	0.99	50.0	24.2	80.6	1.01	50.0	24.2	79.7
SS10052_PV	0.99	50.0	24.2	81.2	1.00	50.0	24.2	80.0
SS10054_PV	0.99	50.0	24.2	81.2	1.00	50.0	24.2	80.0
SS781364_PV	0.99	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7914_PV	0.99	50.0	24.2	80.9	1.00	50.0	24.2	79.9
SS7915_PV	0.99	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7916_PV	0.99	50.0	24.2	80.8	1.00	50.0	24.2	79.9
SS7917_PV	1.00	50.0	24.2	80.3	1.01	50.0	24.2	79.7

6.6 Scenario 2 – Islanded

Table 20 shows the load flow results for Scenario 2 during island operation. There is no curtailment of the 2MW centralised solar during minimum demand. The BESS inverter has sufficient capacity to allow full capture of excess solar generation, depending on battery energy management. This scenario seems feasible to supply loads and manage voltage during islanding.

Table 20 – Scenario 2 load flow results (island)

HV Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0	0	0	0	0	0	0	0
SS10050	1.00	37.8	12.1	2.1	1.00	14.3	6.0	0.8
SS10051	1.00	73.4	21.3	4.0	1.00	27.5	9.0	1.5
SS10052	1.00	195	55.4	10.6	1.00	72.8	20.9	4.0
SS10054	1.00	179	51.0	9.8	1.00	67.0	19.6	3.7
SS781364	1.00	0.2	1.5	0.1	1.00	0.2	1.5	0.1
SS7914	1.00	130.7	37.6	7.1	1.00	49.0	15.4	2.7
SS7915	1.00	69.7	21.7	3.8	1.00	26.3	10.3	1.5
SS7916	1.00	106.9	31.3	5.8	1.00	40.1	13.4	2.2
SS7917	1.00	5.9	6.0	0.4	1.00	2.5	5.1	0.3
Microgrid TF	1.00	-800	-238	43.7	1.00	-310	-264	21
BESS	1.01	800	140	1166	1.01	**-1690**	151	2436
Central PV	1.01	0.0	105	151	1.01	**2000**	114	2875
Wind	0.00	0.0	0	0	0.00	0	0	0
SS10050_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS10051_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS10052_PV	0.99	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS10054_PV	0.99	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS781364_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7914_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7915_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7916_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0
SS7917_PV	1.00	0.0	0.0	0.0	1.00	0.0	0.0	0.0

6.7 Scenario 3 – Islanded

Table 21 shows the load flow results for Scenario 3 during the island. The study assumes the microgrid is coupled to the network via 2 x 5MVA power transformers. There is significant curtailment (up to 77%) of the 10MW centralised solar during minimum demand due to the BESS power rating. The microgrid system seems feasible to supply loads and manage voltage, assuming the microgrid system is able to manage energy and excess generation.

Table 21 – Scenario 3 load flow results (island)

HV Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0	0	0	0	0	0	0	0
SS10050	0.998	37.8	12.1	2.1	1.001	14.3	6.0	0.8
SS10051	0.998	23.2	-3.9	1.2	1.001	-22.5	-15.2	1.4
SS10052	0.997	144	28.8	7.7	1.001	22.7	-3.9	1.2
SS10054	0.997	129	24.6	6.9	1.001	16.9	-5.2	0.9
SS781364	0.998	0.2	1.5	0.1	1.001	0.2	1.5	0.1
SS7914	0.998	80.4	11.9	4.3	1.001	-1.0	-9.1	0.5
SS7915	0.998	69.7	21.6	3.8	1.001	26.3	10.3	1.5
SS7916	0.998	56.7	5.9	3.0	1.001	-9.9	-10.9	0.8
SS7917	0.997	-44.1	-18.0	2.5	1.001	-47.4	-18.7	2.7
Microgrid TF 1	0.999	-249	-42	13.3	1.001	0	23	1
Microgrid TF 2	0.999	-249	-42	13.3	1.001	0.19	23	1
BESS	0.999	498	29	720	1.000	-2700	-16	3896
Central PV	0.999	0.0	53	76	1.000	2350	-29	3391
Wind	0.999	0.0	3	5	1.000	350	-2	505
SS10050_PV	0.995	0.0	0.0	0.0	1.000	0.0	0.0	0.0
SS10051_PV	0.999	50.0	24.2	80.3	1.007	50.0	24.2	79.7
SS10052_PV	0.992	50.0	24.2	80.9	1.002	50.0	24.2	80.0
SS10054_PV	0.992	50.0	24.2	80.8	1.003	50.0	24.2	80.0
SS781364_PV	0.999	0.0	0.0	0.0	1.002	0.0	0.0	0.0
SS7914_PV	0.996	50.0	24.2	80.5	1.004	50.0	24.2	79.9
SS7915_PV	0.995	0.0	0.0	0.0	1.000	0.0	0.0	0.0
SS7916_PV	0.997	50.0	24.2	80.4	1.004	50.0	24.2	79.9
SS7917_PV	1.002	50.0	24.2	80.0	1.006	50.0	24.2	79.7

6.8 Scenario 4 – Islanded

Table 22 shows the load flow results for Scenario 4 during island operation. The study assumes the microgrid is coupled to the network via 3 x 5MVA power transformers. There is significant curtailment (77%) of the 10MW centralised solar during minimum demand due to the BESS inverter rating. The microgrid system seems feasible to supply loads and manage voltage, assuming the microgrid system is able to manage energy and excess generation.

Table 22 – Scenario 4 load flow results (island)

HV Bus	Case A Peak Demand and Full BESS Charge				Case B Minimum Demand and Full Generation			
	V (pu)	P (kW)	Q (kVAr)	I (A)	V (pu)	P (kW)	Q (kVAr)	I (A)
Recloser	0.000	0	0	0	0.000	0	0	0
SS10050	0.998	37.8	12.1	2.1	1.000	14.3	6.0	0.8
SS10051	0.998	23.2	-3.9	1.2	1.001	-22.5	-15.2	1.4
SS10052	0.998	144	28.8	7.7	1.001	22.7	-3.9	1.2
SS10054	0.998	129	24.6	6.9	1.001	16.9	-5.2	0.9
SS781364	0.998	0.2	1.5	0.1	1.001	0.2	1.5	0.1
SS7914	0.998	80.4	11.9	4.3	1.001	-1.1	-9.1	0.5
SS7915	0.998	69.7	21.6	3.8	1.000	26.3	10.3	1.5
SS7916	0.998	56.7	5.9	3.0	1.001	-9.9	-11.0	0.8
SS7917	0.998	-44.1	-18.0	2.5	1.001	-47.4	-18.7	2.7
Microgrid TF 1	0.999	-166	-28	8.8	1.000	0	15	1
Microgrid TF 2	0.999	-166	-28	8.8	1.000	0.12	15	1
Microgrid TF 3	0.999	-166	-28	8.8	1.000	0.12	15	1
BESS	0.999	498	18	719	1.000	-2700	-10	3897
Central PV	0.999	0.0	65	94	1.000	2350	-35	3391
Wind	0.999	0.0	3	4	1.000	350	-1	505
SS10050_PV	0.996	0.0	0.0	0.0	1.000	0.0	0.0	0.0
SS10051_PV	0.999	50.0	24.2	80.2	1.006	50.0	24.2	79.7
SS10052_PV	0.992	50.0	24.2	80.8	1.002	50.0	24.2	80.0
SS10054_PV	0.993	50.0	24.2	80.8	1.002	50.0	24.2	80.0
SS781364_PV	0.999	0.0	0.0	0.0	1.002	0.0	0.0	0.0
SS7914_PV	0.996	50.0	24.2	80.5	1.003	50.0	24.2	79.9
SS7915_PV	0.995	0.0	0.0	0.0	1.000	0.0	0.0	0.0
SS7916_PV	0.997	50.0	24.2	80.4	1.004	50.0	24.2	79.9
SS7917_PV	1.003	50.0	24.2	80.0	1.006	50.0	24.2	79.7

6.9 Summary of Results

6.9.1 Power Flow and Conductor Limits

Table 23 shows the load flow summary for grid-connected scenarios.

