EnergyConnect
Connecting Community through Micro-Grids

Yarrabah Microgrid
Feasibility Study

Final

February 2022

Acknowledgements

This report acknowledges the Traditional Owners, those people with historical association and all community members of the Yarrabah community. This report also acknowledges that their customs and traditions have nurtured and managed the land and sea for centuries.

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Finally, thank you to all the members of the Yarrabah community, who welcomed us into their community, their homes, their country and took the time to have a yarn with us. We are extremely grateful and touched by the community's trust and openness with the whole team.

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 Management Group

Ener-G Management Group is a highly credentialled provider of Power Engineering consultancy services in the Electrical Power industry. Ener-G specialises in Power Infrastructure and Asset Management, Electricity Network Connection negotiation, Microgrid concept and feasibility studies, Renewable Energy generation feasibility and engineering, Power System Regulatory advice, and Remote Energy Supply. Ener-G's key clients include electrical power utilities, resource development companies, renewable energy developers, major energy users, and aid donors in developing countries.

Ener-G can provide Grid Connection assessment for embedded generation projects and new large industrial loads including network technical studies and Generator Performance Standard (GPS) development and AEMO generator registration advice, assistance with delivery of new electrical infrastructure with preparation of concept and functional designs and design reviews, Regulatory assessments for new power infrastructure and connections, Renewable Energy project concept planning and feasibility studies, and Off-grid and remote power station planning and management both in Australia and in the Pacific region.

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 team are specialists in environmental management, community engagement, and Integrated Management System development. They take complex science, engineering or government policy and translate it into 'real language' for their clients or communities. The Missing Link helps parties to understand how these factors apply to their operations and provide practical advice on how to make projects work in their world whilst reducing potential risks.

The Missing Link has extensive experience in supporting proponents and engaging communities affected by large scale renewable energy projects - particularly in remote or tropical environments. They regularly partner with other consultants to provide ultimate flexibility for their client base, and successfully collaborate to offer the specific skills clients require for particular deliverables, ensuring they receive the most holistic, effective and professional service.

Planz Town Planning

With over 25 years' experience in Northern Australia, Planz understands living and doing business in regional and rural areas and they are known for their ability to consistently proving tangible, culturally appropriate outcomes for communities. Planz has been awarded multiple times for Public Engagement & Community Planning, Community Well Being & Diversity and Improving Planning Process by the Planning Institute of Australia (Queensland). Nikki Huddy is the Australian Planner of the Year 2020-21. Jesse Marnock has received national commendation from the Planning Institute of Australia for his work on Sustainable Indigenous Livelihoods.

About This Report

The Yarrabah Microgrid Feasibility Study aims to analyse the options to showcase Yarrabah microgrid as a self-reliant, sustainable, community-based energy solution that can be replicated at other fringe-of-grid and regional and remote communities.

This report was commissioned through the Australian Government's Regional and Remote Communities Reliability Fund administered by the Department of Industry, Science, Energy and Resources.

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.

EnergyConnect

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Abbreviations

ABS – Australian Bureau of Statistics

ACR – Automatic Circuit Reclosers

AEMO – Australian Energy Market Operator

AER – Australian Energy Regulator

ARENA – Australian Renewable Energy Agency

CB – Circuit Breaker

CSIRO – Commonwealth Scientific and Industrial Research Organisation

CSO – Community Service Obligation

DNSP – Distribution Network Service Provider

DOGIT – Deed Of Grant In Trust

DRED – Demand Response Enabled Device

EBITDA – Earnings Before Interest, Taxes, Depreciation, and Amortization

EDNC – Electricity Distribution Network Code

ENO – Embedded Network Operator

ERP – Estimated Resident Population

EV – Electric Vehicle

FiT – Feed-in Tariff

FNQROC – Far North Queensland Regional Organisation of Councils

GRP – Gross Regional Product

ISO – International Organization for Standardization

kV – kilovolt

kVA – kilovolt-ampere

LCOE – Levelized Cost of Electricity

LET – Local Energy Trading

LGA – Local Government Area

LGCs – Large Scale Generation Certificates

LUOS – Local Use Of System

MaaS – Mobility as a Service

MCS – Master Control System

MEDs – Major Event Days

MID – Ministerial Infrastructure Designation

ML – Megalitre

MVA – megavolt-amperes

MW – Megawatt

MWh – megawatt hour

NBN – National Broadband Network

NEM – National Electricity Market

NIAA – National Indigenous Australians Agency

NPBT – Net Profit Before Tax

O&M – Operation & Maintenance

PBC – Prescribed Body Corporate

PMO – Project Management Office

PPA – Power Purchase Agreement

PR – Poles

QGSO – Queensland Government Statistician Office

RAMPP – Regional Australia Microgrid Pilots Program

RNTBC – Registered Native Title Body Corporate

SAIDI – Supply Average Interruption Duration Index

SAIFI – Supply Average Interruption Frequency Index

SCADA – Supervisory control and data acquisition

SEIFA – Socio-Economic Indexes for Areas

SoC – State of Charge

UPS – Uninterruptible Power System

UQ – University of Queensland

VF – Voltage Frequency

VPP – Virtual Power Plant

VRE – Variable Renewable Energy

YASC – Yarrabah Aboriginal Shire Council

YLF – Yarrabah Leaders Forum

Executive Summary

This feasibility study analysed a range of options to showcase the town of Yarrabah (see

Figure 1) as a self-reliant, sustainable microgrid to enhance community resilience. The study identified the most financially and technically viable option for deployment with the aim that the deployment model used can be rolled out to other, similar, fringe-of-grid communities.

The Yarrabah Microgrid Feasibility Study was one of the successful projects in Round one of the Regional and Remote Communities Reliability Fund (RRCRF).

The feasibility study was conducted in accordance with the following 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 View from Mt Yarrabah, showing Mission Bay and the southern suburb of Oombunghi[1]

[1] Image from: www.yarrabah.qld.gov.au/council/community-profile/

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 or island mode.'*

Typically, the reference to the grid is the main distribution or transmission grid. It should also 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 a main grid blackout.

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 main grid if this was the most economic option.

This 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.

Yarrabah Social Snapshot

Yarrabah is the largest Aboriginal community in Australia with a population of approximately 4,000 residents. Most residential homes in Yarrabah, approximately 380, are owned by the Yarrabah 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 and at this location, limited 'buildable' land, sandwiched between mountains and sea.

Yarrabah residents experience financial hardship due to high levels of unemployment and limited opportunity for local employment. Additionally, a shortage of public housing results in overcrowding of existing residences with up to 10 people living in a 3-bedroom house. This in turn results in higher-than-average electricity bills, associated with residents spending more time at home, higher demand for hot water combined with inefficient hot water systems, limited use of off-peak tariffs, and use of inefficient appliances such as box air-conditioners. Rooftop solar systems that could offset the energy required to be purchased from the local energy retailer have not been deployed to Council-owned residences and residents have low levels of energy literacy and limited financial capacity to fund the purchase of energy-efficient appliances.

The project team has worked closely with the Yarrabah Aboriginal Shire Council, the Gunggandji Prescribed Body Corporate (PBC) Aboriginal Corporation Registered Native Title Body Corporate (RNTBC) and Gunggandji-Mandingalbay Yidinji Peoples PBC Aboriginal Corporation RNTBC, the Yarrabah Leaders Forum and community leaders, the broader community, and a range of other stakeholders, to ensure that all inputs were considered when developing and assessing microgrid options. Community feedback was valuable in identifying opportunities, clarifying community expectations and needs, cultural requirements, and to flag potential barriers to implementation.

Existing Energy Snapshot

The Yarrabah community is connected to the Ergon Energy Network distribution grid via a single circuit 90km overhead 22,000 volt powerline that navigates a path to the south and east of Trinity Inlet before traversing sections of the Wet Tropics World Heritage Rainforest Area at Murray Prior Range and descending into the Yarrabah town area (see Figure 2).

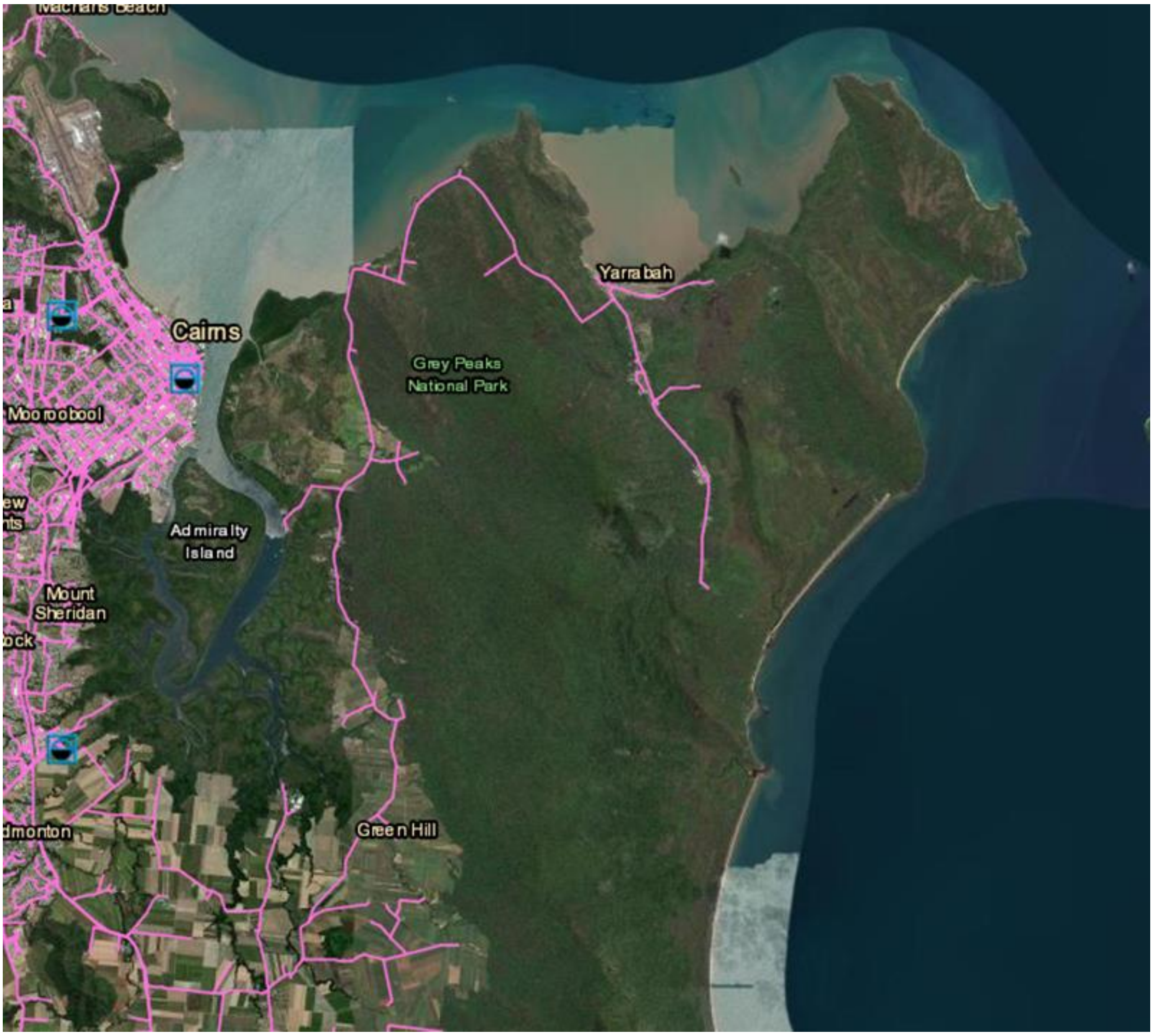

Figure 2 The Yarrabah Electrical Grid overview.

The existing electricity network has the capacity to meet the current and forecast energy demand for the Yarrabah community.

Yarrabah, like many other fringe-of-grid communities, experiences longer and more frequent electricity supply disruptions than urban locations that are generally serviced by networks that have additional in-built redundancy through meshed grid networks.

During the period January 2018 to June 2020 Yarrabah experienced 44 outages (planned, unplanned and forced) including 27 momentary outages. The longest outage lasted for 24 hours due to damage to overhead powerlines on the upstream network. The average outage duration for sustained outages was 5.6 hours.

Whilst there were no major weather events recorded during this same period, the Yarrabah power supply network is susceptible to weather-related events as was evidenced when tropical cyclones Kimi and Niran visited the Far North Queensland coast in January and March 2021 resulting in extended power outages of several days to the Yarrabah community due to upstream impacts to the feeder.

Based on an analysis of electrical grid load data supplied by Energy Queensland for the 2019/20 period, the project team assessed that the total electrical load of the Yarrabah community on the Energy Queensland grid fluctuates between around 600 kVA and 1,800 kVA. The low load periods tend to occur between 3am and 5am in the mornings, and the peak loads tend to occur later in the day and throughout the evening.

Winter loads tend to vary between 600 kVA and 1,400 kVA whilst during the tropical summer months when air-conditioning is predominantly used, the load ranges between 1,000 kVA and 1,800 kVA.

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 battery energy storage system 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.

As a result, in Australia, it is now generally economical to design new, isolated power systems so that their MWh annual load is predominantly met (i.e. 50%-95%) with solar PV and BESS, while retaining standby generation for the balance of annual generation. The enhanced reliability and affordability of electricity supply assuming an effective program for energy consumption behavioural changes with the installation of rooftop solar PV has the potential to remove multiple levels of disadvantage for fringe-of-grid communities like Yarrabah 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. This new way of thinking usually requires careful management of supply and demand via new technology 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 a main grid extension or diesel-only generation.

All of the trends described above are widely expected to continue over the medium-term, increasing the incentive for substituting long-distance power line connections to the main grid with isolated microgrids.

The business models that are possible for islandable microgrids that incorporate renewable energy revolve around the different technology configurations. This feasibility study discusses the business models options for microgrids in Australia, and also discusses the alternative outcomes available when the local microgrid distribution grid is either privately owned as an embedded network, or is owned by the local Distribution Network Service Provider (DNSP) which in the case of Yarrabah is Ergon Energy Network, a subsidiary of Energy Queensland.

E-mobility & Community Connectedness

The maturing of e-mobility technologies presents opportunities for communities like Yarrabah to leapfrog conventional transport technology options, and shift towards innovative, affordable, equitable and environmentally friendly alternatives. Such an approach could provide a pathway for remote and regional communities to reduce social disadvantage.

The potential integration of e-mobility into a future Yarrabah microgrid has been considered as part of the microgrid feasibility assessment, including the detail of the types of e-mobility vehicles that are likely to be of most benefit to the local community; how these transport options would integrate and support a microgrid; what impact e-mobility deployment would have on the microgrid operations, and importantly, how the delivery of e-mobility in Yarrabah could provide broader social, health, environmental and economic benefits.

Transport is a path to opportunity but is usually a priority for larger population centres. Yarrabah Aboriginal Shire Council intends to be at the forefront of the technology change and the e-mobility strategy aims to support this ambition in delivering long-term and meaningful change for the local community.

Asset Ownership and Management

The microgrid could be developed using a range of investment or ownership models. The preferred model, as adopted for this study, includes YASC retaining outright ownership of the project assets.

To support YASC, it is proposed that a special purpose, not-for-profit community entity (Implementation Entity) is established, and engaged in the capacity of a head contractor. The primary objective of this entity is to perform a Program Management function for the development, construction and operational phases of the project, and also perform an ongoing contract management role for the operation and maintenance of key microgrid assets. This includes responsibility for establishing commercial arrangements such as asset lease agreements or risk-and-profit sharing contracts for the central microgrid facilities. To optimise community engagement and governance, it is recommended that the entity establishes a management committee comprising of community and stakeholder representatives and independent members.