For Scenario 1, the connection to the 11kV Napranum feeder is feasible, with minor network restrictions on charging or exporting under normal conditions. This study has not assessed system abnormal or contingent conditions. There may be restrictions on the RTA network due to the increased potential of loading and generation back to the RTA network.

For Scenario 2, the voltage levels seem feasible based on the typical reactive power capability of the automatic access standard. However, power transfer is high, and network augmentation is likely needed to enable the power flows.

Scenario 4 is extreme, and there is a restriction on both the EEN and RTA network in terms of power transfer over the existing EEN/RTA distribution infrastructure. Reconductoring and building new feeder circuits would likely be needed for transferring the MW generation of Scenario 4 back to RTA.

Table 24 and Table 25 shows the feeder currents and utilisation through selected branches (as per Figure 14. This shows exceedances of feeder conductor ratings for Scenario 2 and 4 grid-connected cases. The islanded case is not shown since Napranum has very little load and conductor overloading is unlikely when islanded.

Detailed studies of the existing overhead and underground cables (RTA network) are required to determine the power transfer capability back to the RTA power station. Further analysis will be required to determine the microgrid output during contingency scenarios.

Table 23 – Summary of load flow for grid-connected scenarios

Scenario	Operation	Network Case	Network Voltage	CP Voltage	Recloser		Microgrid CP	
			pu	pu	P (kW)	Q (kVAr)	P (kW)	Q (kVAr)
1	Grid-Connected	A - Worst case load	0.977	0.976	1503	262	1000	-348
		B - Worst case generation	1.025	1.028	-1840	370	-1850	407
	Island	A - Worst case load	0.993	0.994	0	0	-498	-84
		B - Worst case generation	1.001	1.001	0	0	-9	9
2	Grid-Connected	A - Worst case load	0.955	0.952	3540	-1503	2700	-1768
		B - Worst case generation	1.044	1.049	-4333	1984	-4700	1835
	Island	A - Worst case load	1.002	1.004	0	0	-800	-238
		B - Worst case generation	1.002	1.003	0	0	-310	-264
3	Island	A - Worst case load	0.998	0.999	0	0	-498	-84
		B - Worst case generation	1.001	1.001	0	0	0	46
4	Grid-Connected	A - Worst case load	0.974	0.973	3249	2692	2700	-2811
		B - Worst case generation	1.067	1.079	12440	8560	-13050	8178
	Island	A - Worst case load	0.998	0.999	0	0	-498	-84
		B - Worst case generation	1.001	1.000	0	0	0	46

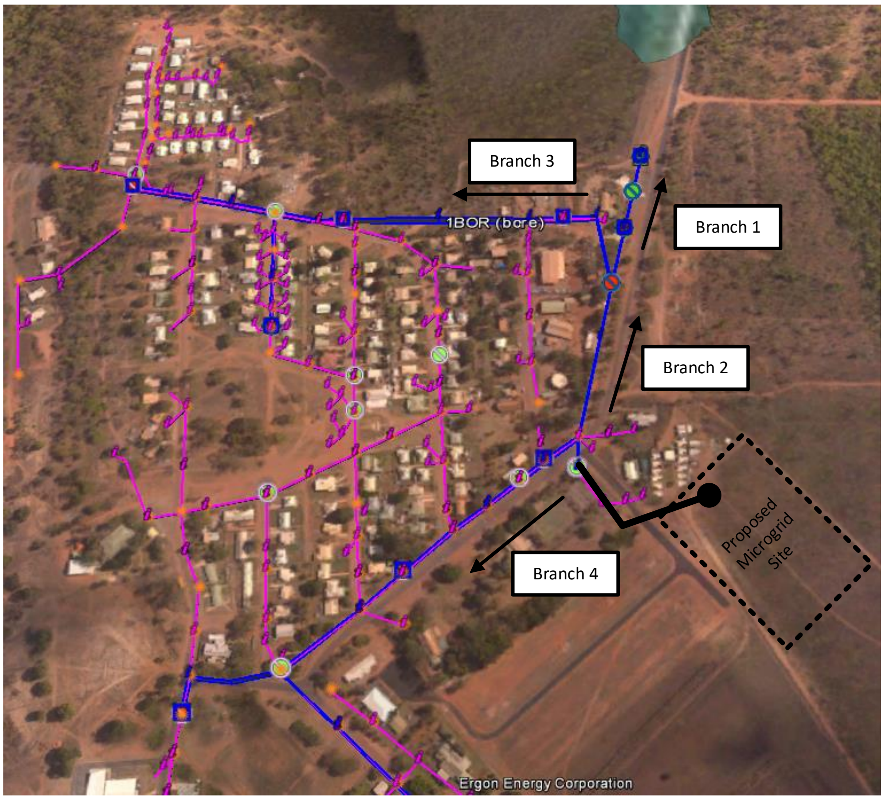


Figure 14 – Feeder branches for current utilisation

Table 24 – Amps through selected feeder branches

Branch	Scenario 1		Scenario 2		Scenario 4	
	Case A	Case B	Case A	Case B	Case A	Case B
1	81.7	96.3	211	240	227	748
2	72.9	96.5	199	244	221	749
3	9.5	0.6	15.7	5.5	9.5	0.6
4	17.6	1.7	30.1	10.4	17.7	1.5

Table 25 – Feeder conductor utilisation

Branch	Scenario 1		Scenario 2		Scenario 4	
	Case A	Case B	Case A	Case B	Case A	Case B
1	38%	44%	97%	111%	105%	345%
2	34%	44%	92%	113%	102%	345%
3	4.4%	0.3%	7.2%	2.5%	4.4%	0.3%
4	8.1%	0.8%	13.9%	4.8%	8.1%	0.7%

6.9.2 Voltage Steps

Table 26 shows the comparison of voltage for the different scenarios in grid-connected operation (excluding Scenario 3), based on the existing network with no rooftop PV. This shows progressively higher voltage swings as the microgrid capacity increases. The same voltage droop parameters (5% droop with 1pu reference) were used to allow for ease of comparison. This means the voltage performance can likely be tightened through more detailed studies to tune the droop setting (See discussion in Section 5.6).

Both Scenario 2 and Scenario 4 have a large voltage drop and rise due to the power flows and the existing conductors in the network. In general, network voltage management seems feasible as long as microgrid reactive capability is sized appropriately.

Table 27 shows the voltage step at the microgrid CP and the level of reactive power as a % of the automatic access standard. This shows that despite the reactive power for Scenario 4 far exceeding the typical reactive power capability, the voltage step is still very extreme due to the limitation of the conductors.

Table 26 – Comparison of voltage step for each microgrid scenario compared with the base

	Case A Peak Demand and Full BESS Charge			Case B Minimum Demand and Full Generation		
Bus Location	**Scenario 1**	**Scenario 2**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 4**
Recloser	-1.3%	-2.7%	-1.5%	2.3%	4.5%	5.8%
SS10050	-1.3%	-2.9%	-1.6%	2.5%	5.1%	6.8%
SS10051	-1.3%	-2.8%	-1.6%	2.4%	4.8%	6.3%
SS10052	-1.4%	-2.9%	-1.6%	2.5%	5.1%	6.8%
SS10054	-1.4%	-2.9%	-1.6%	2.5%	5.1%	6.8%
SS781364	-1.3%	-2.8%	-1.6%	2.4%	4.8%	6.3%
SS7914	-1.3%	-2.8%	-1.6%	2.4%	4.8%	6.3%
SS7915	-1.3%	-2.8%	-1.6%	2.4%	4.8%	6.3%
SS7916	-1.4%	-2.9%	-1.6%	2.5%	5.1%	6.8%
SS7917	-1.4%	-2.9%	-1.6%	2.5%	5.1%	6.8%

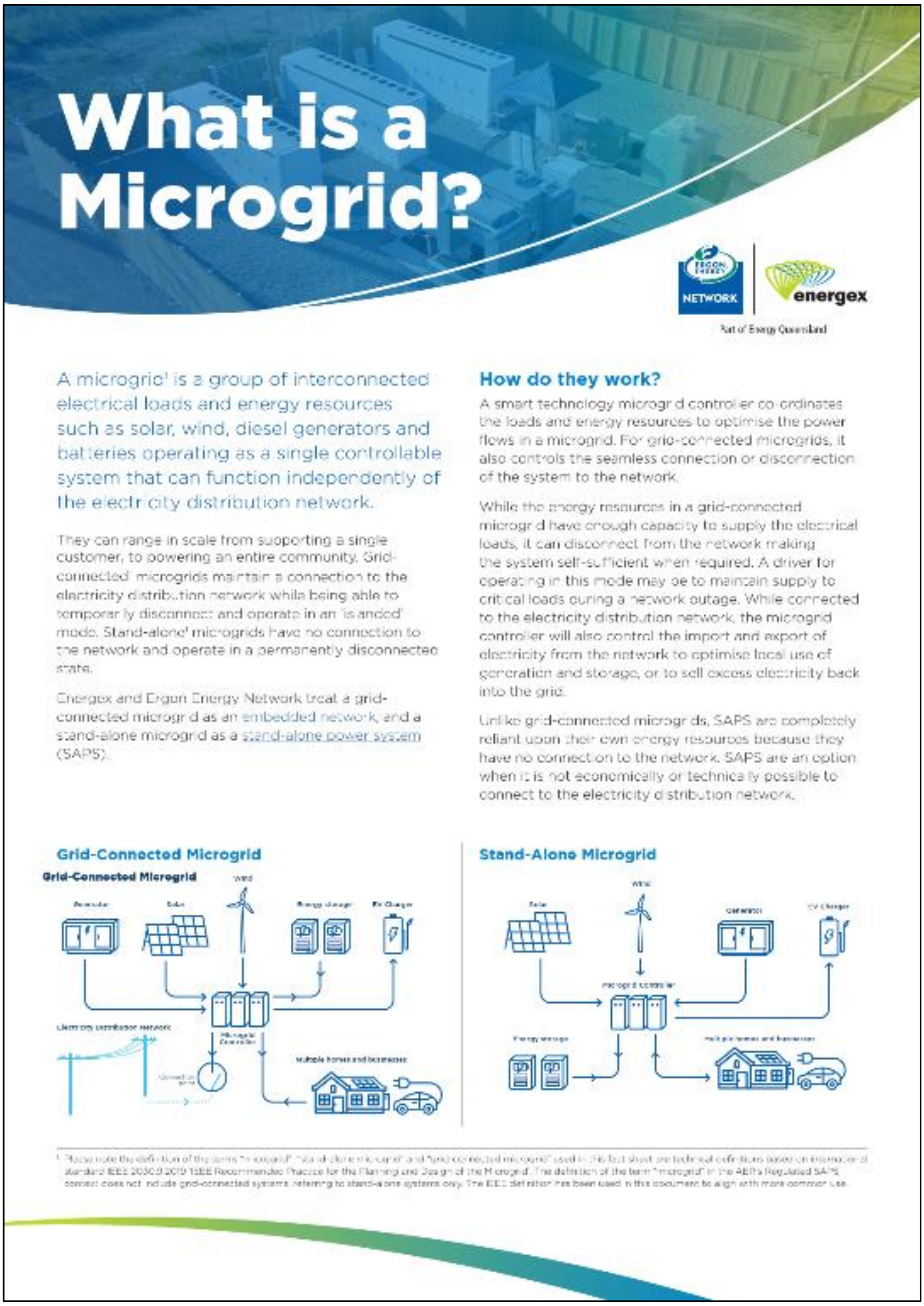
Table 27 – Worst case voltage step at microgrid CP

	Case	CP Voltage Step	CP Reactive Power as % of Rating
Scenario 1	A	-1.5%	-48%
	B	2.7%	56%
Scenario 2	A	-3.1%	-95%
	B	**5.6%**	99%
Scenario 4	A	-1.8%	-58%
	B	**7.8%**	**168%**

7 APPENDIX

7.1 Ergon Energy Microgrid Fact Sheet

[Microgrid Factsheet (ergon.com.au)](#)



What is a Microgrid?

ERGON ENERGY NETWORK | energex
Part of Energy Queensland

A microgrid[1] is a group of interconnected electrical loads and energy resources such as solar, wind, diesel generators and batteries operating as a single controllable system that can function independently of the electricity distribution network.

They can range in scale from supporting a single customer, to powering an entire community. Grid-connected microgrids maintain a connection to the electricity distribution network while being able to temporarily disconnect and operate in an 'islanded' mode. Stand-alone microgrids have no connection to the network and operate in a permanently disconnected state.

Energex and Ergon Energy Network treat a grid-connected microgrid as an embedded network, and a stand-alone microgrid as a stand-alone power system (SAPS).

How do they work?

A smart technology microgrid controller co-ordinates the loads and energy resources to optimise the power flows in a microgrid. For grid-connected microgrids, it also controls the seamless connection or disconnection of the system to the network.

While the energy resources in a grid-connected microgrid have enough capacity to supply the electrical loads, it can disconnect from the network making the system self-sufficient when required. A driver for operating in this mode may be to maintain supply to critical loads during a network outage. While connected to the electricity distribution network, the microgrid controller will also control the import and export of electricity from the network to optimise local use of generation and storage, or to sell excess electricity back into the grid.

Unlike grid-connected microgrids, SAPS are completely reliant upon their own energy resources because they have no connection to the network. SAPS are an option when it is not economically or technically possible to connect to the electricity distribution network.

Grid-Connected Microgrid

Stand-Alone Microgrid

[1] Please note the definition of the terms "microgrid", "stand-alone microgrid" and "grid-connected microgrid" used in this fact sheet are technical definitions based on international standard IEEE 2030.9 2019 IEEE Recommended Practice for the Planning and Design of the Microgrid. The definition of the term "microgrid" in the AER's Regulated SAPS context does not include grid-connected systems, referring to stand-alone systems only. The IEEE definition has been used in this document to align with more common use.

Who owns the Microgrid?

Microgrids may be:

- privately owned, like embedded networks or privately owned SAPS, or
- owned by distribution network service providers (DNSPs) such as Energex and Ergon Energy Network.

All electrical network infrastructure in a private microgrid must be owned, operated, and maintained by the microgrid owner. In privately owned grid-connected microgrids, the owner is responsible for their network up to the Connection Point (CP) to the DNSP-owned network.

If you propose to acquire infrastructure owned by the DNSP to create a private microgrid, you must also consider whether the area includes other electrical infrastructure such as public lighting owned by the Local Government Authority (LGA), Department of Transport and Main Roads (DTMR), or other utilities. Transfer of ownership of these assets requires approval from the owner and commercial negotiation based on the function and value of the assets. Some DNSP assets cannot be privately owned due to their role in the operation and security of the electricity distribution network.

Do customers connected to a microgrid still pay a power bill?

In a grid-connected microgrid where the owner is the only customer, the microgrid owner will still purchase electricity supplied from the network through a retailer. For a microgrid supplying multiple customers, each customer can elect to purchase their electricity either from a retailer of their choice or from the microgrid owner.

How to connect a private microgrid to the Energex or Ergon Energy Network

Privately owned SAPS are not connected to Energex or Ergon Energy Network electricity networks and therefore no connection application is required for this type of microgrid. You should be aware that state and national regulations governing the construction and operation of the SAPS will still apply.

It is likely your connection of a private grid-connected microgrid that supplies multiple customers will be treated as an embedded network. A summary of regulatory information regarding embedded networks can be found on this website Embedded electricity networks. A connection enquiry can be submitted through the Energex or Ergon Energy Network portals: Portals - Energex or Portals - Ergon Energy.

To help determine if a microgrid is appropriate for your requirements, you should speak to a suitably qualified consultant.

What to consider when thinking about creating a private microgrid

Ownership – Who will own the electrical infrastructure in your microgrid? Under present arrangements, you must own the infrastructure in your private microgrid, including any public lighting, and have responsibility for its operation and maintenance. This may require you to negotiate the purchase of existing DNSP, DTMR or LGA assets that are within the proposed microgrid.