The operating model for the microgrid is underpinned by a commercial operate and maintain (O&M) arrangement, with a third-party operator, for the core microgrid assets (community PV, battery, standby generator and microgrid control system). The other elements of the project will be managed directly by the Implementation Entity.

The preferred arrangement for Yarrabah includes Ergon Energy Network retaining responsibility for the electrical distribution network, and no changes to current energy retailing arrangements are envisaged within the community. Energy Queensland is expected to have a significant interest in the operation of the central microgrid assets and the integrated control system as it is intended for the microgrid to operate in grid-connected mode most of the time, and in island mode in the event of a sustained upstream outage.

Financial Summary

Collectively, the total estimated capital cost for the microgrid project is expected to be $23.5 million over a 3-year period (excluding GST). Since YASC are unlikely to monetise many of the benefits arising from the assets, it is expected that the project will be heavily dependent on Government funding for establishment and ongoing operation. For the purposes of this assessment, it has been assumed that a combination of State and Federal Government funding will be sourced for the full capital value of the project and ongoing operating requirements of approximately $1.5 million per annum (unadjusted for inflation).

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.

Recommendations

The Yarrabah microgrid is intended to be designed and operated as an 'islandable microgrid', which will retain the connection to the Ergon Energy Network / Energy Queensland grid for the majority of the year, but will be able to switch over seamlessly to operate in island mode for short periods of time, when the main grid is either not available due to an outage event occurring, or in a planned manner when line maintenance may be required.

Solar PV energy is the most reliable and technically suitable renewable energy source recommended for application in Yarrabah, and when combined with energy storage systems such as batteries, this renewable energy source can be phased in alongside the current grid-based supply to start to transition Yarrabah to a more sustainable future power supply system whilst reducing greenhouse gas emissions.

Operation of an embedded DNSP owned microgrid 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 Yarrabah 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 generator.

The microgrid DER design with centralised storage can absorb excess solar PV energy being exported to the local grid to increase network hosting capacity, and to reduce network demand peaks. This design of microgrid may also allow future operation as a virtual power plant (VPP) where the microgrid load is aggregated by a suitable retailer, which can then participate in external markets such as the wholesale electricity spot market or the frequency control ancillary services (FCAS) markets.

To enhance the potential benefits of the implementation of the Yarrabah microgrid project, a significant educational/engagement program is proposed, that commences with the installation of smart meters in each household, individualised energy audits for each house, and feedback on current performance and information on appliance selection and operations to minimise power use and cost that can be quantified and recognised.

The authors have developed a draft implementation plan for consultation with key stakeholders and interested parties to guide and support the transition to a renewable energy microgrid based energy future for the Yarrabah community.

The implementation of renewable energy solutions in Yarrabah must recognise and acknowledge the unique demographic and logistical circumstances and the significant impacts that energy plays in managing community resilience in fringe-of-grid communities like Yarrabah. It must also consider the important functions of Energy Queensland and the Queensland Government as the current providers of an economical, reliable, efficient, and safe electricity supply system for the people of Yarrabah.

The Yarrabah microgrid Feasibility Study proposes a strategic future energy solution to an existing and very real energy challenge. This study delivers a realistic opportunity to improve the sustainability, reliability, and affordability of power supply to the Yarrabah community as well as co-benefits such as improved health, education, equity outcomes and increased community resilience. In addition, the study considers benefits that could be gained by considering other energy challenges such as a transition in transport infrastructure from fossil-fuels to predominantly electric-powered vehicles in the future.

To maximise the demonstration value of the Yarrabah microgrid it is proposed to establish an interpretive facility within the central microgrid site, referred to in this report as the Yarrabah Energy Knowledge Hub.

This facility will provide educational, tourism and employment opportunities for locals and visitors, focusing on renewable energy resources, microgrid control technologies, energy efficiency and community support.

It is envisaged that other commercial enterprises may ultimately benefit from the facility including use of the site as a future hub for local e-mobility services, and as a maintenance depot for local renewable energy systems such as rooftop solar PV systems.

The facility may also be suitable as a cyclone shelter to improve the community's climate resilience.

In summary, the proposed microgrid solution for Yarrabah incorporates the following:

- An energy efficiency program to target demand reduction via education, behavioural change and the replacement of inefficient air-conditioners and hot water systems
- 1,500 kW rooftop solar PV on 300 dwellings
- 400 kW of rooftop solar PV on commercial / community buildings
- 1,450 kW solar farm + 1,700 kW BESS + 550 kW standby generator
- Microgrid control system to optimise DER and integration with the Energy Queensland grid
- Yarrabah Energy Knowledge Hub

Contents

Tables

Figures

1

Introduction

1 Introduction

1.1 About the Regional and Remote Communities Reliability Fund

The Yarrabah Microgrid Feasibility Study was made possible with funding from Round One of the Australian Government's Regional and Remote Communities Reliability Fund (RRCRF). The RRCRF was established in October 2019 to support regional and remote communities to investigate whether replacing, upgrading or supplementing a microgrid[2] 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, and
- Increased dissemination of technology and/or project knowledge regarding the deployment and upgrading of microgrids.

1.2 Background

Yarrabah is a fringe-of-grid community of approximately 4,000 residents located east of Cairns, supplied via a 90 km overhead single-circuit 22,000-volt powerline which experiences regular power supply interruptions. The community is particularly vulnerable to extended power interruptions during severe weather events such as tropical cyclones due to the heavily vegetated sections of the powerline route especially where it traverses Wet Tropics World Heritage rainforest areas across the Murray Prior range.

Yarrabah has very limited opportunity for economic development and 62.3% of the eligible population is unemployed. Overcrowded housing also contributes to higher-than-average monthly household electricity bills which puts additional pressure on household budgets.

Reliable and affordable electricity supply removes multiple levels of disadvantage for fringe-of-grid communities like Yarrabah by addressing cost-of-living pressures, providing reliable access to on-line services such as banking, improving health and education outcomes,

[2] 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.

supporting reliable communications infrastructure and ensuring safe and reliable water supply is available.

Yarrabah is an ideal location to establish a microgrid demonstration facility due to its proximity to Cairns, the gateway and collaboration hub for regional and remote communities across northern Australia. It has nearby access to a range of education institutions from primary to tertiary levels, offers potential tourism value and the opportunity to provide a much-needed infrastructure project that can stimulate economic activity and create long-term employment opportunities within the community.

1.3 Study Purpose

The purpose of this study is to identify the most technically and financially viable microgrid solution that could be deployed at Yarrabah to complement the existing grid connection, enhance electricity supply reliability, and meet the community's annual energy needs whilst optimising the socio-economic benefits for Yarrabah.

The aims of the study are to:

- Define the feasibility of a microgrid for the Yarrabah Aboriginal community in a way that allows the knowledge gained to be shared to create increased awareness and understanding of the costs and benefits of microgrid systems and technologies.
- Develop optimal solutions and facilitate successful implementation at Yarrabah as a demonstration site for other remote and fringe-of-grid communities.

Yarrabah will be showcased to other regional and remote communities as a self-reliant, sustainable and energy-efficient community in a Wet Tropics World Heritage rainforest setting that relies on modern, environmentally-friendly, microgrid technology as its primary energy source.

The intended audience for this report is the Australian Government, the Yarrabah community and the wider end of grid and fringe of grid communities; and the future developers of the microgrid. Accordingly, while the report is a technical document, it is also intended to be a document that can easily be read by a wider audience.

1.4 Study Scope

This study explores a range of potential local energy generation solutions that may be available at Yarrabah for a fringe-of grid solution. 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 Ergon Energy Network 22 kV 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 Yarrabah community in the event of an outage to the upstream 22 kV network.

The study examines a range of:

- Energy efficiency options,
- Renewable generation and energy storage technologies,
- Microgrid and load control systems,
- Potential impacts of e-mobility deployment, ownership and business models, and
- Social, financial and economic 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), either behind-the-meter or metered separately, in conjunction with battery energy storage systems (BESS).

2

Project Plan and Methodology

2 Project Plan and Methodology

The Yarrabah Microgrid Feasibility Study project plan was developed to efficiently coordinate the efforts of the four businesses that had formed EnergyConnect to deliver the project outcomes. The plan was critical to ensuring the necessary resources and skills were allocated to meet project milestones and budget targets.

The project team anticipated a significant level of engagement with the Yarrabah community and its leaders to fully understand the context in which the microgrid would operate and to ensure community ownership of the project recommendations. It was critical to identify and confirm community expectations of impacts and benefits and to bring the community along the journey from "understanding what a microgrid is", to embracing a solution that would underpin a future more resilient Yarrabah.

The Project Plan was therefore punctuated with checkpoints for focused stakeholder engagement activities at critical times in the project lifecycle.

The team worked closely with Yarrabah Aboriginal Shire Council, the Prescribed Bodies Corporate, community leaders, the broader community and a range of other stakeholders, to ensure that their input was considered when developing and assessing microgrid options. Community feedback was valuable in identifying opportunities, clarifying community expectations and needs, cultural requirements, and to establish potential barriers to implementation.

2.1 Project Plan

The project commenced in July 2020 with a target end date of February 2022.

A timeline outlining the key project stages is presented in Figure 3.

A brief description of each phase of the project plan is outlined below.

2.1.1 Project Establishment

This initial period was essential to confirm the roles of the project partners that had come together to form EnergyConnect, review and prepare detailed project plans and undertake other project administrative activities.

EnergyConnect was adopted as the project brand name for the consortia of businesses working on the project led by Ener-G Management Group and including ITP Renewables, The Missing Link, and Planz Town Planning.

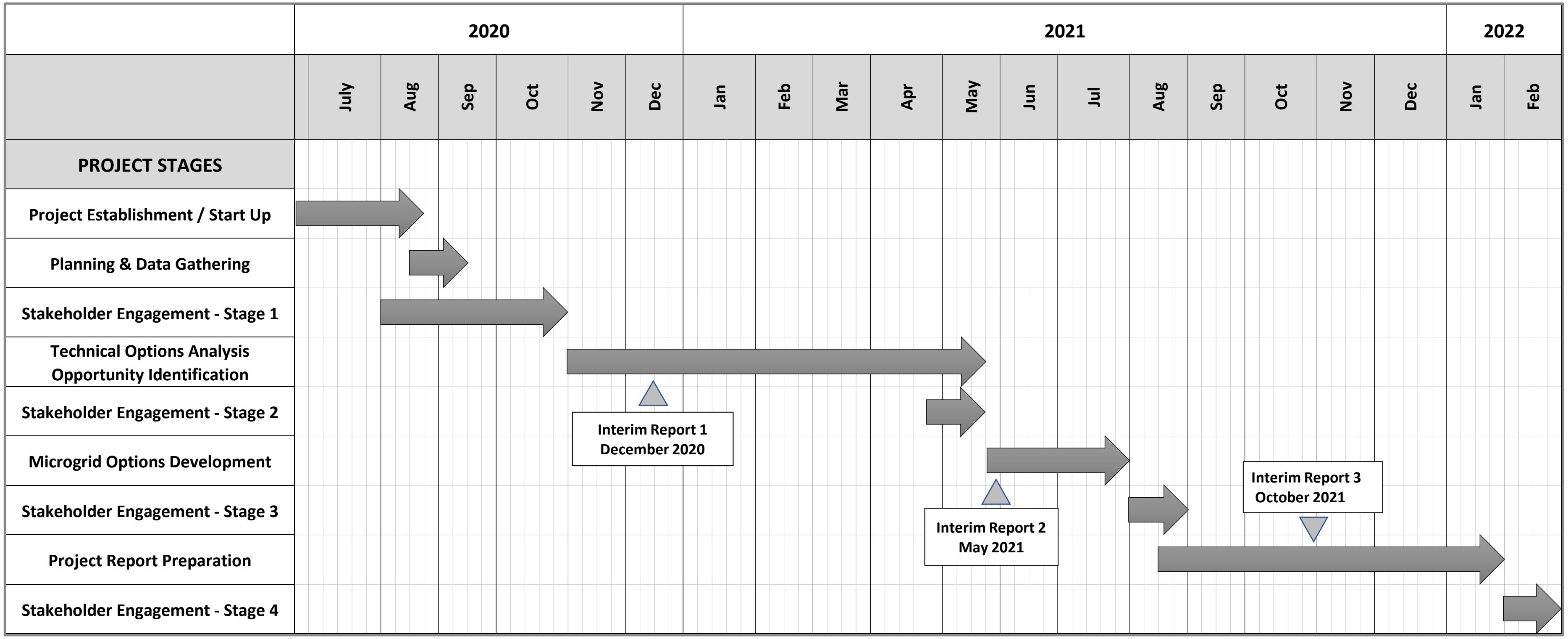

Figure 3 Yarrabah Microgrid Feasibility Study project stages and timeline

2.1.2 Planning & 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, and electricity network data from Energy Queensland.

Key stakeholders were briefed on the scope of the project, the project team, project objectives and the delivery plan.

An important and interesting component of this period was a Cultural Heritage Induction provided to project team members by Yarrabah Elder Darryl Murgha prior to site visits by all team members to ensure an understanding of the cultural context of the project, the community and technological considerations within the climatic and geographic location of the Yarrabah community.

2.1.3 Stakeholder Engagement Phase 1

This phase 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.

Key stakeholders consulted during this period included:

- Yarrabah Aboriginal Shire Council,
- Gunggandji Aboriginal Corporation Prescribed Body Corporate,
- Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate,
- Energy Queensland,
- Members of Parliament, and
- Other Queensland Government agencies that supply essential support and infrastructure to the Yarrabah community including
    - Department of Aboriginal and Torres Strait Islander Partnerships
    - Queensland Health
    - Education Queensland
    - Department of Housing and Public Works
    - QBuild

Energy audits of residences, Council offices and commercial buildings also commenced and an initial workshop was convened with community leaders and Council representatives to identify community needs and expectations and to receive preliminary input to the project.

2.1.4 Technical Options Analysis and Opportunity Identification

The broad range of data collected during earlier phases of the project were assessed and modelled using the min-E version of openCEM modelling tool[3] to provide preliminary assessments of alternative renewable generation to meet 100% of Yarrabah's current and future energy requirements.

The data assessed included:

- Electricity distribution network configuration and operating regimes,
- Energy consumption, load profiles, and existing renewable energy capacity,
- Local site information, geography and community development masterplans,
- Weather patterns and an assessment of renewable energy generation sources,
- Future energy demand including e-mobility considerations, and
- Building configuration and orientation (for rooftop solar PV).

A preliminary review of energy efficiency initiatives was undertaken, and behind-the-meter opportunities identified, based on current residential and community / commercial requirements using energy audit results, observations and community feedback.

An assessment of current solar energy usage and daily generation profiles was undertaken based on the small number of solar PV systems currently installed predominantly on Council buildings at Yarrabah.

A preliminary assessment of all potential options was undertaken, and shortlisted options were identified for optimisation analysis.

A preliminary risk assessment was completed including consideration of local constraints and barriers. This included land availability and conflicting demands (such as requirements for residential development), weather and seasonal impacts assessment, and cultural requirements.

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[3] openCEM is a free, open-source model of the national electricity market (NEM) which can be used to model an unlimited number of scenarios about how the NEM should develop (see http://www.opencem.org.au/). The min-E model is a generation and storage simulation tool for a grid-connected electricity network which computes the optimal combination of embedded generation technology options and energy storage to satisfy a given electricity load profile over a multi-year period at the least cost.

2.1.5 Stakeholder Engagement Phase 2

This phase of stakeholder engagement focused on validating outcomes of the initial technical options analysis, including:

- Options analysis review and community forum including two-way exchange of ideas to ensure community-appropriate infrastructure (generation types, location, ownership, operation, and maintenance regimes),
- Identifying potential conflicts and synergies for future infrastructure and development needs, and
- Promoting community project ownership and engagement.

The key stakeholders consulted in Phase 2 were similar to those from Phase 1, with a focus on entities with potential future implementation responsibilities.

2.1.6 Microgrid Options Development

The shortlisted options were assessed using min-E Open CEM to identify the most technically and financially viable DER options for Yarrabah.

Network modelling studies were also undertaken to confirm that the generation plant would not adversely affect network voltage profiles.

This phase involved financial evaluation and development of business cases, and the identification of project implementation, management and governance issues and risks including regulatory factors, planning approval requirements, licences and property tenure requirements. It also involved the review and assessment of economic, environmental and social impacts and indicators.

2.1.7 Stakeholder Engagement Phase 3

This phase of stakeholder engagement commenced in August 2021 but was extended through to December 2021, well beyond the initial one-month period, reflecting the dynamic nature of project activity associated with finalising all elements of the proposed microgrid and associated activities that would benefit the Yarrabah community whilst working in a Covid-safe manner.

The outcomes of the optimisation analysis, financial and economic analysis, ownership and operating models were presented to key stakeholder groups throughout this period.

The project team also commenced investigations and consultation to identify potential funding partners and government grant opportunities for project implementation.

The stakeholder engagement activity culminated in a delegation from the project team, all Yarrabah councillors and the Yarrabah Council CEO, travelling to Brisbane to provide a presentation to Queensland Government Ministers, Members of Parliament, and Senior Department representatives at Parliament House.

The key feasibility study findings and recommendations were presented, and it was agreed to establish a Working Group to progress the potential implementation of the microgrid upon completion of the feasibility study.

The Working Group is chaired by Speaker of the House and Member for Mulgrave (Honourable Curtis Pitt) and Minister for Tourism, Innovation and Sport and Minister Assisting the Premier on Olympics and Paralympics, Sport and Engagement and Queensland Government champion for Yarrabah (Honourable Stirling Hinchcliffe) with membership from other key government departments including the Department of Energy and Public Works, and the Department of Aboriginal and Torres Strait Islander Partnerships.

The Mayor and CEO of Yarrabah Aboriginal Shire Council are also members of the Working Group.

The first meeting of the Working Group was convened on 15th December 2021 to review project outcomes and approve the Working Group Terms of Reference.

2.1.8 Project Report Preparation

Given the scope of the project it was anticipated that a significant amount of time (more than 6 months) would be required to finalise feasibility study outcomes and recommendations, collate reporting resources, and for drafting and reviewing the final report.

All project partners were allocated responsibility for preparing various chapters of the report and a review process was implemented to coordinate compilation of the report and review of draft versions.

Report-drafting activity was accelerated towards the end of 2021 with a first draft version of the report available for internal review by end of December 2021.

The final report was expected to be delivered on time by the due date of 28th February 2022 and to enable a briefing of final feasibility study outcomes to be presented to the Queensland Government Working Party meeting in February 2022.

2.1.9 Stakeholder Engagement Phase 4

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

The Queensland Government Working Group received a formal briefing on the Feasibility Study Report and is the key entity likely to be working with Yarrabah Aboriginal Shire Council and other key stakeholders including Energy Queensland, to progress implementation of the project, on behalf of the Yarrabah Community.

2.2 Risk Assessments and Management Plans

As part of project planning, a comprehensive Risk Register, compliant to ISO 9001 Quality Standards, was developed and maintained to identify and manage risks associated with the Yarrabah Microgrid Feasibility Study.

The Risk Register identified:

- Inherent Risks
- Areas of impact without controls
- Agreed controls and the resultant risk
- An evaluation of the effectiveness of those controls over time, and
- Mitigation strategies to be implemented should those controls be found to be ineffective.

This was a 'living' document, that was updated as different risks were identified or controlled as the project progressed. It saw the addition of a Risk and Management strategy for the COVID 19 virus, including requirements for isolation from site, use of sanitiser and masks and sign in requirements at each location visited.

Risks associated with impacts from the EnergyConnect team being unable to visit the site, or even Queensland were also addressed, and communication and evaluation strategies were amended to continue appropriate engagement and information sharing in a timely fashion.

Throughout the project the Risk Management Plan was able to ensure that the team met key timeframes for milestone delivery set at the commencement of the project.

The EnergyConnect team are satisfied that they identified and mitigated all the significant risks, over which they had control during this project.

3

Yarrabah Profile

3 Yarrabah Profile

3.1 Location

Yarrabah Aboriginal Shire Council (YASC) is 15,609 hectares situated approximately 11 kilometres east of the Cairns City Centre, separated by the Murray Prior Range and Trinity Inlet. Travel distance by road is approximately 52 kilometres from the Cairns CBD to the township of Yarrabah at Mission Bay, where most of the population is settled (Figure 4 and Figure 5).

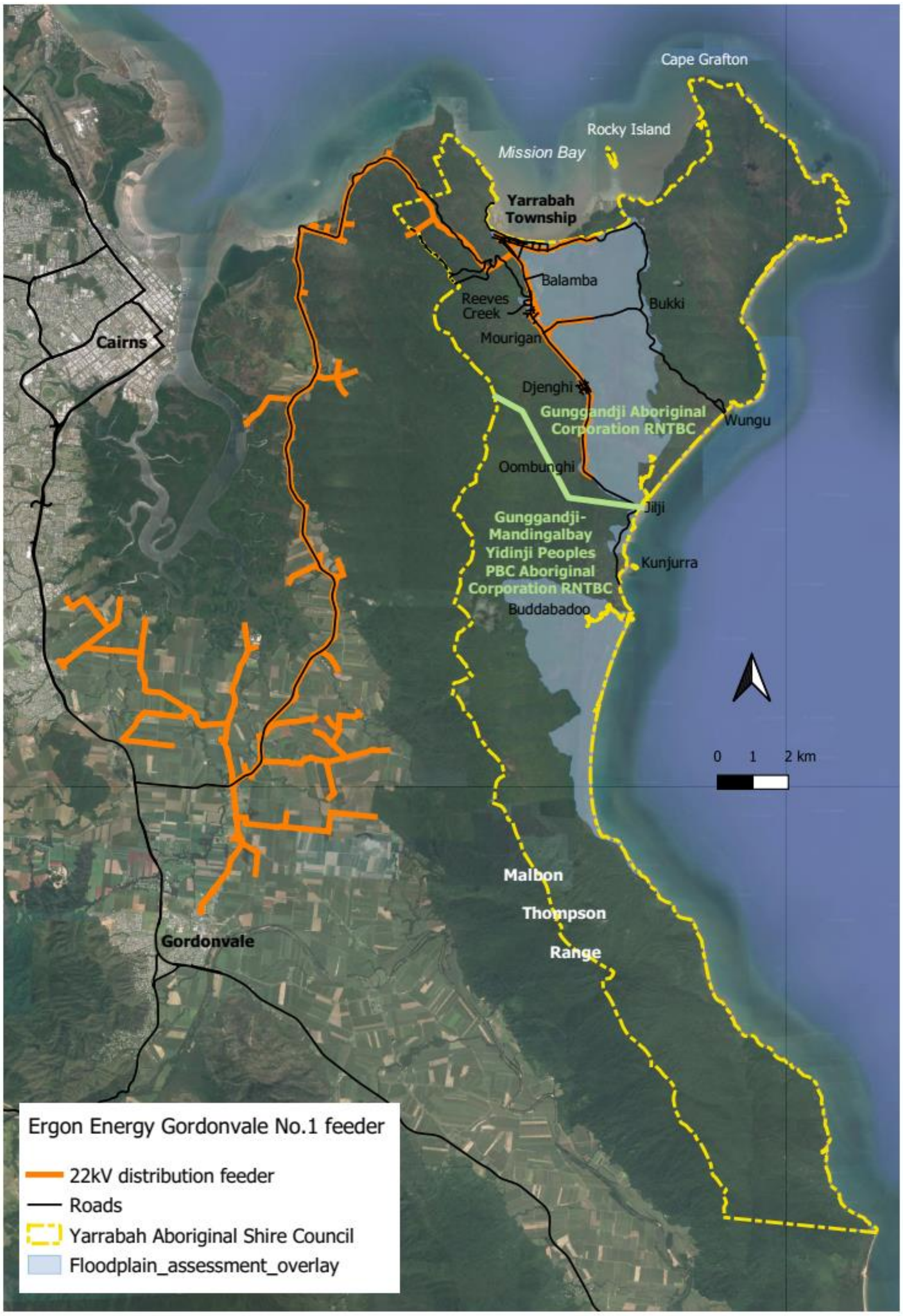

Figure 4 Map showing Yarrabah Aboriginal Shire boundary and location of township

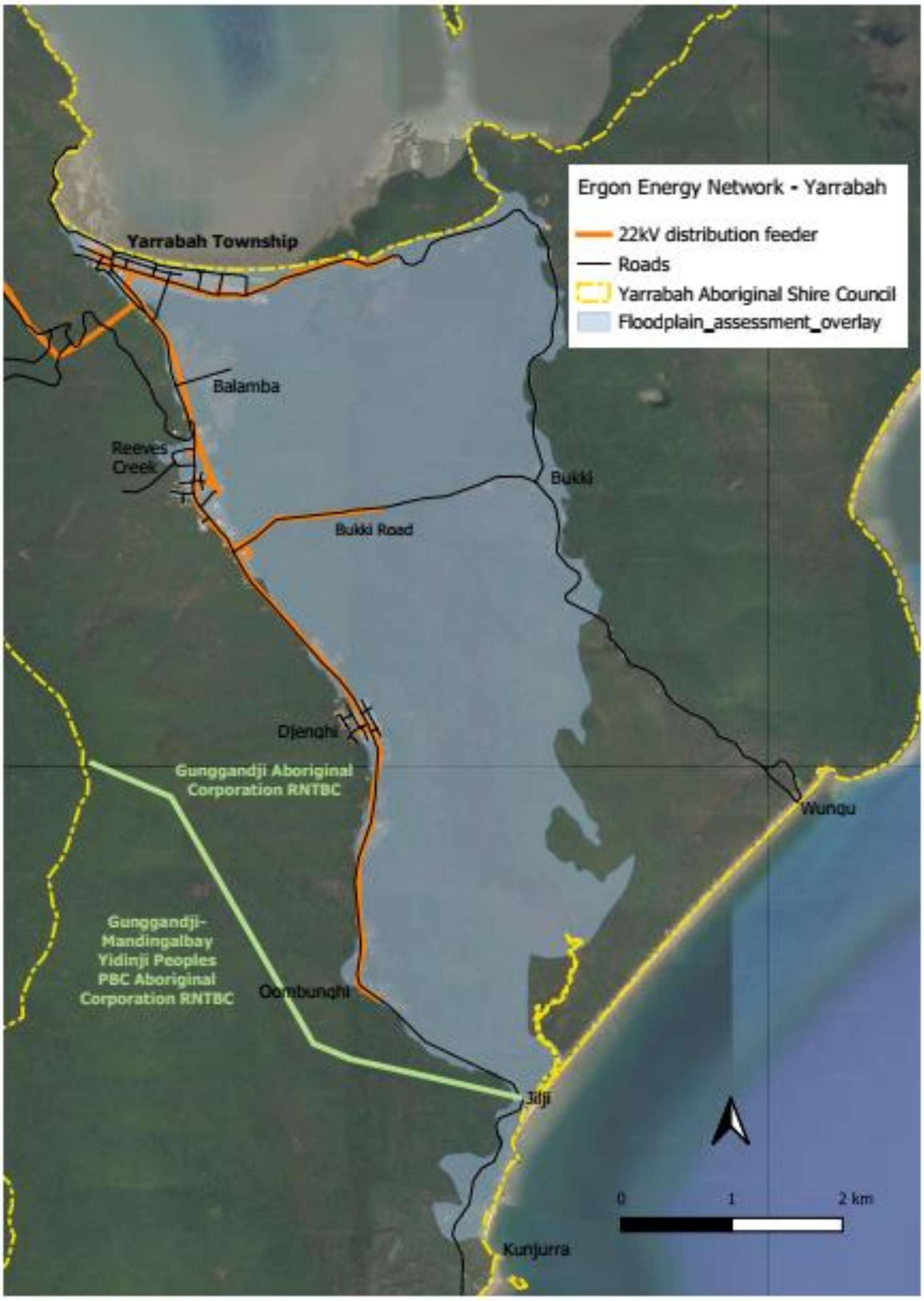

Figure 5 Inset of map from Figure 4 showing floodplains

Tenure and natural constraints mean that there is a very limited amount of developable land in Yarrabah. Significantly the mountains and the low-lying areas in Yarrabah limit the developable area of Yarrabah to just 2% (312 ha). Much of the developed land is within the Council Deed of Grant in Trust area, however new development will primarily be in areas that form part of the Gunggandji Prescribed Body Corporate Aboriginal Corporation RNTBC (for land in the northern part of the shire) and the Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate Aboriginal Corporation RNTBC (for land in the southern part of the shire) (refer to section 3.2 on Tenure).

Within Yarrabah, the arterial Back Beach Road connects the Yarrabah township at Mission Bay to Oombunghi Beach, Buddabadoo and Grey Peaks National Park. Several smaller settled areas are located along Back Beach Road between the two coastlines, including Reeves Creek, Mourigan, Djenghi, Oombunghi and Djilji. There are also a number of smaller housing settlements spread throughout the shire such as Bukki, Wungu, Judil, Woikinu, Kunjurra and Buddabadoo.

3.1.1 Context – World Heritage and Natural Environment

The community is located between two World Heritage listed areas: the forests of the Wet Tropics along the ranges to the west and the Great Barrier Reef Marine Park to the north and east. Yarrabah contains a great diversity of environments including the forested slopes of the Murray Prior Range, grassy coastal plains, freshwater wetlands, beaches, mangroves, salt pans and rocky headlands.

3.1.2 Climate

Yarrabah has an average daily temperature range of 19.7°C to 27.0°C, an average maximum temperature during the wet season of 30°C[4], an average of between 23 and 26 rainy days in the 'wet' season and an average annual rainfall of 3,289 mm. Yarrabah is vulnerable to tropical cyclones and heavy rains between October and April each year. Flooding caused by runoff from the bounding ranges and flash flooding of inland waterways also affect the community throughout the year.

3.1.3 A Linear Community

Due to the topography, the single point of access into Yarrabah for both electricity and vehicles, is along Pine Creek-Yarrabah Road, which is a narrow road, one lane each way that winds through the rainforest and hills of the Yarrabah Range. Yarrabah is a linear community stretching for 13 km along Backbeach Road (one lane each way). The town centre at the northern end of the Shire, provides many services including Government Offices, Store, Child Care, Primary School, Health Care and Pharmacy. However other essential services including Police, Hospital, Rehabilitation Centre, Aged Care, High School, Pool, Art Centre, and Sporting Fields are spread along Backbeach Road. All new housing is also being provided towards the southern end of Backbeach Road.

The linear nature of the Shire and the linear provision of services also means that all residents are required to travel to one or more services. There is no public transport in Yarrabah. The difficulty in physically accessing services is compounded by limited (no NBN) internet and mobile phone coverage. The unreliable electricity supply and poor transport builds layers of disadvantage to residents.