Customers – If the private microgrid includes customers who are currently connected to the electricity distribution network, they must **all** provide written consent to becoming a part of the microgrid. This will require the abolishment of their existing connection agreements with the DNSP and may impact their options for energy retailer choice.

Network Regulations – Where a private microgrid supplies multiple customers the microgrid owner may need to register the system with AEMO or seek a network and retail exemption from the AER. Consideration also needs to be given to any Queensland specific requirements. There are a range of regulatory, technical and safety obligations relating to the specification of equipment, the sale of energy, and the operation and maintenance of the system that will apply. More information can be found on these websites: AEMO - Register as a Network Service Provider (NSP) in the NEM, AER - Authorisations & Network exemptions and Energy | Business Queensland.

Storing and Exporting Energy – Will the grid-connected microgrid store or export energy back to the electricity distribution network? Network limitations and dynamic operating envelopes (DOE) may govern the amount of energy that can be imported from or exported to the distribution network and when this is permitted. Read more on Dynamic Customer Standards FAQ.

Operating Mode – Will the microgrid run permanently stand-alone with no connection to the main electricity distribution network i.e. is it a SAPS? Will it have a connection to the network and operate in a connected mode for most of the time, only islanding as a back-up function? Or will it operate in an islanded mode for most of the time, only using the network as a back-up? The operating mode will determine the rules and regulations the microgrid must comply with and the type of switching and protection equipment required. See the Qld Electricity Connection Manual for more information.

For more information visit
ergon.com.au | energex.com.au

Part of Energy Queensland

Appendix F. Funding Programs

Federal Government

Initiative	Description
Powering Australia[61] and National Energy Performance Strategy[62]	The Australian Government's Powering Australia plan is focused on creating jobs, cutting power bills and reducing emissions by boosting renewable energy. Under Powering Australia, the government seeks to reduce Australia's emissions and to achieve a net zero 2050 target. To support this plan, the Federal Government announced the National Energy Performance Strategy (NEPS). The NEPS is designed to be a national framework that will improve energy performance across the economy. The NEPS is focused on reducing energy costs for households and businesses, lowering the demand pressure on Australia's whole energy system and contributing to the efforts to meet the legislated emission reduction goals. A consultation paper was released in 2022 providing context to the elements that will inform the NEPS. Critical to the strategy will be a transition to renewable energy, and direct household and commercial actions towards improving energy efficiency. Specific funding commitments were made under the Powering Australia Plan as part of the 2022-23 Federal Budget. Certain commitments under this have been discussed in the following sections, and include: $224.3 million for the Community Batteries for Household Solar grants program, to deploy 400 community-scale batteries for up to 100,000 Australian households. $83.8 million to develop and deploy First Nations Community Microgrid projects. Remote communities will benefit from improved security and affordability of energy supply.
Australian Renewable Energy Agency[63]	Australian Renewable Energy Agency (ARENA) was established by the Australian Government on 1 July 2012. ARENA operates with the purpose of supporting the global transition to net zero emissions by accelerating the pace of pre-commercial innovation, to the benefit of Australian consumers, businesses and workers. ARENA's strategic priorities include: Priority 1. Optimise the transition to renewable electricity. Priority 2. Commercialise clean hydrogen. Priority 3. Support the transition to low emissions metals. Priority 4. Decarbonise land transport. To support the delivery of the above strategic priorities, ARENA administer grant funding on behalf of the Australian Government to improve the competitiveness and supply of renewable energy in Australia. As part of recent Federal Budgets, the Australian Government has committed over $300 million to deliver targeted programs, including: Future Fuels Fund, Industrial Energy Transformation Studies Program and Regional

[61] https://www.energy.gov.au/government-priorities/australias-energy-strategies-and-frameworks/powering-australia

[62] https://www.energy.gov.au/government-priorities/australias-energy-strategies-and-frameworks/national-energy-performance-strategy

[63] https://arena.gov.au/

	Australia Microgrids Pilot Program, First Nations Community Microgrids and Community Battery program. Regional and Remote Communities Reliability Fund (RRCRF)64 and Regional Australia Microgrid Pilots Program (RAMPP)65 In October 2020, the Australian Government announced the $50 million Regional Australia Microgrid Pilots Program (RAMPP) to support pilot demonstrations of microgrids in regional and remote areas. Run over a six-year period, the RAMPP aims to improve the resilience and reliability of power supply for regional and remote communities. RAMPP builds upon the Australian Government's $50.4 million Regional and Remote Communities Reliability Fund (RRCRF), which funded feasibility studies for regional and remote communities to investigate deployment of local microgrid technologies. In the 2022-23 Federal Budget, the Federal Government announced $83M under the First Nations Community Microgrids Program to develop and deploy microgrid technology across First Nations communities. The intent of the program is to increase access to cheaper, cleaner and more reliable energy. ARENA – First Nations Community Microgrids Program66 Administered by ARENA, the program will facilitate the development of microgrid projects in consultation with Aboriginal and Torres Strait Islander groups, First Nations clean energy experts and the states and territories. Community Battery for Household Solar Program67 The Community Batteries for Household Solar Budget Measure was announced in the October 2022 Commonwealth Budget. Funding of up to $171 million to be administered by ARENA over 4 years (until 2025-26). The focus of the program is to deploy 400 community batteries across Australia to lower bills, cut emissions and reduce pressure on the electricity grid by allowing households to store and use excess power they produce.
Renewable Energy Target (RET) Program[68]	The Renewable Energy Target (RET) scheme encourages renewable electricity generation. Administered by the Clean Energy Regulator, the scheme aims to reduce greenhouse gas emissions from the electricity sector. The RET comprises 2 schemes: Large-scale Renewable Energy Target Small-scale Renewable Energy Scheme The Large-scale Renewable Energy Target (LRET) incentivises investment in renewable energy power stations such as wind and solar farms. These power stations can create large-scale generation certificates (LGCs) for the eligible renewable electricity they produce. They can sell LGCs to liable entities (mainly electricity retailers) or companies who want to demonstrate renewable energy use for voluntary purposes. The Small-scale Renewable Energy Scheme (SRES) incentivises households and businesses to install small-scale renewable energy systems. These include rooftop solar panels, solar water heaters and small-scale wind or hydro systems. System owners can create small-scale technology

[64] https://www.energy.gov.au/government-priorities/energy-programs/regional-and-remote-communities-reliability-fund

[65] https://arena.gov.au/funding/regional-australia-microgrid-pilots-ramp/

[66] https://arena.gov.au/news/new-funding-for-arena-in-federal-budget/

[67] https://arena.gov.au/funding/community-batteries-for-household-solar/

[68] https://www.dcceew.gov.au/energy/renewable/target-scheme

	certificates (STCs) when an eligible system is installed. The relevant STCs may be sold to an energy retailer.
National Indigenous Australians Agency (NIAA)[69]	The National Indigenous Australians Agency (NIAA) is committed to improving the lives of all Aboriginal and Torres Strait Islander peoples. The NIAA works to influence policy across the entire Australian Government. NAIA works closely with State and Territory governments, Indigenous peak bodies, stakeholders and service providers to ensure that Indigenous programs and services are delivering for Aboriginal and Torres Strait Islander peoples as intended. The NIAA funds projects aimed at helping Indigenous Australians. Funding is allocated through the Indigenous Advancement Strategy (IAS), National Partnership Agreements, Special Accounts and Special Appropriations. Under the IAS, the NIAA considers grant proposals that address a need for Aboriginal and Torres Strait Islander people. Proposals must be developed with the community or group who will be impacted by the activity.
Indigenous Land and Sea Corporation (ILSC)[70]	The Indigenous Land and Sea Corporation (ILSC) is a corporate Commonwealth entity established under the Aboriginal and Torres Strait Islander Act 2005 (ATSI Act). ILSC's long-term vision for meeting its ATSI Act mandate is for Aboriginal and Torres Strait Islander people to enjoy the rightful entitlements, opportunities and benefits that the return of country and its management brings. ILSC's primary grant program – Our Country Our Future – provides assistance for acquiring and managing rights and interests in land, salt water and fresh water country in order to achieve this vision. Assistance through the program is provided through investment in projects, advice and capability support and facilitating connections with technical experts and support networks.
Clean Energy Finance Corporation[71]	The Clean Energy Finance Corporation (CEFC) supports energy efficiency, renewable energy and low emissions technology projects through the provision of loans and other equity investments. CEFC is an Australian Government-owned "Green Bank" that was established to facilitate increased flows of finance into the clean energy sector. The CEFC invests in accordance with its legislation, the Clean Energy Finance Corporation Act 2012 (CEFC Act) and the prevailing Investment Mandate. The CEFC may make debt or equity investments into eligible clean energy or renewable energy projects that provide an appropriate commercial return to the Australian taxpayer.

State Government

Initiative	Description

[69] https://www.niaa.gov.au/

[70] https://www.ilsc.gov.au/

[71] https://www.cefc.com.au/

Queensland Energy and Jobs Plan[72]	The Queensland Energy and Jobs Plan outlines the Queensland State Government's plan to deliver clean, reliable and affordable energy. Specifically the plan is focused on: building a clean and competitive energy system for the Queensland economy and industries as a platform for accelerating growth; delivering affordable energy for households and businesses and support more rooftop solar and batteries; driving better outcome for workers and communities as partners in the energy transformation. The Powering Queensland Plan delivers $1.16 billion investment to support the transition to a cleaner energy sector and create new investment and jobs. Under the Queensland Energy and Jobs Plan, certain initiatives have been announced that have specific application to the proposed microgrid project at Napranum. These initiatives include the Queensland Microgrid Pilot Fund and the Queensland Renewable Energy and Hydrogen Jobs Fund. Both have been discussed in further detail below. Queensland Microgrid Pilot Fund (QMPF)73 The $10 million Queensland Microgrid Pilot Fund (QMPF) will support Queenslanders living in regional and First Nations grid connected communities by giving them access to more resilient electricity as part of the state's energy system transformation. The program aims to: increase energy and network resilience in regional and remote communities; contribute to the decarbonisation of these communities, which are generally reliant on diesel generation. As one of the first programs to be delivered under the Queensland Energy and Jobs Plan, the two-year program offers grants for feasibility studies and projects to develop and deliver microgrid projects across regional and remote areas of Queensland, boosting the network resilience of these communities against extreme weather events. It is noted that the program currently only applied to grid-connected communities. Queensland Renewable Energy and Hydrogen Jobs Fund (QREHJF)74 The Queensland Renewable Energy and Hydrogen Jobs Fund allows Government owned corporations to increase ownership of commercial renewable energy and hydrogen projects, as well as supporting infrastructure, including in partnership with the private sector. The Fund complements the commitment of $145 million to establish three Queensland Renewable Energy Zones – the northern, central and southern QREZs – to support significant renewables investment. In these areas, the Queensland Government will undertake strategic network investments, streamline the development of new renewable energy projects, and work to match new and existing industrial energy demand with our low-cost renewable energy. As outlined in the Queensland Energy and Jobs Plan, this funding will ensure publicly owned energy businesses can continue to invest in renewable energy, storage and hydrogen projects in the QREZ regions, and

[72] https://www.epw.qld.gov.au/energyandjobsplan

[73] https://www.epw.qld.gov.au/about/initiatives/queensland-microgrid-pilot-fund

[74] https://www.treasury.qld.gov.au/programs-and-policies/queensland-renewable-energy-and-hydrogen-jobs-fund/

	will help deliver on the long-term targets for these regions to reach at least 25GW of total renewable energy by 2035.
Decarbonising Remote Communities - Solar for Remote Communities[75]	As part of the $3.6 million Decarbonising Remote Communities program, 4 Indigenous communities in Queensland's far north had renewable energy systems installed to reduce the use of diesel power. Participating Aboriginal and Torres Strait Islander Councils were key project partners in planning and delivering these projects. Using renewables such as solar and battery storage directly benefits remote communities that run on diesel by creating jobs and power savings, as well as bringing the environmental benefits of reduced emissions. The communities that benefited from the program included Doomadgee, Mapoon, Pormpuraaw and Northern Peninsular Area. In total almost 1,000kW of new solar generation was installed across Council owned building rooftops or through the establishment of community solar farms.
Affordable Energy Plan[76]	The Affordable Energy Plan invested more than $300 million in a range of pilots and programs to assist households to reduce their energy use and costs. Specific initiatives under this plan included: Energy Efficient Appliance Rebate - $20 million provided to householders that purchase certain energy efficient appliances. Energy Savvy Families - invested $9 million to help low-income families learn about their electricity use and manage their bills by providing digital meters. Solar for Rental Properties program - provided $4 million to incentivise landlords to install solar for their tenants to reduce their household electricity bills. Interest-free Loans for Solar and Storage program - provided $21 million to support Queenslanders manage the upfront costs of solar and battery technologies with interest free loans. Business Energy Savers program - provided $20 million for energy efficiency audits and grants to fund energy efficiency upgrades.
CleanCo Queensland[77]	CleanCo Queensland is a Queensland government-owned electricity generation and trading company. The entity, fuelled by a mix of renewable energy and innovative energy solutions, is tasked with delivering reliable clean energy solutions with a target to support 1,400 MW of new renewable generation by 2025. CleanCo holds a strategic portfolio of low and no emission power generation assets, and will build, construct, own and maintain renewable energy generation in Queensland. CleanCo has a commercial mandate to increase competition to the energy market at peak demand times when wholesale electricity prices are at their highest. In turn, CleanCo aim to reduce the overall wholesale price of energy for all Queenslanders.
Ergon Energy - Community Service Obligation[78]	As part of its commitment to keep regional Queensland power prices on par with the southeast, the Queensland Government provides a subsidy to meet the additional costs involved in supplying electricity to regional Queensland.

[75] https://www.epw.qld.gov.au/about/initiatives/solar-remote-communities

[76] https://www.epw.qld.gov.au/about/initiatives/affordable-energy-plan

[77] https://cleancoqueensland.com.au/

[78] https://www.ergon.com.au/retail/help-and-support/100-qld-owned

	This subsidy is called the Community Service Obligation (CSO) payment, which is around $500 million each year.

Local Government

Initiative	Description
Queensland Climate Resilient Councils program[79]	The Queensland Climate Resilient Councils program was a unique partnership between the Local Government Association of Queensland (LGAQ) and the Queensland Government to support local governments to plan for and respond to climate change. Funded to 30 June 2022, the program sought to deliver services and products that would strengthen skills and capacity to plan for and respond to the challenges and opportunities arising from climate change.
Napranum Aboriginal Shire Council (NASC) Corporate Plan (2017 -2022)[80]	In 2017, NASC presented its five-year Corporate Plan. The Corporate Plan provides the framework against which NASC will operate and outlines its strategic objectives for the community over the five-year horizon. A key strategic objective of NASC as outlined in the Corporate Plan is to develop an economically progressive and prosperous community. Importantly, this objective is underpinned by a focus on developing new economic development projects and creating jobs for the community members. Major projects, such as upgrades to the energy supply for the community, present many opportunities for NASC and the community to grow economically. Furthermore, the potential direct and indirect employment opportunities arising from such a project is high.
Cape York and Torres Strait Regional Resilience Strategy[81]	The Cape York and Torres Strait Regional Resilience Strategy is a partnership between the Queensland Government and the Torres and Cape Indigenous Councils Alliance and the Torres Strait Island Regional Council. Published in 2022, the strategy is focused on developing a framework for the enhancement of resilience across the region, particularly in response to natural disaster events that impact the region. The strategy also provides a framework against which local action plans can be developed and actions implemented at a community level. The strategy identifies a range of core resilience needs for the region, including (but not limited to) improved facilitated infrastructure or innovation in water and energy, support to transition to renewable and independent energy technologies and development of local industries.