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[4] https://www.worldweatheronline.com/yarrabah-aboriginal-community-weather-averages/queensland/au.aspx

Power outages in Yarrabah can be attributed to a range of issues such as maintenance along the single line, or damage from falling vegetation. In the event of a power outage, the community is vulnerable. If there is no power, for example:

- Centrelink does not open. Centrelink payments are made weekly and recipients are required to report directly to the Centrelink to confirm payment. The 62%+ unemployed population of Yarrabah cannot access their welfare payment which has flow on implications for purchase of medicines, food, and payment of electricity bills.
- Cooking is difficult and being inside in the humid and often still air (or blowing sideways rain) and contributes to living conditions that are well below national standards.
- Schools do not open, and once children have missed a day of school, it can be very difficult to get them to return for the rest of the week. Teachers and school administration staff are then diverted to managing truancy rather than teaching.

3.2 Tenure

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

Land within the Yarrabah Aboriginal Shire comprises freehold (including land held under Deed Of Grant In Trust (DOGIT)) and non-freehold (reserve) land. 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.

3.2.1 Deed of Grant in Trust

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.

In accordance with the *Aboriginal Land Regulation 2011*, approval to issue leases must be made in accordance with Aboriginal tradition and residential leases require Ministerial consent. Furthermore, there are also two determined native title claims over the Yarrabah region. The area covered by these determinations includes the Yarrabah DOGIT and surrounding land.

The presence of both Native Title determinations and DOGIT land tenures over land in Yarrabah provide some challenges. The traditional owners have a recognised common law right to their traditional lands, and 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.

In accordance with the *Native Title Act 1993*, all developments in Yarrabah are future acts and traditional owners must be consulted.

3.2.2 Traditional Owners and Indigenous Land Use Agreements

Land outside the DOGIT area is held by the Gunggandji Prescribed Body Corporate Aboriginal Corporation RNTBC (for land in the northern part of the shire) and the Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate Aboriginal Corporation RNTBC (for land in the southern part of the shire). These agencies act as trustees to hold the land in trust for the benefit of the Aboriginal people, particularly as concerned with the land and their ancestors and descendants, and under the *Aboriginal Land Act 1991*.

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. There are a number of ILUAs that apply to Yarrabah each having varying planning significance.

3.3 Population

3.3.1 Estimated resident population

There is often disparity between recorded population and the actual population of indigenous communities. Yarrabah has a recorded population of 2,559 as at the 2016 Census[5].

In 2017 YASC undertook its own count of population and estimated the resident population (ERP) to be 4,000 persons[6]. As of 30 June 2018, the Australian Bureau of Statistics (ABS) identified the ERP Yarrabah (S) LGA was 2,848 persons with an average annual growth rate of 1.2% over five years and ten years. The ABS ERP figure is the official population estimate[7]. The Queensland Government Statistician Office (QGSO)[8] estimated the resident population to be 2,901 persons as at June 2019.

To enable comparison of the estimated population, the QGSO medium series population projection of 1.1% annual population growth has been applied to the 2016 Census recorded

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[5] Australian Bureau of Statistics, *2016 Census of Population and Housing, General Community Profile, Catalogue number 2001.0.*

[6] Economic Associates, *Yarrabah Retail and Community Needs Assessment*, 2017

[7] For sub-state geographies, ERP figures are updated annually using a model which includes administrative data that indicate population change, such as registered births and deaths, dwelling approvals, Medicare enrolments and electoral enrolments

[8] Queensland Government Statistician's Office, Queensland Treasury, *Queensland Regional Profiles: Resident Profile for Yarrabah (S) Local Government Area,* 2020

population, the QGSO 2020 estimated resident population and the population estimate provided by Yarrabah Aboriginal Shire Council in 2017 as shown in Table 1. This identifies a significant disparity between recorded and reported population numbers that will have an impact on household size and composition.

Source	2016	2021	2026	2031	2036	2041	2046
Census	2,559	2,703	2,855	3,015	3,185	3,364	3,553
QGSO	NA	2,965	3,132	3,308	3,494	3,691	3,898
Yarrabah Aboriginal Shire Council	NA	4,179	4,414	4,662	4,924	5,201	5,493

Source: Compiled by EnergyConnect from identified sources

Table 1 Comparison of estimated resident population over 25 years

Notwithstanding the discrepancy between the recorded and reported population of Yarrabah, the age profile of the recorded population is considerably different to that of the Cairns local government area and Queensland.

The age profile identifies that Yarrabah has a significantly greater percentage of population aged 0-24 and lower population of aged 45+ when compared to both Cairns and Queensland, as shown in Table 2. This is reflected in the median age for Yarrabah being 22.8 years compared to 37.7 and 37.4 for Cairns and Queensland respectively[9].

This indicates a community of young families with children and is indicative of poor health outcomes for the aging population.

Age Group										
	0-14		15-24		25-44		45-64		65+	
	Number	%	Number	%	Number	%	Number	%	Number	%
Yarrabah	982	33.9	567	19.5	738	25.3	492	17	125	4.3
Cairns	33,824	20.3	20,232	12.1	46,217	27.7	43,899	26.6	22,700	13.6
Queensland	989,819	19.4	661,901	13	1,389,355	27.3	1,253,511	24	799,924	15.7

Source: ABS 3235.0, Population by Age and Sex, Regions of Australia

Table 2 Estimated resident population by age, Yarrabah LGA, Cairns LGA and Queensland, 30 June 2019

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

The family composition of the Yarrabah community presents a substantial difference when compared to Queensland for families with no children and one-parent families as shown in Table 3.

The 2016 Census indicates a near equal population of females and males[10] with over 97% of the population identifying as Aboriginal and/or Torres Strait Islander[11].

Family composition							
	Couple family no children		Couple family with children		One-parent family		Total
	Number	%	Number	%	Number	%	Number
Yarrabah	47	8.4	223	40.0	254	45.5	588
Queensland	481,451	39.4	518,494	42.5	201,3080	16.5	1,221,148

Source: ABS, Census of Population and Housing, 2016, General Community Profile - G25

Table 3 Family composition Yarrabah and Queensland, 2016

3.4 Income and Employment

The median total personal income was $288 per week, there were 162 low-income families (29%) and the median total family income was $869 per week or $45,188 per year.

The poverty line in Australia is $968.41 per week or $50,357 per year for a household with 2 adults not working and 2 children[12]. Many households in Yarrabah are below the poverty line. In 2016 Yarrabah had a Socio-Economic Indexes for Areas (SEIFA) score of 518 compared to Cairns (980) and Brisbane (1048).

As at the March 2021 quarter, there were 830 people receiving government payments:

- 102 recipients of the Age pension
- 124 recipients of the Disability support pension
- 604 recipients of Job Seeker payment[13].

The unemployment rate in Yarrabah is reported as being 62.3% compared to 6.1% for Queensland as at the March 2020 quarter [14].

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[10] ABS 3235.0, Population by Age and Sex, Regions of Australia

[11] ABS, 2002.0, 2016 Census of Population and Housing, Aboriginal and Torres Strait Islander Peoples Profile

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

[13] Australian Government, DSS Demographics – March 2021

[14] Queensland Government Statistician's Office, Queensland Treasury, *Queensland Regional Profiles: Resident Profile for Yarrabah (S) Local Government Area*

As per the 2016 Census, most of the employed people in Yarrabah (343 people) worked in the service industry: public administration and safety (92 people), health care and social assistance (79 people), education and training (68 people), and other services (44 people).

There were 13 businesses registered as of 30 June 2019, with three businesses (or 23.1%) non-employing, five businesses (or 38.5%) employed 1 to 4 employees and three businesses (or 23.1%) employing 5-19 employees. These businesses were equally spread across construction, retail trade, rental, hiring and real estate services and health care and social assistance industry[15].

In a community where 343 people have jobs (2016 Census), there are approx. 350 essential workers per day (i.e., at least 100-200 vehicles per day) that drive to Yarrabah for work. This does not include the 'non-essential' workers who were not permitted to work in Yarrabah during the COVID19 2020 lockdown, as Aboriginal Communities were 'closed' to people leaving or entering the communities other than 'essential workers'.

3.4.1 Home Ownership and Affordability

The housing stock in Yarrabah is approximately 425 houses (including units), of these 383 houses are owned by Council (social houses) and 30-40 houses are privately owned. The housing stock includes a number of dwellings that have been erected without land ownership (tenure) or building approval.

Rent for a Council 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. Housing is income assessed through the State Government's public-community-housing scheme. Many households are overcrowded and have "floating tenants" that are not reported as part of the income.

The energy audits undertaken as part of this project confirms many houses are overcrowded with up to 12 individuals living in 3- or 4-bedroom houses.

There are about 310 families on the housing waiting list. Many of these families are currently living in overcrowded conditions within Yarrabah. It is expected that, as new houses become available, some tenants will move into the new houses, and some will remain in the existing ones. Accordingly, adding new houses to the existing stock does not necessarily correlate to population growth as existing residents are redistributed throughout the community.

Despite the overcrowding, there are larger houses of 3, 4, or 5 bedrooms with only 1 or 2 occupants. These are generally families whose children have moved away and the parents

[15] Queensland Government Statistician's Office, Queensland Treasury, *Queensland Regional Profiles: Resident Profile for Yarrabah (S) Local Government Area*

choose to remain in the house, often because of the network of family and social support that is established with neighbours.

3.5 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 YASC owns and maintains most of the housing stock and there is an ongoing maintenance program. New houses are designed in accordance with the *Design and Construction Standards for Remote Housing*[16] (see also *Social Housing Dwellings Minimum standards for building products, fixtures, fittings and other items typically required in dwellings*[17]).

3.5.1 Mechanical Cooling

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.

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,

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

[17] 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.

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.

3.5.1 Solar PV and Solar Hot Water Systems

Solar PV is not provided on any social housing in Yarrabah.

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 at Yarrabah the booster is used daily to meet hot water demand requirements especially in large, overcrowded, households.

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

There is also limited application of controlled tariff use for water heating at Yarrabah due to the household demand for continuous hot water.

Gas hot water systems are not installed at Yarrabah.

3.6 Energy Affordability

While regulated electricity tariffs provided by Ergon Energy Retail for Yarrabah residents are consistent with tariff charges for other Ergon Energy Retail customers throughout regional Queensland, overcrowded housing, and high levels of unemployment result in increased energy consumption and consequently very high electricity bills for many households in Yarrabah.

The average annual energy consumption for a residence in regional Queensland (Ergon Energy Network supply area) was 5,588 kWh in 2020[18].

A review of energy consumption at six residences at Yarrabah for the 12-month period to September 2020 revealed energy consumption ranging from 4,166kWh to 23,504kWh with an average of 14,959 kWh (2.7 times the regional Queensland average).

The reported number of residents at these households ranged from 5 to 12.

[18] AER Residential Energy Consumption Benchmarks December 2020

At current Ergon Energy Retail tariff charges[19], this equates to a range of $906.52 to $5,114.47 per annum and an average of $3,435.36 per annum.

Consumption modelling undertaken for this Project, confirms that heating and cooling accounts for approximately 40% of the electricity consumption. However, the high unemployment rate in Yarrabah means that people on the lowest incomes have extra heating and cooling costs associated with staying home.

There is anecdotal evidence of difficulty in paying electricity bills, with some monthly bills of up to $1,000 per household viewed during site energy audits.

Some residents have taken up the option of paying their energy account through regular fortnightly payments.

3.7 Economic Development Plans

The aim of Council's Economic Development Strategy[20] is to

- Broaden the structure of the local economy
- Achieve growth for existing businesses
- Support a smart approach to planning
- Recognise the interdependence of the economy, environment, and the Yarrabah community

The Economic Development Strategy identifies two significant factors that challenge the economic growth of Yarrabah:

- **Tenure and Land Availability:** the process for the future release of land is cumbersome, preventing development of much needed homes and premises for business to create jobs and service the community
- **Infrastructure:** the community does not have access to reliable electricity, appropriate buildings for incubation and start-up of businesses, satisfactory internet connectivity and there is a lack of transport choice with no taxis, limited shuttle bus services, no public transport and no e-mobility. Accordingly, there is an inability to support the community, attract business and local delivery of government services, all of which can be a catalyst for local economic activity

The Economic Development Strategy priorities are:

- Build on our strengths and develop further capacity within the community
- Secure land availability for housing and business

[19] Ergon Energy Retail December 2021: Tariff 11 ($0.2176/kWh) and Tariff 33 ($0.15744/kWh)

[20] Yarrabah Economic Development Strategy 2018-2028 https://www.yarrabah.qld.gov.au/wp-content/uploads/2020/12/Yarrabah-Economic-Development-Plan.pdf

- Prioritise enabling infrastructure to support growth
- Support small business to establish and grow
- Pursue tourism industry opportunities & promote local success
- Supporting the creation of local business opportunities
- Communicate and collaborate

The Yarrabah microgrid project is aligned with the Economic Development Strategy and has the potential to provide direct and indirect jobs. The energy security afforded by the project offers new opportunities for economic development and employment.

3.8 Planning and Approvals

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

3.8.1 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 4-8 months and objectors do not have appeal rights in the Planning and Environment Court.

3.8.2 The Planning Scheme and Planning Act

Development of land in Yarrabah 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.

3.8.3 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 YASC 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.

3.8.4 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.

3.9 Summary of Yarrabah Profile

Yarrabah is a vulnerable community, typified by high unemployment levels, overcrowded living conditions, low levels of home ownership, and limited access to services.

The average income of a Yarrabah household is $45,188 per annum which is below the poverty level of $50,357 per annum.

Overcrowding of dwellings results in higher-than-average household electricity bills for residents, generally associated with higher hot water energy usage, inefficient air-conditioners, and limited application of off-peak electricity tariffs. Yarrabah residents perceive that they pay more for their power than other nearby communities like Cairns, however Yarrabah residents have access to the same standard Ergon Energy Retail tariff charges as other regional Queenslanders. Energy usage patterns, low efficiency appliances, and total household consumption are the main drivers of high household energy costs.

Standard house designs currently provide a basic level of accommodation without air-conditioning or rooftop solar PV systems. Whilst many of the newer homes are fitted with solar hot water systems, household hot water demand means that electric boosters are used frequently to provide sufficient hot water. Energy efficient heat pump hot water systems are not currently installed.

Low household income combined with a high level of rental housing means that residents make purchase decisions based on initial up-front costs and portability of appliances, and this tends to result in tenants acquiring less efficient appliances such as plug-in box-type air-conditioners, that are cheaper to purchase, easy to install, but more expensive to run.

Whilst rooftop solar PV systems, energy-efficient air-conditioners and heat-pump hot water systems are commonplace throughout regional Queensland and can contribute to reducing household electricity bills and reduce financial hardship, they are not common at Yarrabah.

A key priority for the Yarrabah Council is to provide sufficient housing for its residents. Yarrabah leaders and residents have a strong connection to their environment and a strong desire to transition to a reliable, locally based, renewable energy future, including the transition to electric mobility services.

They also see the development of a microgrid at Yarrabah as an opportunity for the community to take more accountability for their energy security, creating job opportunities and facilitating other opportunities through education and tourism.

The community has acknowledged that it is currently 20 years behind where it should be and needs both technical and financial support to implement modern technology-based solutions to become more resilient.

4

Stakeholders and Community Engagement

4 Stakeholders and Community Engagement

Ineffective consultation and engagement with communities is a key contributor to social conflict around developments in Australia. The sense of acceptance and ownership of a local energy generation project can differ according to both the scale but, perhaps more importantly, the depth and involvement in the consultation and engagement process afforded to the impacted community.

A CSIRO study in Australia in 2012 found that community engagement and involvement are key factors to successful project delivery and achieving a broad "social licence to operate". Seeking a social licence to operate means asking the community to accept changes in their local area because they understand the importance of the project and can see the benefits for the community.

EnergyConnect's goal was to work closely with the Yarrabah community, its leaders, Energy Queensland, government department representatives, and a range of other important stakeholders to earn and maintain its social license to operate, and to deliver a project feasibility report that met community expectations and would receive broad support for project implementation (see Figure 6).

Figure 6 EnergyConnect discussions with members of YASC

4.1 Community 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 Community Engagement Strategy, to scope expectations and match potential microgrid solutions to community preferences. The

Community Engagement Strategy was developed to effectively coordinate communication, consultation, and engagement with the Yarrabah community, its leaders and all other stakeholders. The strategy was developed in line with best practice principles 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

The Communication Plan documented in the Strategy provided the framework for all subsequent project communication, building on established relationships with key stakeholders. Based on this strategy, communication, consultation, and engagement has evolved throughout the course of the project to form a strong platform for future project implementation activities upon completion of the feasibility study.

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.

4.1.1 Stakeholders and supporters

EnergyConnect identified three core stakeholder groups that would be influential or have an interest in the development of the feasibility study.

The primary stakeholder group with the highest level of influence and interest in the project included:

- Yarrabah Aboriginal Shire Council
- Gunggandji PBC Aboriginal Corporation RNTBC and Gunggandji-Mandingalbay Yidinji Peoples PBC Aboriginal Corporation RNTBC
- Traditional Owners – Gunggandji people

- Energy Queensland (Ergon Energy Network and Ergon Energy Retail)
- Federal Government Department of Industry, Science, Energy and Resources

The secondary stakeholder group included:

- Elected State and Federal Members of Parliament
- Other Local Government Councils
- Far North Queensland Regional Organisation of Councils (FNQROC)
- MSF Sugar
- State and Federal Government Departments
- Local businesses and community representative bodies
- Media

Figure 7 shows a project briefing session by EnergyConnect in October 2021.

The third group of stakeholders identified as an interest group for the project included:

- Yarrabah residents
- Universities and educational institutions
- Other Utilities
- Transport and Tourism Industry groups

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

Targeted communication strategies were developed for each of the stakeholder groups, and for 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 undertaken is summarised in Table 4.

Total No. of engagement sessions	**130**
Total duration of engagement sessions (hrs)	165
Total no. of stakeholders consulted	548

Table 4 Composition of engagement activities

Figure 7 EnergyConnect project briefing to Queensland Ministers, October 2021

4.1.2 Relationships with the community

Before commencing any significant site investigation work for this project, EnergyConnect team members participated in cultural awareness training delivered by Yarrabah Traditional Owner Darryl Murgha, to ensure that culturally appropriate protocols were followed whilst engaging with locals (see Figure 8).

This included being respectful of "sorry days" (periods of mourning following a death in the community) and ensuring that meetings and presentations were not undertaken at those times, and being aware of the risks that the COVID-19 pandemic presented to Yarrabah residents and following the appropriate protocols and observing periods of community lock-down.

Communication protocols were also developed, which identified the appropriate or designated representatives of the Prescribed Body Corporates and Traditional Owners responsible for speaking on behalf of the Yarrabah Trustee Areas. These were respected throughout the feasibility project.

Through its community and stakeholder engagement program, EnergyConnect was able to form a comprehensive understanding of community context and social framework, as well as 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.

Figure 8 EnergyConnect team receiving cultural awareness training from Darryl Murgha

Regular site visits (aimed for fortnightly, at minimum) 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.

4.1.3 Major Community Activities

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

- Presentations to Yarrabah Council meetings
- Meetings with the Prescribed Body Corporate representatives (see Figure 9)
- Presentations and workshops with Yarrabah leaders
- Pop-up community information stalls in public areas
- A community e-mobility “come and try” demonstration day (May 2021)
- Direct engagement with residents through household energy audits and education programs
- One-on-one meetings with stakeholders
- Participation in the Energy Queensland and Indigenous Consumer Assistance Network ‘Bring your Bill’ and ‘Yarrabah Yarnin’ Energy Day (September 2021)

A range of media were developed and used to support the community engagement activities including:

- Project Update Newsletters
- Yarrabah Council community dashboard messages and updates
- EnergyConnect website https://energy-connect.net.au/
- EnergyConnect YouTube videos[21] to explain concepts and provide regional and cultural context to the project and provide educational information to local students
- Power Point Presentations developed for specific audiences and briefings
- Media releases and interviews

Figure 9 Beachside meeting with Southern PBC in 2020

A record of major communications activity was maintained in the Community Engagement Communications Register, a shared document, updated by all EnergyConnect team members on completion of engagement activities.

At each Engagement Activity an accurate record was made of attendees, the purpose of the meeting, duration, and venue. Records were also kept of the key points raised, and actions required to address concerns in a timely manner. Within the project team, actions were assigned to a responsible officer and targeted resolution date was set. Progress on status of actions was reviewed at fortnightly team meetings. A Stakeholder Register, maintained throughout the process, recording each of the details above.

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

4.1.4 Stakeholder Engagement Learnings - Yarrabah

During the delivery of the Yarrabah Feasibility Study the team was able to assess the effectiveness of its stakeholder engagement strategy, noting potential improvement opportunities for application in future projects.

A formal survey (via Survey Monkey) was developed and circulated to the community to assess the initial level of understanding of "what is a microgrid?". This survey received no responses and was therefore of no value to the project. The contributing factors could include limited access to required devices such as computers or tablets with internet access and access issues caused by intermittent mobile phone coverage. It may also be attributed to unfamiliarity with the technology / survey tool, or the level of general knowledge and understanding of the project within the community at that time.

A major community leader workshop scheduled for November 2020 had poor attendance despite personal invitations and confirmations of intended attendance beforehand. The purpose of this workshop was to engage with representatives of PBCs, Council, and infrastructure and service providers in Yarrabah. It was considered unsuccessful because few of the Traditional Owners attended and several senior Council representatives were unavailable due to other urgent matters.

Requests to provide formal presentations to PBC Board meetings were often unsuccessful due to several reasons including that the PBCs had more pressing matters of community health during COVID 19 to deal with, and organisational matters associated with the Boards administrative functions.

Key lessons learnt were that:

- Formal surveys are not an effective form of engagement in this community. Face-to-face communication in small groups or one-on-one was more effective.
- It is difficult to get large numbers of the community representing multiple agencies to attend 'formal' workshops and meetings, likely due to their involvement in many aspects of community life and the resulting competing demands for their time, especially in response to 'emergencies'.
- The use of briefing papers and formal written communications would ensure that key messages are delivered to entities such as PBCs and Council that generally have full agenda for their scheduled meetings, and these can be supplemented with face-to-face presentations when appropriate.

Other strategies did allow the EnergyConnect team to get formal input from the YASC, the community and the PBCs on their desires and expectations regarding the microgrid. Successful strategies included engaging directly through the Yarrabah Community Leaders Forum meetings and YASC meetings. It was also learnt that successful engagement had activities that were ‘fun’ and ‘hands on’, involved all ages in the community and included social elements such as a BBQ.

Informal attitudes were captured during the ‘pop up’ information sessions held during October and November 2020, outside Yarricino, the local coffee shop. Discussions were held with approximately 25 passers-by which were valuable in capturing community attitudes. Generally, the community was in favour of initiatives that would save them money and make energy supply more reliable. Detailed feedback was captured in the Communications Register.

Informal assessment continued to be conducted during 2021, towards the end of the project, to assess attitudes towards, and understanding of, microgrids and the community’s readiness to implement the recommendations of the feasibility study. Of particular note is the significant level of project support from the Yarrabah Aboriginal Shire Councillors and the Yarrabah Leadership Group, illustrated by the fact that the whole Council attended and led briefings in Parliament House, Brisbane to the Queensland Government Minister for Energy and Public Works the Honourable Mick de Brenni; Minister for Tourism, Industry Development and Innovation, Honourable Stirling Hinchcliffe; Speaker of the House and local Member, Honourable Curtis Pitt and their senior advisors, and representatives of key infrastructure agencies: Department of Energy and Public Works and Energy Queensland, on 20th October 2021.

A high level of community interest was generated via an e-mobility demonstration day at which a range of renewable energy powered transport methods were showcased, and community members were encouraged to try them out. This included an e-bus supplied by the CAPTA group (Cairns), which transported community members around the township and a number of e-bikes and e-scooters supplied by Urban Wheelz that allowed community members to ride. Dr Jake Whitehead, e-mobility expert (UQ Research Fellow - School of Civil Engineering Advance Queensland Industry Research Fellow - School of Chemical Engineering) provided a general overview and conducted a question-and-answer session at which many community members of all ages participated.

4.2 Community Attitudes – Current State Assessment

An initial series of workshops were undertaken with Yarrabah leaders and key stakeholders in November 2020 to inform the project team of current state conditions and community aspirations that may influence the direction of the microgrid feasibility study.

Four key themes were explored including:

- Current state – energy challenges for Yarrabah community
- Development plans and future growth at Yarrabah
- Sustainability and environmental factors, and
- Potential impacts of electric transportation

The key outcomes from the workshop participants are as follows:

- Lack of access to affordable power
- Lack of infrastructure
- Social impacts of lack of ready access to power means moving back to town into crowded houses
- Police lose important communications in a black/brown out
- Lack of timely information about outages
- Cascading effects of a black/brown out:
- Social and economic costs
- Health service provision impacts
- One day off school leads to flow-on effect of poor attendance
- Future of microgrid is tied to social opportunity
- Ergon Energy to supply generators to cover power outages and reduce impact
- Aspiration of southern PBC:
    - Reduce cost of electricity
    - Small things for big savings
- Perceptions of accessibility and education of community:
    - 20 years behind where they should be
    - Technology and services in this community are limited
- Need skills and access to local electrical trades people – would like this but need a tradesperson and cannot afford one:
    - Opportunity for the microgrid project to provide training for community members and potential employment on microgrid and other electrical jobs.
- Increase sustainability and reliability
- Council has limited resources and have objectives so report should align with community objectives and aid in seeking funding to meet initial high capital costs
- Want tourism but need infrastructure to attract visitors
- Upgrade housing stock – more and with better insulated roofs – but need funding
- Make plan for electricity future
- Electric fleet opportunity for Council

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

Key themes highlighted by stakeholders during the feedback sessions are summarised in Figure 10.

Figure 10 Themes from stakeholder feedback sessions

4.3 Community Awareness over the Project Lifecycle

During this Feasibility Study project, there has been an increased awareness amongst the community. Primarily this was achieved via the newsletters and updates on the project and the Yarrabah Council website, the ‘pop-up’ site, and the ‘come and try e-mobility day’. Feedback received from the community has generally been positive.

There have been few imposts on the community as a result of the feasibility project. Those individuals and businesses who were part of the energy audits to collate site-specific energy use volunteered to be a part of the program, as part of YASC regular house inspections program, and were rewarded with a coffee voucher at the local café. No negative feedback was received from this or any part of the program.

Improved awareness of the opportunities associated with the installation of a microgrid at Yarrabah was particularly noticeable amongst Council Housing and Infrastructure Team employees, who assisted with the energy audits and site assessments.

These teams significantly enhanced the effectiveness of engagement by introducing energy audit participants and encouraging householders to ask questions of the energy audit team.

The outcome of the community and stakeholder consultation conducted to date has facilitated the sharing of information and raised awareness of the potential benefits of microgrids for the Yarrabah community. It encouraged community feedback with a view to engaging and collaborating with interested or impacted community members and key stakeholders to determine the most appropriate technical solutions and potential siting considerations of the microgrid project. This has been achieved, to a large extent, within the constraints of protecting the community against the COVID-19 epidemic and compliance with community requirements and cultural norms, like respecting ‘sorry days’.

5

Social Impact, Benefits and Considerations

5 Social Impact, Benefits and Considerations

5.1 Introduction

An affordable, reliable, sustainable, and modern energy supply is globally recognised as a necessity for sustainable development; is a key driver towards creating thriving, resilient communities and elevating people from disadvantage[22]. Improving access to modern energy services for fringe of grid and low-socioeconomic groups is essential for achieving good outcomes in the areas of employment, health and well-being, education, clean water and sanitation, and sustainable communities[23].

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 on the economic viability and social outcomes of communities[24].

The cost-effective provision of electricity to remote and regional communities by government has always been subsidised, due to Australia's size and diversity. This has focussed primarily on cost equity subsidies 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 the energy provider, 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 Yarrabah 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 Yarrabah microgrid has been undertaken with extensive consideration of the operating conditions, policy environment, community capacity and governance capabilities and technology options, with the intent that the solution will provide both technical benefits and social benefits. That is, the

[22] 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

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

[24] 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

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

5.1.1 Additional layers of social disadvantage

Yarrabah 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.

Yarrabah 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.

5.1.2 Drivers of residential electricity demand

Drivers of residential electricity demand include[25]:

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

In considering the drivers of residential electricity demand Yarrabah provides a discrete case study of the costs of energy for people living in social housing across Australia. In particular:

- The unemployment rate is 62.3% compared to 6.1% for Queensland as at the March 2020 quarter[26]. 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 (see Figure 11). 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 energy efficient appliances such as air-conditioners or hot water systems.

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[25] 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

[26] Queensland Government Statistician's Office, Queensland Treasury, *Queensland Regional Profiles: Resident Profile for Yarrabah (S) Local Government Area*

Figure 11 Newer housing stock in Yarrabah

5.1.3 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 (e.g. the initial lockdown in Queensland from 26 March 2020 to June 12, 2020, and the work from home directive for Queensland State and Local Government Employees from 4 January 2022 to 6 February 2022). The lockdowns resulted in noticeably reduced energy use across the network however there was an increase in 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 and 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 and all State Governments responded with measures that directly support individuals in being able to afford their energy bills.

5.1.4 The quantification of social benefits of the microgrid

The quantification of the social benefits associated with the Yarrabah microgrid include not only the value of increased reliability, but also the benefits of control over the microgrid as a community resource that would otherwise be relinquished to the electricity provider[27].

The Yarrabah microgrid provides an opportunity to take baseline data for each of the five measures below and provide post implementation data that quantifies the benefit of the microgrid to the community.

[27] 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

This quantification would be for a sample size of approximately 2,901-4,000 people and approximately 425 dwellings (houses and units), including 383 dwellings owned by Council (social houses). Typically social housing is dispersed across suburbs, towns and states, and it is rare to have access to almost an entire community of social housing that can be measured and extrapolated to other situations. The discrete community of social housing makes it easier to identify and measure the social impacts, benefits and considerations for the Yarrabah microgrid and in turn some of these social impacts and benefits can be applied to, for example:

- The wider social housing supply across Australia
- Other Indigenous communities
- Fringe-of grid communities of less than 5,000 people.

The five primary social benefits associated with the Yarrabah 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.

5.2 Household Debt

Overcrowding and high levels of unemployment result in increased energy consumption and consequently very high electricity bills for many households in Yarrabah (an average of $3,435.36 per annum which is 2.7 times the regional Queensland average).

While electricity bills are high, the bill is more likely to be paid than other bills as the consequences of not having electricity outweigh other aspects. Within Yarrabah, the scale and dimensions of accumulated energy bill debt is essentially transferred to rent. Social housing is owned by Council, and it is not practical to evict tenants in a small discrete community. Accordingly, Council carries rent arrears of $1.9 million or approximately $7,200 for each of the 262 tenants currently in arrears.