Non-Government

Investment in renewable energy generation has increased markedly in Australia over recent years, driven by a combination of factors including Government policy incentives, elevated electricity prices and declining costs of renewable generation technology. Importantly, non-

[79] https://qcrc.lgaq.asn.au/

[80] https://www.napranum.qld.gov.au/nasc/documents/publication-scheme

[81] https://www.qra.qld.gov.au/regional-resilience-strategies/cape-york-torres-strait

Government investment in renewable energy projects, such as that proposed for the Napranum community, may come from a range of sources including:

- Direct corporate sector investment
- Renewable energy investment funds
- Social enterprise investments
- First Nation and Indigenous community investment programs and funds

Non-Government investment programs commonly adhere to an investment mandate that seeks an appropriate commercial return on monies invested in capital infrastructure. While the investment mandates will vary across each funding source, these mandates often require clear and reliable revenue streams that are assured over the long term.

Appendix G. Detailed Financial Assessments

Financial Statements

PROFIT AND LOSS

	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43
Operating Revenue	-	-	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415	1,216,392	1,234,638	1,253,157	1,271,954	1,291,034	1,310,399	1,330,055	1,350,006	1,370,256	1,390,810	1,411,672	1,432,847
Capital Revenue	2,950,000	17,305,831	-	-	-	-	-	-	-	-	-	7,895,792	-	-	-	-	-	-	-	-
Other Revenue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Revenue	**2,950,000**	**17,305,831**	**1,112,441**	**1,129,128**	**1,146,065**	**1,163,256**	**1,180,705**	**1,198,415**	**1,216,392**	**1,234,638**	**1,253,157**	**9,167,747**	**1,291,034**	**1,310,399**	**1,330,055**	**1,350,006**	**1,370,256**	**1,390,810**	**1,411,672**	**1,432,847**
Direct Costs	(347,298)	(353,812)	(1,036,026)	(1,051,566)	(1,067,340)	(773,234)	(784,833)	(796,605)	(808,554)	(820,682)	(832,993)	(845,488)	(858,170)	(871,042)	(884,108)	(897,370)	(910,830)	(924,493)	(938,360)	(952,435)
Gross Profit	**2,602,702**	**16,952,020**	**76,416**	**77,562**	**78,725**	**390,022**	**395,872**	**401,810**	**407,838**	**413,955**	**420,164**	**8,322,259**	**432,864**	**439,357**	**445,947**	**452,636**	**459,426**	**466,317**	**473,312**	**480,412**
Operating Expenses	(49,200)	(49,938)	(50,687)	(51,447)	(52,219)	(53,002)	(53,797)	(54,604)	(55,423)	(56,255)	(57,099)	(57,955)	(58,824)	(59,707)	(60,602)	(61,511)	(62,434)	(63,371)	(64,321)	(65,286)
EBITDA	**2,553,502**	**16,902,082**	**25,729**	**26,115**	**26,506**	**337,020**	**342,075**	**347,206**	**352,414**	**357,700**	**363,066**	**8,264,304**	**374,039**	**379,650**	**385,345**	**391,125**	**396,992**	**402,947**	**408,991**	**415,126**
Interest & Depreciation	(118,000)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(810,233)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)	(1,126,065)
Net Profit/ (Loss) Before Tax	**2,435,502**	**16,091,848**	**(784,504)**	**(784,119)**	**(783,727)**	**(473,214)**	**(468,158)**	**(463,027)**	**(457,819)**	**(452,533)**	**(447,167)**	**7,138,239**	**(752,025)**	**(746,415)**	**(740,720)**	**(734,940)**	**(729,073)**	**(723,118)**	**(717,074)**	**(710,939)**

BALANCE SHEET

	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43
Bank Account	(381,640)	(783,884)	(788,595)	(760,981)	(732,930)	(403,768)	(61,503)	285,885	638,554	996,341	1,359,567	1,728,231	2,102,501	2,482,201	2,867,674	3,258,919	3,656,115	4,059,073	4,468,159	4,883,372
Trade Receivables	265,984	1,564,637	100,577	102,086	103,334	105,171	106,749	108,350	109,675	111,625	113,299	828,865	116,405	118,474	120,252	122,055	123,548	125,744	127,631	129,545
Other Current Assets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Current Assets	**(115,656)**	**780,753**	**(688,018)**	**(658,896)**	**(629,596)**	**(298,596)**	**45,245**	**394,235**	**748,229**	**1,107,966**	**1,472,866**	**2,557,096**	**2,218,905**	**2,600,676**	**2,987,926**	**3,380,975**	**3,779,663**	**4,184,818**	**4,595,790**	**5,012,917**
Fixed Assets	2,832,000	19,327,598	18,517,365	17,707,131	16,896,898	16,086,665	15,276,432	14,466,198	13,655,965	12,845,732	12,035,499	18,805,226	17,679,161	16,553,096	15,427,031	14,300,966	13,174,902	12,048,837	10,922,772	9,796,707
Other Non-Current Assets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Non-Current Assets	**2,832,000**	**19,327,598**	**18,517,365**	**17,707,131**	**16,896,898**	**16,086,665**	**15,276,432**	**14,466,198**	**13,655,965**	**12,845,732**	**12,035,499**	**18,805,226**	**17,679,161**	**16,553,096**	**15,427,031**	**14,300,966**	**13,174,902**	**12,048,837**	**10,922,772**	**9,796,707**
Total Assets	**2,716,344**	**20,108,351**	**17,829,347**	**17,048,236**	**16,267,302**	**15,788,068**	**15,321,677**	**14,860,433**	**14,404,194**	**13,953,698**	**13,508,365**	**21,362,322**	**19,898,067**	**19,153,772**	**18,414,957**	**17,681,941**	**16,954,565**	**16,233,654**	**15,518,562**	**14,809,623**
Trade Payables	275,098	1,573,914	52,226	53,009	53,657	54,611	55,430	56,262	56,950	57,962	58,832	773,580	60,444	61,519	62,442	63,379	64,154	65,294	66,274	67,268
Other Current Liabilities	5,743	7,087	34,275	36,499	38,644	31,670	32,618	33,570	34,462	35,486	36,451	37,420	38,327	39,372	40,354	41,342	42,263	43,331	44,332	45,339
Total Current Liabilities	**280,841**	**1,581,000**	**86,501**	**89,508**	**92,301**	**86,281**	**88,048**	**89,832**	**91,412**	**93,449**	**95,283**	**811,001**	**98,771**	**100,891**	**102,796**	**104,720**	**106,417**	**108,625**	**110,606**	**112,607**
External Debt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Liabilities	**280,841**	**1,581,000**	**86,501**	**89,508**	**92,301**	**86,281**	**88,048**	**89,832**	**91,412**	**93,449**	**95,283**	**811,001**	**98,771**	**100,891**	**102,796**	**104,720**	**106,417**	**108,625**	**110,606**	**112,607**
Net Assets	**2,435,502**	**18,527,351**	**17,742,846**	**16,958,728**	**16,175,001**	**15,701,787**	**15,233,629**	**14,770,601**	**14,312,782**	**13,860,249**	**13,413,082**	**20,551,321**	**19,799,296**	**19,052,881**	**18,312,161**	**17,577,221**	**16,848,148**	**16,125,030**	**15,407,956**	**14,697,016**
Retained Earnings	2,435,502	18,527,351	17,742,846	16,958,728	16,175,001	15,701,787	15,233,629	14,770,601	14,312,782	13,860,249	13,413,082	20,551,321	19,799,296	19,052,881	18,312,161	17,577,221	16,848,148	16,125,030	15,407,956	14,697,016
Total Equity	**2,435,502**	**18,527,351**	**17,742,846**	**16,958,728**	**16,175,001**	**15,701,787**	**15,233,629**	**14,770,601**	**14,312,782**	**13,860,249**	**13,413,082**	**20,551,321**	**19,799,296**	**19,052,881**	**18,312,161**	**17,577,221**	**16,848,148**	**16,125,030**	**15,407,956**	**14,697,016**