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.

The microgrid will reduce the amount of energy households purchase from the grid, and can potentially reduce the cost per unit of energy produced. This feasibility study finds that behind-the-meter rooftop solar will reduce the household electricity cost per household and will provide return of approximately $1.7 million per annum to approximately 425 dwellings i.e. as much as $4,000 per dwelling per year.

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[28]. 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 bill by bill basis. This type of economic signal (efficiency values created within a microgrid) are a strong driving force for acceptance and promotion of microgrids.[29]

The Yarrabah microgrid has been designed to consider the local consumer benefit (i.e. end consumer perspective). The microgrid ownership and operation model assumes that the economic benefits of a microgrid will be enjoyed by all residents and business owners.

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

- Change in rent arrears for Council managed social housing.
- Change in household electricity bills.

5.3 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."*[30]

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

Electricity to Yarrabah is provided by the Gordonvale No.1 feeder which supplies 960 distribution customers and consists of 90 km of overhead and 2 km of underground high voltage distribution lines and has a maximum demand of 2MVA[31]. Power to the Yarrabah community may be cut off for a number of reasons including maintenance anywhere along the line; motor vehicle accidents involving power poles; farm vehicles accidently nudging power poles; vegetation on powerlines; natural disasters including cyclones and bushfires.

Due to the topography, the single point of access into Yarrabah for both electricity and vehicles, is along Pine Creek-Yarrabah Road, which is a narrow road that is one lane each

[28] 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.

[29] 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

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

[31] AER Annual Reporting RIN Response 2019-20 Table 3.6.8 Network Feeders

way and winds through the rainforest and hills of the Yarrabah Range. Natural disasters and accidents can often mean that when power does go out, residents also cannot get out, due to obstructions on the road.

During a normal year it is typical for Yarrabah to experience outages lasting for as little as 2-3 hours after an accident involving a power pole; up to 6-8 hours for scheduled maintenance; and power can be interrupted for several days or weeks after a cyclone, as was experienced during cyclone Niran in March 2021 which disrupted power supply to the community for 5 days. Anecdotal evidence is that generators that supplement power for the pumping of water and sewerage and at local health facilities, including the Dialysis Centre run out of fuel in 2 days, and at times it is not possible to get additional fuel supplies due to the road out of Yarrabah being blocked.

Leapfrogging to renewable energy such as microgrids is a cost-effective route to achieving energy security and substantially improved resilience on a day-to-day basis as well as in response to natural disasters.[32]

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

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

5.4 Employment Opportunities

A range of potential employment opportunities from the implementation of the Yarrabah microgrid, e-mobility strategy and establishment of the Yarrabah Energy Knowledge Hub have been identified and discussed in section 14 of this report. These include employment associated with construction, operation, and maintenance of the microgrid:

- 17 Full Time Equivalent (FTE) jobs (13 direct FTE) during construction
- 3.5 FTE jobs (3.1 direct FTE) during operation

In a community where the unemployment rate is 62.3%, and most jobs are in construction or roadworks and generally targeted to men, 16-20 new jobs, in a new field that is suitable for males and females is a substantial offering. Further employment opportunities are anticipated with the development of the Energy Knowledge Hub associated with the microgrid, which is expected to provide a further 14.6 FTE jobs (12.9 direct FTE).

Furthermore the proposed ownership model facilitates self-determination outcomes for Yarrabah and also provides opportunities for participating on boards and management committees.

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[32] 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

Finally, employment opportunities occur from the simple ability of local businesses to establish and operate locally, through the confidence of reliable service. Yarrabah's employment agency Wugu Nyambil has confirmed that locals struggle to establish a small business due to lack of rental space and frustrations over both the cost and reliability of electricity supply.

The total number and composition the employment opportunities are difficult to accurately predict as they will depend on the deployment specifics and level of implementation of the various elements. A list of potential, direct and indirect employment opportunities have been included Table 5.

Microgrid Strategy Element	Employment Opportunity
Microgrid implementation and operation	Opportunities for a committee to manage the project and its operations
Construction, operation and maintenance	Opportunities for direct employment to undertake microgrid works and maintenance.
Yarrabah Energy Knowledge Hub	Opportunities for employment through staffing of the YEKH either as permanent staff or event and hospitality staff
Energy related skill development	Opportunities for creating career paths through upskilling and training community member in energy related skills including operation and maintenance of microgrid components or energy audits and efficiency
Local cultural and art installation	Opportunities to commission artists for design elements of the YEKH and potential hosting of local artists work for viewing or sale
Installation of e-mobility infrastructure	Opportunities for building/improving infrastructure in Yarrabah to support the use and parking of e-mobility devices Opportunities to managing and running the safety/awareness campaign on micro-mobility devices for local residents
Deployment of a shared micro-mobility scheme	Opportunities in managing and operating the micro-mobility fleet, charging and maintaining the fleet, and redistributing devices around the community each day to meet local demand
Development of a zero-carbon emission ferry	Opportunities to support the research, development and construction of the ferry Opportunities to support the operation and maintenance of the ferry after deployment
Deployment of electric shuttle buses	Opportunities to support the operation and maintenance of the electric shuttle buses after deployment
Local business stimulation	Opportunities for local businesses to increase their service provision and in turn their number of employees
Collaboration with MSF Sugar	Opportunities to increase job opportunities with MSF Sugar through increased collaboration on e-mobility and energy generation, as well as increased connectivity through the deployment of e-mobility vehicles
Tourism	Opportunities to increase business operations through tourism opportunities delivered as a result of edu-tourism, increased connectivity, and local charging infrastructure to support EV tourism

Table 5 Employment opportunities from the Yarrabah Energy Knowledge Hub and microgrid implementation

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.

5.5 Health

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

Power outages affect the local Gurriny Yealamucka Primary Health Care Service (see Figure 12) which provides a range of services including clinical; child and maternal health; social and emotional; and school attendance strategy services. The Gurriny Yealamucka Primary Health Care Service also serves as the communities Hospital, Emergency Department and the Dialysis Centre where the incidence of kidney disease and hospitalisations for dialysis are 10 times higher in the Indigenous population when compared to the non-Indigenous population[33]. Following the January 2021 cyclone Yarrabah was without power for 5 days, anecdotal evidence is that generators that supplement power at the local health service facilities ran out of fuel in 2 days.

Figure 12 Gurriny Yealamucka Primary Health Care Service

The outages also affect the ability of the Gindaja Treatment & Healing Indigenous Corporation to provide substance abuse rehabilitation services. The 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 for the hospital, staff are required to leave work to pick up students and supervise / care for them during work hours when the school is without power.

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

In addition, current house design and overcrowding has health impacts. Houses not designed 'fit for the tropics' which allow for flow through ventilation, large windows, covered

33 Queensland Health, 2011 StatBite#40 Dialysis prevalence in Queensland adults by Indigenous status: Projected trends to 2026 available from https://www.health.qld.gov.au/__data/assets/pdf_file/0024/361581/statbite40.pdf

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.

Examples of the impacts on power outages:

- Increase in the number of days that health care services are closed.
- Individuals must show up in person to claim unemployment benefits. When there is no power Centrelink is unable to open. The flow-on effects include reduced access to funds for groceries and medicine.
- Cooking in Yarrabah's 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 are self-evident and include 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.

5.6 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 of time. These impacts included parents having to leave work to pick up kids and also noted 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 environment 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.

Examples of the impact of a power outage:

- When the power goes out, schools 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 of time people have to 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 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.

5.7 Environment

At the global level, both technology transfer and capacity building have been included in the Kyoto Protocol[34] and the Paris Agreement[35] 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 compared to for example the closest coal fired power plant which is 1000 km from Yarrabah. There are many examples of a strong 'not in my back yard' response to having a localised power supply. However, in the case of Yarrabah, there is a high level of acceptance of microgrid technology due to the extent of engagement during the feasibility study and the opportunities for ownership, employment and household savings. The community has an understanding of the potential social and economic benefits which is reflected in their acceptance of green infrastructure.

Environmental benefits of microgrids at the community and household scale include:

- Increased awareness of energy efficiency and climate change.
- The localised ownership model for the microgrid provides the end consumer with motivation for behaviour change around energy savings where other concepts fail to do so.

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

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

- Respect for Country and less environmental damage to land through reduced requirements for energy infrastructure in environmentally sensitive areas including the World Heritage listed Wet Tropics rainforest of the Yarrabah Range.
- Reduced impacts of vegetation management along powerline infrastructure: including less disturbance on a regular basis to maintain line clearances and access tracks; less impacts from uncontrolled or controlled fire; less introductions of feral species like cane toads, cats and feral pigs to Wet Tropics and other vegetation communities; less introduction of weeds and pathogens, particularly phytophthera as a result of regular line maintenance activities or emergency powerline reinstatement activities[36].

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.
- Change in the numbers of days required for vegetation clearing and management by the Land and Sea Ranger program.

5.8 Drivers for Change

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

A reliable and affordable electricity supply removes multiple levels of disadvantage for fringe-of-grid and remote communities like Yarrabah by:

- Relieving cost of living pressures
- 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

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[36] Wet Tropics Management Authority / QESI Code of Practice for Infrastructure Maintenance in the Wet Tropics World Heritage Area.

6

Existing Electricity Supply and Infrastructure

6 Existing Electricity Supply and Infrastructure

6.1 Yarrabah Supply Network

6.1.1 Network 22 kV line

Ergon Energy Network is the DNSP responsible for the electricity network for Yarrabah.

The Yarrabah community is serviced via a single-circuit, 22 kV, overhead spur that tees off the Gordonvale No. 1 feeder (10020799). The Gordonvale 1 feeder is one of three feeders that interconnect the Gordonvale 22 kV switching station and the 132/22 kV Edmonton zone substation (see Figure 13).

The feeder is classified as a *Short Rural* feeder, in line with the Queensland Electricity Distribution Network Code (EDNC) definitions, for the purposes of assessing the applicable Minimum Service Standards and Guaranteed Service Levels as set out in the EDNC.

The spur line also supplies smaller cluster communities, rural residential properties, farms, television, and telecommunication facilities located along the route as it winds its way around the southern and western reaches of Trinity Inlet before crossing the Murray Prior Range and descending into Yarrabah which is located at the very end of the spur.

According to data reported to the Australian Energy Regulator[37] the Gordonvale No.1 feeder (100210799) supplies 960 distribution customers and consists of 90 km of overhead and 2 km of underground high voltage distribution lines and has a maximum demand of 2MVA.

The route of this line is shown highlighted in pink in Figure 13.

The spur has 3 sets of 22 kV Voltage Regulators installed at poles PR.5 (Pine Ck Rd), PR.182.A (Sturt Cove) and PR.226.A (Yarrabah Range).

22 kV Automatic Circuit Reclosers (ACRs) are installed at poles PR.46 (Pine Ck Rd) and PR.183 (Sturt Cove), and 22 kV Sectionalisers are located at poles ST.10, SA.1A, and SA.16A at Yarrabah.

The ACRs and Sectionalisers SA.1A and SA.16A have remote load monitoring capability.

[37] AER Annual Reporting RIN Response 2019-20 Table 3.6.8 Network Feeders.

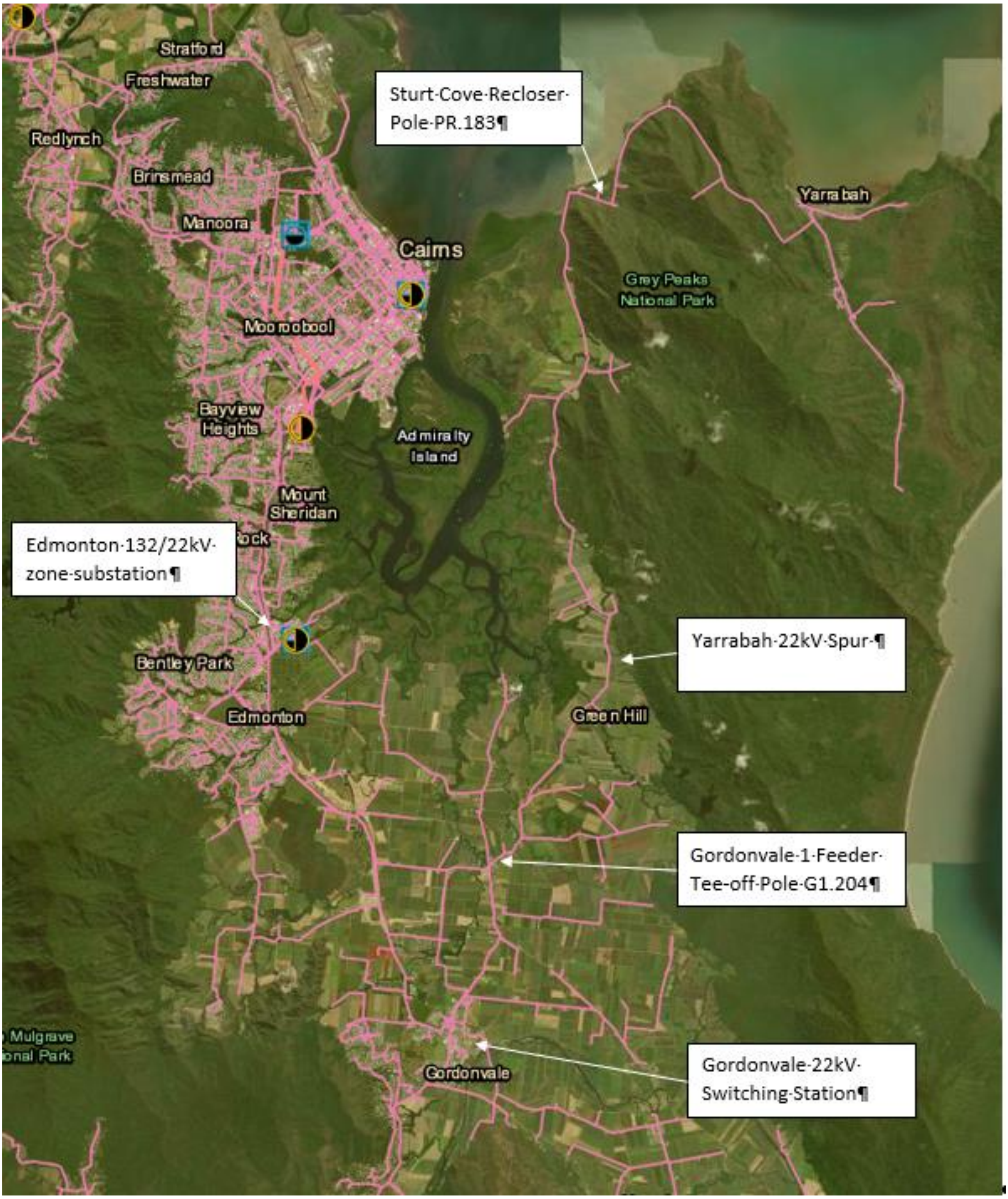

Figure 13 Yarrabah 22 kV spur line route.

A simplified version of the single line diagram for the Yarrabah 22 kV spur, reproduced from the Ergon Energy Operating Schematic drawing, is shown in Figure 14 below.

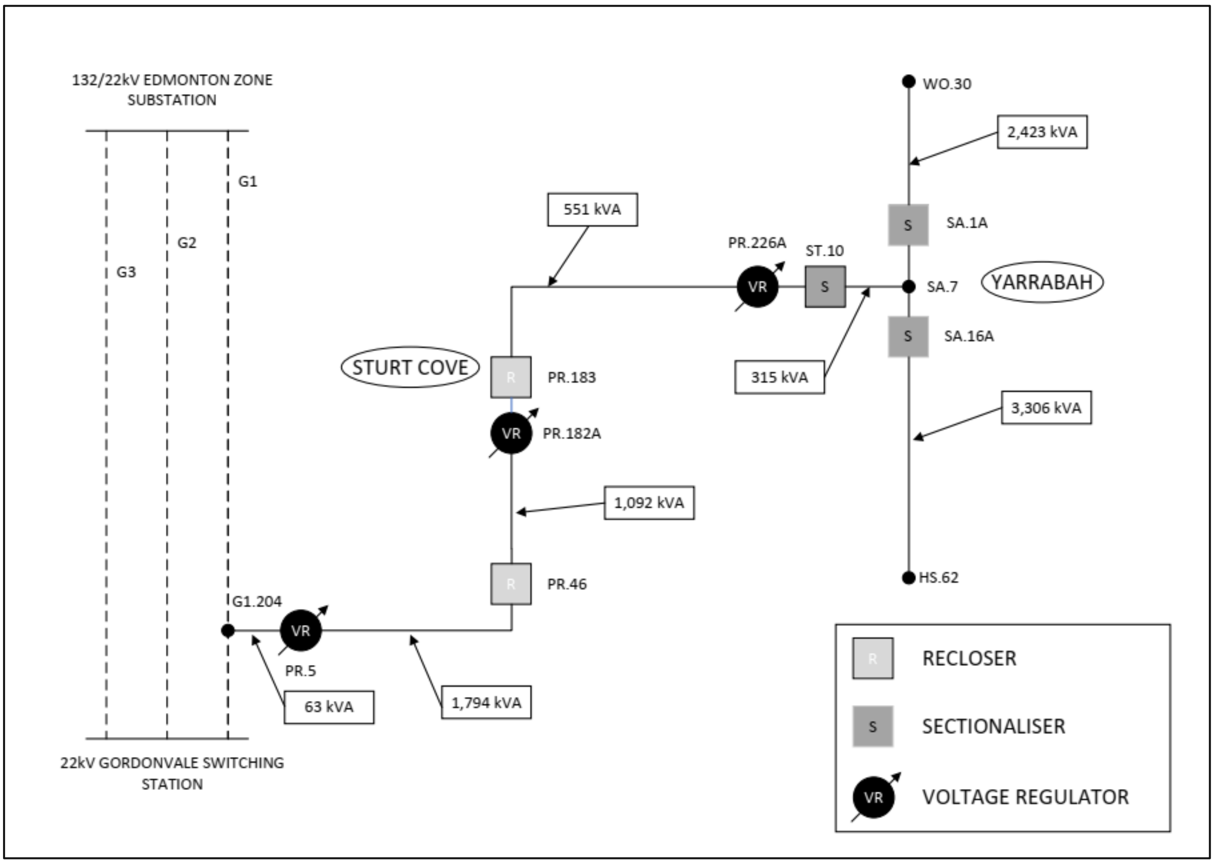

Figure 14 Single Line Drawing[38] of the Yarrabah network

This diagram identifies the locations of major network devices (voltage regulators, ACRs and sectionalisers) along the spur, between the Gordonvale No. 1 feeder tee-off and Yarrabah, as well as the connected distribution transformer capacity in each section.

Ergon Energy Network provided 15-minute load data for the microgrid feasibility study, recorded at poles PR.46, PR.183, SA.1A and SA.16A, for the period 1 July 2019 to 30 June 2020.

Load data recorded at Sturt Cove Recloser (pole PR.183) includes data associated with distribution customer connections located upstream of the Yarrabah community.

There is 551 kVA of distribution transformer capacity connected between Sturt Cove (pole PR.183) and Yarrabah (pole PR.226A), and a further 6,044 kVA of distribution transformer capacity at Yarrabah, beyond this point.

The Yarrabah distribution network can be split into northern and southern sections via two 22 kV sectionalisers installed at poles SA.1A and SA.16A. There is 2,423 kVA of connected capacity in the northern section, and 3,621 kVA[39] of connected capacity in the southern area.

[38] Extract from Ergon Energy Operating Schematic Drawing 972716-02 (12/01/2018) with permission

[39] 315 kVA connected between pole PR.226 and pole SA.16A

Ergon Energy's network does not extend to the areas at Yarrabah known as Wungu, Bukki, Back Beach, Buddabadoo, King Beach and Turtle Bay, generally located to the south and south-east of the main populated areas of Yarrabah.

These locations have numerous informal dwellings that are not currently connected to the Ergon Energy distribution network.

There are a small number of dwellings in this area that have modern standalone power systems consisting of rooftop solar PV, battery and small generators.

6.2 Historical and Forecast Demand and Load Profile

To understand the existing load profiles and microgrid design requirements for Yarrabah the Ergon Energy 15-minute load data taken at Sturt Cove Recloser (Pole PR.183) was analysed.

Typical summer and winter load profiles were extracted and data for the periods 8-12 February 2020 (sample summer load profile) and 20-24 July 2019 (sample winter load profile) are shown in Figure 15 and Figure 16.

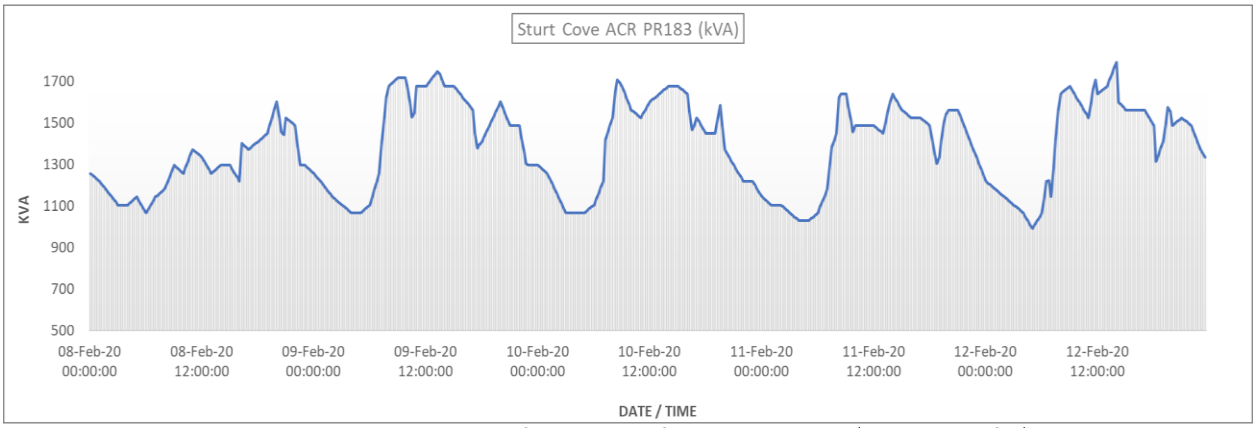

Figure 15 Time series load data for Yarrabah for 8-12 Feb 2020 (summer profile)

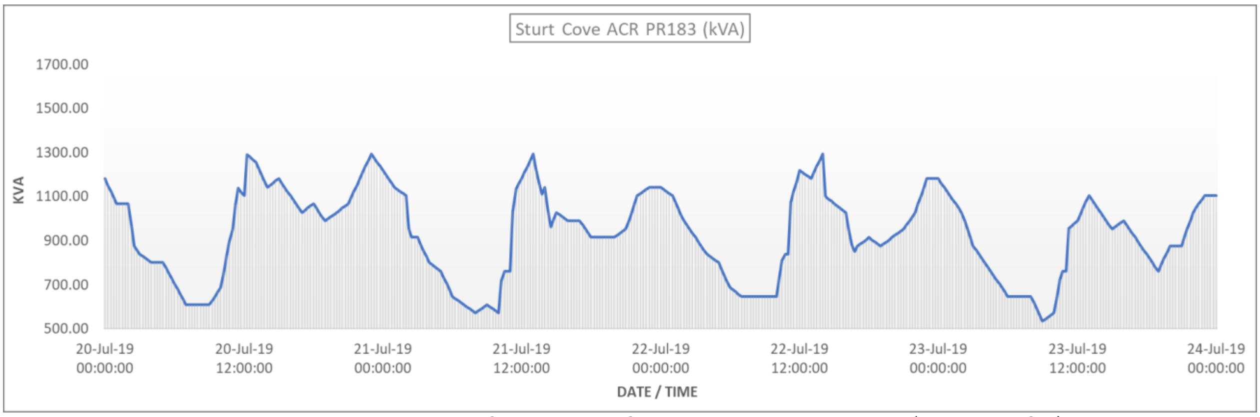

Figure 16 Time series load data for Yarrabah for period 20-24 July 2019 (winter profile)

During the winter sample period the load measured at Pole PR.183 ranged between approximately 600 kVA minimum and 1,300 kVA maximum.

For the summer sample period the load measured at Pole PR.183 ranged between approximately 990 kVA minimum and 1,830 kVA maximum.

The increases in both minimum and maximum demand during the summer period is a result of household air-conditioning systems which are operated continuously at Yarrabah during the tropical summer period.

From the daily load pattern for Monday 10th February 2020, peak load is generally sustained throughout the day between 8:00am and 5:00pm reflecting the absence of any significant quantity of rooftop solar PV at Yarrabah.

6.3 Network Performance – Reliability and Power Quality

Ergon Energy Network's Table of Network Outages (refer Appendix A) shows that in the period 4 January 2018 to 6 June 2020 there were 41 Unplanned or Forced outages for Yarrabah. While 27 of these were for periods less than a minute, the remaining 14 outages averaged a duration of 5.6 hours. There are also noticeable peak load events after the longer duration power outages.

It was noted from the data provided that there were two Forced outages within the local Yarrabah community network for Public Safety Isolation lasting 116 minutes and 65 minutes respectively. These outages affected half of the local network beyond the sectionaliser on pole SA.1A in the southern part of the community. All other outages occurred on the upstream network and impacted all Yarrabah customers.

It is noted that there were no significant weather events recorded in the Yarrabah area during the period that this data was logged.

Yarrabah is particularly susceptible to power interruptions associated with severe weather events that impact the Far North Queensland coastline from time to time.

In early 2021, Yarrabah was impacted by Tropical Cyclone Kimi (16-19 January) and Tropical Cyclone Niran (27 February – 5 March) as shown in Figure 17. Both events affected Yarrabah power supply.

As a result of TC Niran, power supply to the Yarrabah community was interrupted for more than 56 hours due to damage to the electricity distribution network. Access to Yarrabah was restricted due to fallen powerlines (typical example shown in Figure 18), vegetation and land slippages across Pine Creek Road, the only road in and out of the community. It is unknown if any damage occurred on the local Yarrabah network because of these events.

Apart from the two Forced outage events to the local Yarrabah network mentioned above, no specific data has been reviewed regarding the risk of damage to the local Yarrabah network associated with recent cyclonic events. However, it is acknowledged that events affecting the local network or proposed microgrid infrastructure may impact how quickly power supply can be reinstated following a significant weather event. If roads and upstream networks are damaged there are options to fly or ship repair crews into the community to isolate damaged sections to make safe and reinstate power supplies via the microgrid should there be extensive damage to the upstream network and the access road is cut.

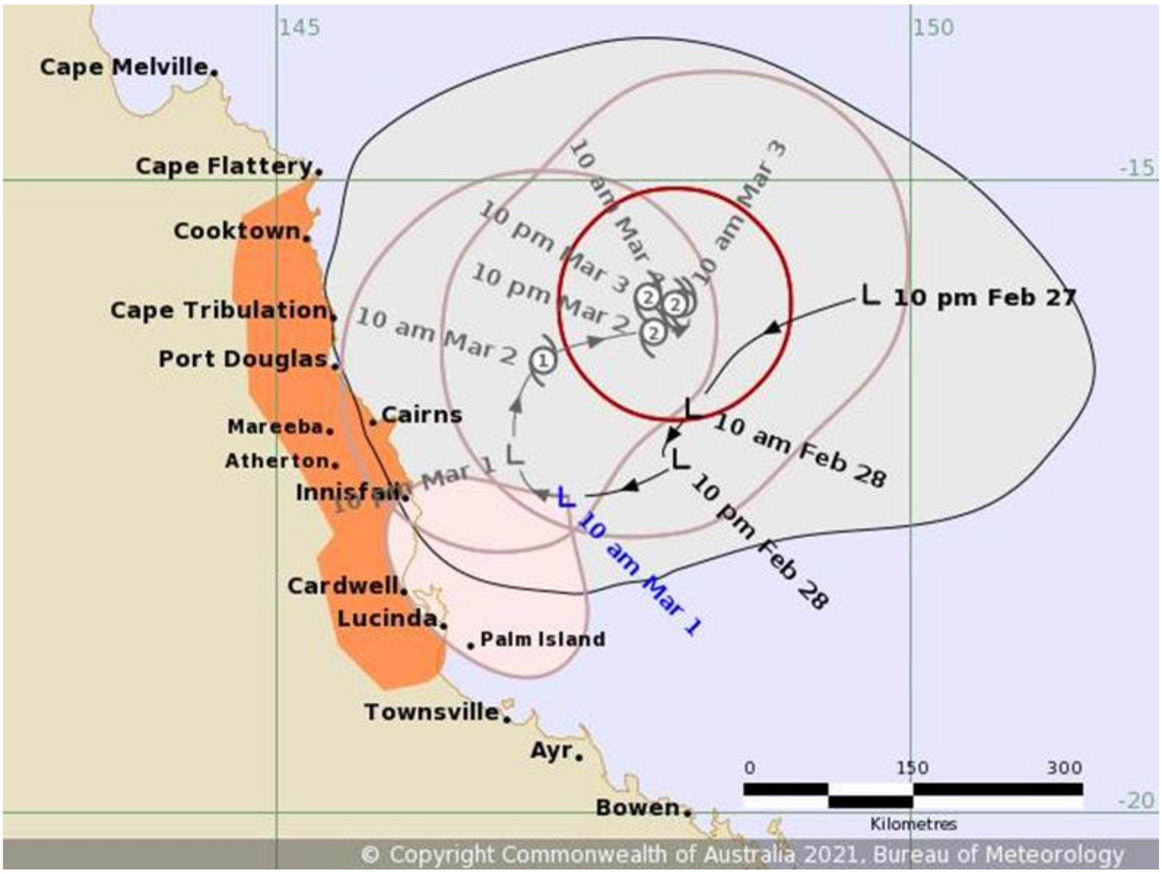

Figure 17 Cyclone tracking map – TC Niran 2021


Figure 18 Typical powerline damage indicative of cyclonic activity

The powerline that services Yarrabah experiences regular power supply interruptions for both planned maintenance activities and unplanned events.

Network reliability is generally expressed using the standard industry-recognised indices SAIDI (Supply Average Interruption Duration Index) and SAIFI (Supply Average Interruption Frequency Index).

Annual network reliability data sourced from the Australian Energy Regulator for the Gordonvale 1 (10020799) feeder which includes the Yarrabah spur is shown in Table 6 below.

	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
Total number of unplanned outages	52	56	39	56	74	65	60
Unplanned customer minutes off-supply (SAIDI) including excluded events and MEDs	844,499	1291939	378.04	591.24	1,052.91	652.61	441.91
Unplanned customer minutes off-supply (SAIDI) after removing excluded events and MEDs	68,224	668,183	377.82	588.05	548.81	419.01	441.91
Total number of planned outages	10	43	10	17	27	34	59
Planned customer minutes off-supply (SAIDI) including MEDs	86,963	382,729	12.43	8.71	89.12	432.64	134.37
Planned customer minutes off-supply (SAIDI) after removing MEDs	-	-	12.43	8.71	89.12	431.80	134.37
Planned + Unplanned SAIDI after removing excluded events	68,224	668,183	390.25	596.77	637.93	850.80	576.28

Table 6 Gordonvale No. 1 feeder - AER Annual RIN Reporting - Ergon Energy

The data indicates that the current Minimum Service Standard (SAIDI) for Gordonvale 1 Feeder of 424 minutes per annum was exceeded in six out of the seven reporting periods.