CASHFLOW STATEMENT

	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43
Cash From Operations																				
Operating Revenues	-	-	1,112,441	1,129,128	1,146,065	1,163,256	1,180,705	1,198,415	1,216,392	1,234,638	1,253,157	1,271,954	1,291,034	1,310,399	1,330,055	1,350,006	1,370,256	1,390,810	1,411,672	1,432,847
Direct Costs	(347,298)	(353,812)	(1,036,026)	(1,051,566)	(1,067,340)	(773,234)	(784,833)	(796,605)	(808,554)	(820,682)	(832,993)	(845,488)	(858,170)	(871,042)	(884,108)	(897,370)	(910,830)	(924,493)	(938,360)	(952,435)
Operating Expenses	(49,200)	(49,938)	(50,687)	(51,447)	(52,219)	(53,002)	(53,797)	(54,604)	(55,423)	(56,255)	(57,099)	(57,955)	(58,824)	(59,707)	(60,602)	(61,511)	(62,434)	(63,371)	(64,321)	(65,286)
Profit/ (Loss) From Operations	**(396,498)**	**(403,750)**	**25,729**	**26,115**	**26,506**	**337,020**	**342,075**	**347,206**	**352,414**	**357,700**	**363,066**	**368,512**	**374,039**	**379,650**	**385,345**	**391,125**	**396,992**	**402,947**	**408,991**	**415,126**
Working Capital Movements	9,115	162	(57,628)	(725)	(600)	(883)	(758)	(770)	(637)	(937)	(805)	(817)	(676)	(995)	(854)	(867)	(717)	(1,056)	(907)	(920)
Total Cash From Operations	**(387,383)**	**(403,588)**	**(31,899)**	**25,389**	**25,906**	**336,136**	**341,316**	**346,436**	**351,777**	**356,763**	**362,261**	**367,695**	**373,364**	**378,655**	**384,490**	**390,258**	**396,274**	**401,891**	**408,084**	**414,205**
Cash From Investments																				
Capital Grants	2,950,000	17,305,831	-	-	-	-	-	-	-	-	-	7,895,792	-	-	-	-	-	-	-	-
Assets Purchased/ Capital Expenditure	(2,950,000)	(17,305,831)	-	-	-	-	-	-	-	-	-	(7,895,792)	-	-	-	-	-	-	-	-
Total Cash from Investments	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Cash From Financing																				
Proceeds from External Borrowings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Repayment of External Borrowings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Add: Short Term Asset Movements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Add: Short Term Liability Movements	5,743	1,344	27,189	2,224	2,145	(6,974)	948	952	892	1,024	965	969	906	1,045	983	987	921	1,067	1,002	1,007
Total Cash From Financing	**5,743**	**1,344**	**27,189**	**2,224**	**2,145**	**(6,974)**	**948**	**952**	**892**	**1,024**	**965**	**969**	**906**	**1,045**	**983**	**987**	**921**	**1,067**	**1,002**	**1,007**
Total Cash Movement	**(381,640)**	**(402,244)**	**(4,711)**	**27,613**	**28,051**	**329,163**	**342,264**	**347,388**	**352,669**	**357,787**	**363,226**	**368,664**	**374,270**	**379,700**	**385,473**	**391,245**	**397,196**	**402,958**	**409,086**	**415,212**
Opening Cash Balance	**-**	**(381,640)**	**(783,884)**	**(788,595)**	**(760,981)**	**(732,930)**	**(403,768)**	**(61,503)**	**285,885**	**638,554**	**996,341**	**1,359,567**	**1,728,231**	**2,102,501**	**2,482,201**	**2,867,674**	**3,258,919**	**3,656,115**	**4,059,073**	**4,468,159**
Closing Cash Balance	**(381,640)**	**(783,884)**	**(788,595)**	**(760,981)**	**(732,930)**	**(403,768)**	**(61,503)**	**285,885**	**638,554**	**996,341**	**1,359,567**	**1,728,231**	**2,102,501**	**2,482,201**	**2,867,674**	**3,258,919**	**3,656,115**	**4,059,073**	**4,468,159**	**4,883,372**

Appendix H. Case studies

H1. SAPS and Microgrids

Historically, imported diesel fuel was the principal source of electricity in isolated settlements. As a result of the high transportation, fuel, and operation costs, most utilities incur significant financial outlays. It is obvious that a partial replacement of renewable energy reduces expenditures in such a town. Microgrid technology must be studied to increase renewable energy consumption while maintaining power quality as enticing renewable energy develops and may become the primary energy source for the town.

Considering the above fact, several resource corporations have announced intentions to integrate renewable energy technologies to power their mining operations in recent years. Mining companies of both large and medium sizes are considering the future of energy production for their operations. Their decision-making process is influenced by various factors such as cost, energy reliability, and environmental impact, among others. As a result of this heightened interest, Australia has emerged as the market with the highest growth rate for renewable energy in mining operations. This development creates fresh opportunities for both the renewable energy and mining industries.

H.1.1 Case Studies

Kalumburu Microgrid Horizon Power (Western Australia)

Lead: Horizon Power

Project Partners: N/A

Project Timeline: N/A

Status: In operation

Capex: N/A

Location: Kalumburu, Western Australia

Funding: N/A

Aims: Reduce the dependency on diesel generators

Technologies: Hybrid technologies comprised of solar, BESS and diesel

Description: Kalumburu is the most remote permanent settlement in Western Australia, located on the banks of the King Edward River, 550 kilometres northwest of Kununurra and 650 kilometres northeast of Derby in the Kimberly region. **https://www.pv-magazine-australia.com/2021/10/28/horizon-rolls-out-solarstorage-solution-in-states-most-remote-settlement/**

The community's only power source has been diesel generators, but Horizon Power installing a 700kW solar farm and a 1.78MWh BESS provides a clean, green energy supply to the 400 residents. The power station will still require diesel generation. Still, the new solar and BESS solution allows it to run entirely on renewable energy during the day when weather conditions are favourable.

Onslow Microgrid (Western Australia)

Lead: Horizon Power

Project Partners: PXiSE Energy Solutions, SwitchDin

Project Timeline: October 2018 – June 2019

Status: In operation

Capex: NA

Location: Onslow, Western Australia

Funding: NA

Aims: Increase knowledge and confidence in the use of renewable energy to power off-grid towns and reduce dependency on gas and diesel generators

Technologies: Hybrid technologies comprised of solar, BESS and diesel

Description:

Onslow is a coastal town in Western Australia's Pilbara region, 1,386 km north of Perth. It has an estimated population of 848 people and is part of the Shire of Ashburton LGA. The Onslow project was initiated in 2016 to replace diesel and gas dependency. It was completed in two stages where Stage 1 delivered 8MW of gas-powered station and Stage 2 consisted of 1 MW centralized solar farm and 1 MWh of BESS. The microgrid also includes rooftop solar and household batteries, with residents incentivized to install solar and BESS technology in their homes as part of the project.

During a trail run in 2019 the Onslow microgrid successfully powered the town of around 800 people for about 80 minutes with 100 % renewable penetration. Electricity was generated via 600 KW of utility solar PV and 700 KW of rooftop solar, which were supplemented by BESS technology, and an intelligent control system known as a Distributed Energy Resource Management System (DERMS) was used to maximise the microgrid's potential.

https://www.mediastatements.wa.gov.au/Pages/McGowan/2018/07/Onslow-microgrid-project-Stage-One-completed.aspx

https://www.pv-magazine-australia.com/2021/06/18/landmark-moment-as-pilbara-town-powered-100-by-solar-pv-and-battery/

Flinders Island Hybrid Energy Hub

Lead: Hydro-Electric Corporation

Project Partners: None

Project Timeline: 4th September – 30th April 2021

Status: Operational.

Capex: $13.38 million

Location: Flinders Island, Tasmania

Aims: The project intends to displace more than 60% of Flinders Island's diesel-generated energy by combining solar, wind, fuel, storage, and supporting technologies.

Technologies: Hybrid technologies, solar energy, BESS and wind energy

Funding: $5.5 million ARENA

Description: Hydro Tasmania initiated the Flinders Island Hybrid Energy Hub project to generate a project opportunity to refine a cost-effective strategy for bringing high-penetration renewable energy hybrid systems to the broader market.

https://arena.gov.au/projects/flinders-island-hybrid-energy-hub/

The Flinders Island Hybrid Energy Hub project effectively boosted intended levels of annual renewable contribution by up to 60%. It can run for extended periods of zero-diesel operation (up to over 100 hours continuously and for roughly 50% of the year). The project included the installation of a 200 kW DC solar farm, a 900-kW wind turbine, a 1.5 MW dynamic resistor, an 850 kVA diesel-UPS, a 750 kW/266 kWh BESS, distribution line augmentation, and a feeder management system, all of which were integrated into the existing diesel power plant. These components were combined using an innovative automated hybrid power system controller.

Kalbarri Microgrid (Western Australia)

Lead: Western Power

Project Partners: N/A

Project Timeline: 2016 - 2019

Status: In operation

Capex: N/A

Location: Kalbarri, Western Australia

Funding: $15 million investment by the State Government

Aims: Improve the reliability of power supply

Technologies: Hybrid technologies comprised of solar, wind and battery

Description: The Mid-West town is linked to the network by a 140-kilometer-long rural feeder line from Geraldton that is exposed to the weather and results in outages. The Kalbarri microgrid, which combines 1.6 MW of wind generation capacity, 1 MW of rooftop solar, and 2 MWh BESS, is unique in that it does not rely on fossil fuels for backup. This is because the microgrid is the backup - in this example, for the main grid.

The Kalbarri microgrid is designed to eliminate 80 percent of the town's outages and potentially significantly shorten the length of outages depending on how power is drawn from the microgrid. Kalbarri's townsite is covered by the microgrid while the wind farm and batteries are located 20 km south of town.

Appendix I. International experiences

An April 2020 study[82] examined the contributing factors to the successful growth of community microgrids[83] implemented in existing electricity grids around the world. The study had a particular focus on:

- the drivers for community microgrids,
- key stakeholders involved,
- the role of informal institutions (utility business approaches and social attitudes), and
- formal institutions (policy and regulatory frameworks).

The review was based on published scientific literature from four regions:

- the USA,
- European Union,
- Asia, and
- Australia.

It found a growing market is emerging but that community microgrids represent a small share of total microgrid projects in the developed world. An overview of the study follows.

I.1.1 USA

To a large extent, recent microgrid developments are responses to aging electricity grids, power outages and increased awareness of vulnerability to extreme weather events (e.g., hurricane Sandy which affected north-eastern USA and the Caribbean in 2012). States which frequently experience disasters are more likely to adopt microgrids.

Incentive programs have specifically required microgrids to be able to separate from the larger grid to provide power to customers in the event of any extreme weather events or emergencies.

Many states in the USA have ambitious targets for renewable energy production from solar PV and wind energy. With an increase in these variable resources, microgrids are seen as one of the most effective methods to integrate these and at the same time provide grid operators with more control.

---

[82] www.sciencedirect.com/science/article/pii/S1364032119308950. Based on published scientific literature with Asia and Australia noted as regions needing further study as they have the lowest levels of literature.

[83] Building on the US DoE's definition of a microgrid, Warneryd defined a community microgrid as *'technically a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries which acts as a single controllable entity with respect to the grid. A community microgrid can connect or disconnect from the grid to enable it to operate in both grid-connected or island-mode. Moreover, a community microgrid is connected with its community through physical placement and can be owned by said community or other part.'*

- The majority of microgrids are funded by government, changes in service tariffs for microgrid services may increase return on investment and lead to more privately funded microgrids.
- Collaboration across a wide cross-section of stakeholders is required in the planning, implementation and operational stages of a microgrid. The stakeholders involved and their roles are:
- Government. Policymaker, funder and influencer of deployment microgrids. For example, in New York funding was provided for 94 feasibility studies for microgrids. In California legislation was introduced for microgrid service tariffs providing compensation for services provided from the microgrid to the connected grid (e.g., in times of peak demand or production).
- Utilities. Local utilities can introduce initiatives in response to government incentives. Examples of utility-led microgrids, include ComEd and Arizona Public Service Electric Company who have introduced new business practices to assist implementation of and understand the impacts of microgrids.
- Technology providers for integration of different technology and microgrid control, often work closely with research institutions to develop and test systems and technologies.
- Communities which use and sometimes own microgrids can set design according to demands.
- Financial investors are increasing present in the market often with an "energy-as-a-service" business model.

I.1.2 EU

Community-driven or initiated microgrids (e.g. Feldheim in Germany and Aardhuizen in the Netherlands) are underpinned by strong self-sustaining communities as a rationale for development. The Feldheim case started with the community investing in a wind farm co-owned by renewable energy developer Energiequelle. Energiequelle then developed nearby a solar PV plant and co-invested into a community owned bioenergy plant. This led to a case to connect the renewable sources of generation as a microgrid, which Energiequelle now operates after utility Eon declined to collaborate. A BESS and control system was later added to the microgrid making the village independent. The installation process occurred from 1995–2013 during which the community went through a series of development steps, decision processes, member conflicts and solutions development leading to increased trust and community confidence. In Aardhuizen village some local members with specific knowledge of energy or electricity systems, and financing have taken on the role of local experts to increase the level of trust in the community.

Several European nations have ambitious decarbonisation targets, policies and incentives that have driven high levels of renewable energy production, with microgrids offering a solution to help balance the grid. Many microgrids are associated with EU research programs and a history with renewable incentives such as feed-in tariffs, net metering, green certificates and energy origin guarantees. The EU commission "clean energy for all" includes the renewable energy directive for member states to remove regulatory and administrative barriers to community energy projects including microgrids and regularly assess progress.

I.1.3 Asia

A number of drivers are present due to the diversity of the region including responding to climate change, ability to integrate within urban environment, increasing energy resilience in the event of disasters (e.g., Fukushima nuclear disaster leading to Sendai microgrid demonstration) and tech-industry development objectives in countries such as South Korea and Taiwan.

In Japan, the funders of demonstration projects included the New Energy and Industrial Technology Development Organisation, research institutions and the City of Sendai local government. In South Korea and Taiwan, government-business initiatives have been prominent with projects shaped by government initiative and visions. In China, many developments are state-driven to help integrate renewable energy in dense cities.

Microgrid funding and planning by government and research institutions has been used in China as an example of formal institutional approach. The 12th five-year plan in China a policy framework for the country's development for 2011–2015, contained targets for distributed energy generation including 30 new microgrid demonstration projects. As of 2017, 28 new microgrid demonstration projects are in the planning stages. Limits to scale for onsite generation, government subsidy and tariff structures have been highlighted as issues needing change to support microgrid development.

I.1.4 Australia

High electricity costs and high uptake of renewable energy, especially distributed solar PV is stimulating interest in microgrids.

There are many stakeholders, reflecting Australia's liberalised national electricity market. Most amount of activity in implementing microgrids is in Western Australia where the state government retains ownership of electricity networks and retailing.

The approach in Australia is a mix of formal institutional with national and state based incentives for distributed solar and regulatory changes for microgrids and informal institutions for microgrid and P2P developments.

I2. Conclusions

The need to balance increasing renewables as a driver for microgrids is a common feature in all regions.

There are also other drivers. In US, it is aging electricity grid and desire to increase resilience of cities, in the EU local autonomy and community energy, in Asia a combination of fast-growing cities and growing demand motivate local energy in urban contexts, disaster resilience, as well as increasing domestic competitiveness in smart microgrid markets, in Australia increased self-sufficiency / reduced reliance on utilities.

Formal institutional developments are playing a role, with changes to microgrid service tariffs and utility regulation occurring in the US and changes to regulations to allow communities to act as aggregators of renewable generation, flexible loads and storage services in the EU.

Government involvement in policy and regulation also influences development of informal institutions. Community microgrids need to present a viable business model and rely on investors. The experiences in the EU show to be able to stimulate community involvement/motivation for implementation, demonstrating increased social value is important. The process is long term and challenging as microgrids are technically complex and developers need to increase social value of implementing and operating the microgrid, to in turn increase social acceptance.

The attitude and involvement of the utility has a strong bearing on microgrid development, with formal and informal institutional development creating pressure on utilities to consider non-traditional electricity infrastructure development.

The US and Asia experiences show a linkage between microgrids and planning for increased resilience in cities. A trend of government investment in microgrids in the context of defence and disaster preparedness may increase in future.


EnergyConnect
Connecting Community through Micro-Grids