6.4 Existing Generation

There are currently ten Solar PV Systems installed on Council buildings at Yarrabah with total inverter capacity of 128 kVA.

Additionally, a small number of solar PV systems installed at other sites including the Yarrabah State Primary School and Yarrabah Police Station (capacity not known).

None of the existing Council-owned and community-tenanted houses have rooftop solar PV systems installed.

An inventory of existing Council-owned rooftop solar PV systems is shown in Table 7 below.

NMI (National Metering Identifier)	Site	Inverter size (KVA)
3030482194	CDEP[40] Sheds	5
3030482330	Works Office	12
3030482763	Museum	5
3030483832	SES – Fire service	9
3030483867	Sawmill shed	5
3030483891	Administration Building	25
3030937841	Community Hall	10
3030986575	Childcare	20
3031149367	Art & Cultural Centre	5
3050966596	Pool	15

Table 7 YASC rooftop solar PV systems

Council-owned standby generation is available for sewerage pumping stations, the community water supply bore pumps and other key facilities at Yarrabah including the Council offices.

Health Service facilities also have their own emergency standby generators.

Ergon Energy Network does not have permanent standby generation installed at Yarrabah.

Based on previous major weather events, road access to Yarrabah is likely to be cut inhibiting the mobilisation of large generators and fuel supply vehicles to the community.

These circumstances impact the timeframe that Yarrabah can continue to operate critical community infrastructure with the current electricity supply and emergency standby arrangements.

6.5 Energy Retailers and Electricity Tariffs

Ergon Energy Retail is the primary electricity retailer for residents and businesses at Yarrabah.

Ergon Energy Retail manages a range of rebate schemes on behalf of the Queensland government for eligible customers and offers a *Customer Assist* program for customers experiencing hardship or difficulty in paying electricity bills.

Tenants of Council-owned public housing at Yarrabah are responsible for their own electricity accounts.

[40] Community Development Employment Projects

A standard residential property in regional Queensland supplied under Ergon Energy Retail tariffs will generally have a primary tariff (Residential Tariff 11) and a secondary tariff for hot water or other controllable appliances such as pool pumps (Tariff 31 or Tariff 33). Residences with rooftop solar systems may also access a standard Feed-in tariff.

The number of network connections by tariff type are shown in Table 8.

Tariff Type	Quantity
Small business (<100MWh pa)	113
Large Customer (>100 MWh pa)	12
Residential	429
Controlled load	142

Table 8 Tariff types by network connection

This data indicates that less than 30% of residences at Yarrabah have a controlled load tariff connected and therefore, in most cases, water heating units will be connected directly to the more expensive residential tariff.

6.5.1 Residential T11 Tariff

Most residential consumers in Yarrabah are on Ergon Energy Retail's T11 tariff[41]. This is a general supply tariff that charges (GST inclusive):

- supply charge 97.231c per day or about $355 per year, and
- usage 21.76c per kWh, or about $2,176 to $3,264 per year, for a home consuming 10-15 MWh per year.

There is also a metering service charge of 10.436c per day for the primary tariff regardless of whether basic or digital metering is installed, for residential connections. An additional 3.041c per day applies for a secondary tariff. Solar PV metering is considered as part of the primary tariff.

Existing meters installed at Yarrabah are predominantly basic and there is no current program of replacement. As basic meters are replaced they are upgraded to digital meters, with ~18% of residential and ~50% of business premises in Yarrabah already having digital meters.

6.5.2 Controlled Load Tariffs (T31 & T33)

The current Ergon Energy Retail tariff charges and conditions for tariffs 31 and 33 are shown in Table 9. Usage rates are GST-inclusive.

[41] Ergon Energy Retail Tariffs as of 1st July 2021

Tariff	Access to power	Application	Usage rates
31	Power is available for at least 8 hours each day. The times when power is switched off may change from day to day and vary in duration.	Only suitable for large hot water systems. For smaller systems or other appliances, please consider Tariff 33 for interruptible power or tariff 11 for power 24/7.	Flat rate of 14.329 cents per kWh.
33	Power is available for at least 18 hours each day. The times when power is switched off may change from day to day and vary in duration.	Ideal for hot water systems and pool pumps. For on-demand appliances like air conditioners, you may prefer to use Tariff 11 for power 24/7.	Flat rate of 15.744 cents per kWh.

Table 9 Ergon Energy Retail controlled load tariffs

7

Demand-side Options

7 Demand-Side Options

Demand management is a recognised strategy for ensuring the economic and efficient design of energy systems by reducing peak load and shifting energy use to other periods of the day when it may be cheaper to produce or more plentiful.

Managing energy demand ensures that electricity generation plant is correctly sized and sufficient to meet user requirements.

Community education on demand management and energy-efficiency principles would provide the foundation for optimising the renewable energy generation and energy storage system capacity for the Yarrabah microgrid and maximise benefits to community members through reduced electricity costs.

Energy audits were undertaken to assess baseline data for current energy usage activities and to identify potential improvement opportunities.

7.1 Energy Audits on Existing Facilities

Level 2 Energy Audits were conducted at 15 households and 20 commercial or Council sites at Yarrabah, between October 2020 and March 2021.

A level 2 Energy Audit Report provides a detailed summary of the energy consuming processes that occur at a site, along with recommendations on how to reduce consumption, and includes the following steps:

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

Using an auditing app designed for this project, the EnergyConnect team worked with YASC Housing team to identify willing participants to be audited, and audits were conducted during scheduled quarterly housing inspections to minimise disturbance to household routines. A report was collated 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 comparable to the average for most Australian households, but quite small on a per capita level due to the high average number of residents per house.

For Council and business premises, a similar process was undertaken, under the guidance of the Council Infrastructure Manager. The report identified potential savings and ways to optimise operational regimes and suggestions when upgrading.

7.2 Energy Efficiency

7.2.1 Council and Business Buildings

Most Council and business buildings used for administrative purposes were made of concrete block, whilst those for maintenance depots included some steel framed and sheeted buildings. Air-conditioning and ceiling fans were installed in most office buildings.

As outlined in section 6.5 of this report, some Council buildings have rooftop solar PV systems installed, however at four sites the audits identified that the solar systems had been switched off for several months as they had not been returned to service following maintenance work undertaken on the adjacent distribution powerlines.

As PV system status is not actively monitored and managed, energy and greenhouse gas emissions savings were forfeited during the period that the PV systems were out of service.

The Gurriny Yealamucka Health Service buildings are well insulated and maximised the efficiency of their air-conditioning systems by having automated doors which closed quickly after entry, and sealed windows throughout. Many medical health appliances were utilised in the hospital facilities, but most were turned off when not in use. The Health Services building does not currently have a rooftop solar PV system installed.

7.2.2 Housing

The 13 houses and 2 townhouses audited were of concrete block construction, ranging in age from 30 years to 2 years old. All houses were single storey structures with small windows, small or no shaded verandahs and poor crossflow ventilation. All houses and townhouses had ceiling fans installed.

Being a tropical climate means that the large number of residents require artificial cooling. In many cases, installed fans are supplemented by resident's 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 were noted to increase 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 who 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 local residents and Council staff lead to more care of the house, less maintenance and wilful damage and less health and community issues like domestic violence within the community.

Most houses have electric hot water systems, but few are operated to minimise energy usage. With multi-generational houses, anecdotal evidence is 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 washing of clothes daily.

7.2.3 Appliances

Although most houses had a small number of appliances, energy bills were high because of usage patterns of air-conditioning and cooling, and electric hot water systems, to meet the heating and washing needs of the large numbers of residents with most houses having an average of 8 permanent residents.

Cooking was mainly by electric oven/stove top. Many houses had three or more small bar fridges in addition to a large, shared refrigerator. Few had clothes driers.

Unlike many other houses in Australia, there were very few computers or tablets, games consoles, DVD recorders or set top boxes in the houses audited. Most households did have at least one mobile phone charger and many had two or more TVs and sound systems with very large speakers.

Although there was an awareness of the energy rating system for appliances, the main factor in choice was price and availability at the time of purchase.

7.2.4 Energy Efficiency Education

It is recognised by many experts that the effectiveness of implementing renewable energy solutions is enhanced through tailored education programs. These programs are multifaceted comprising information on energy efficiency, demand reduction and maintenance requirements for the systems, complementing the effective roll-out of renewable energy based microgrid systems.

This cannot be a "one-off" program, as the players and the information change rapidly. An ongoing education program is essential to maximise the appropriate installation, efficient use and longevity of appliances and the energy delivery mechanisms.

All appliances and energy systems have a maintenance requirement to ensure their effective and long-term functioning. In a tropical climate, this is exacerbated by high humidity and rainfall and its resultant growth of mould and rapid growth rates of trees. An ongoing and regular maintenance regime is required.

Of significance to this project, an education campaign should address the following:

- Energy conservation principles
- Reducing the number of appliances being operated at any one time

- Choosing appliances with minimal energy consumption and maximum ratings
- Turning off an appliance at the wall and/or unplugging any appliance not being used to reduce the demand from "standby power"
- Timing of use of high consumption appliances to when local generation is at its peak or tariff prices are at their lowest
- Design of houses to minimise the demand for air-conditioning and other cooling appliances; and to maximise the use of natural light.
- Regular and pro-active /preventative maintenance
- Keeping seals on fridges and freezers clean and in good repair to keep them working properly
- Cleaning filters in air conditioners
- Removing dust and mould from solar panels

Ergon Energy Network has previously implemented sustainability initiative programs like PowerSavvy, which was tailored to Indigenous communities on Cape York and Torres Strait Islands. This program would be an excellent resource for developing future energy efficiency education programs for Yarrabah and other fringe-of-grid communities.

7.3 Load Shifting and Tariffs

In line with the proposed deployment of residential rooftop solar PV systems as part of the Yarrabah microgrid solution, there is a significant opportunity to roll out a locally-specific educational program that explains the benefits and savings of shifting loads to daytimes thus encouraging the use of high consumption activities – hot water services, cooking, washing, drying, and air-conditioning during potential peak solar generation times.

It has been identified that off-peak tariffs for water heating and air-conditioning may be under-utilised at Yarrabah and this may be due to older homes not being wired for off-peak tariffs, small hot water systems with insufficient capacity to meet household water demands, especially with large households, or because tenants are not aware of the availability of the cheaper tariff options.

Electricity Tariffs are discussed further in Section 6.5 of this report and a discussion on energy-efficient hot water systems is provided in Section 8.3.2.

As part of a proposed energy-efficiency program for Yarrabah it is imperative to ensure that appropriate tariff selections and energy-efficient appliances are considered as they can deliver optimal outcomes for the microgrid design and can provide more affordable energy solutions for residents.

8

Microgrid Technology Options

8 Microgrid Technology Options

This section provides a definition of a microgrid and discusses various technologies and their suitability for use in a microgrid in Yarrabah.

8.1 Microgrid definition

This study defines a microgrid in a manner consistent with the US Department of Energy's definition[42]:

> *'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 or island mode.'*

Typically, the reference to the grid is the main grid. It should also 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 a main grid blackout.

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 main grid, if this was the most economic option.

8.2 Distributed Energy

Distributed energy usually refers to small, distribution network connected generation and storage systems, when they are acting as a generator. Distributed energy resources (DER) also includes load control functions that can be provided by devices such as batteries in charging mode, controllers for hot water system boosters and air-conditioners, and timers. There is also growing interest in the potential for electric vehicle (EV) charging and vehicle-to-grid to contribute to DER.

There are a range of potential benefits from DER, both for consumers installing DER and also for consumers that do not. This is due to DER having the potential to defer the costs of network augmentations and reduce the overall emissions intensity of electricity. DER has additional value in islandable and isolated microgrids by being able to reduce the size of the central plant required.

However, markets are still evolving their approach to some aspects of DER to attempt to ensure the most efficient and lowest cost overall approaches are implemented.

42 www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

8.3 Renewable Energy

The Australian Government's Large-scale Renewable Energy Target legislation defines eligible renewable energy 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 Yarrabah.

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 Yarrabah context. Appendix B contains background information on each technology.

8.3.1 Solar photovoltaic

Solar PV is highly modular and, in Queensland, can be cost-effective at small-scale (kW) as well as large-scale (MW). It can be installed behind-the-meter on roof areas or as a merchant[43], ground-mount solar farm connected to the main grid.

Yarrabah has a very good solar resource by international standards, and like many locations in Australia, exhibits annual variability due to seasons. The AREMI website[44] reports an average Global Horizontal Irradiance for Yarrabah of between 20.4 and 20.6 MJ/m^2/day. The BoM Global Horizontal Irradiance data (1990 to October 2021) for the nearest open weather station in Cairns shows an annual average of 19.6 MJ/m^2/day, with the lowest year about 17.5 MJ/m^2/day and the highest year about 21.9 MJ/m^2/day.

An indication of the annual variability and the seasonal nature of Cairns' reported GHI is shown in Figure 19.

43 Built to supply to wholesale electricity market without reliance on an offtake agreement or power purchase agreement.

44 www.nationalmap.gov.au

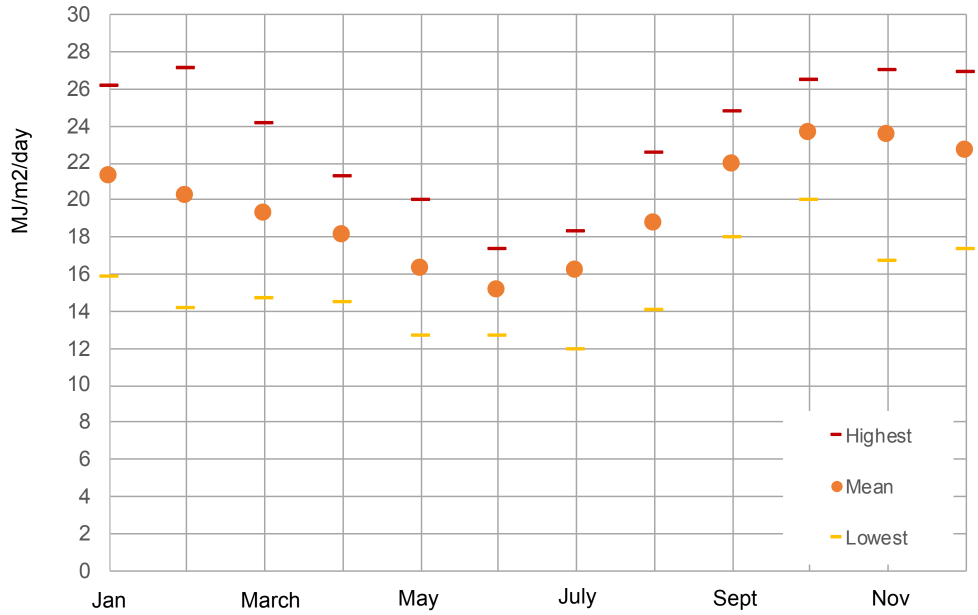

Figure 19 Cairns average GHI by month.

PVWatts[45] was used to generate an indicative annual PV generation performance at Yarrabah which is 16.9 degrees south of the equator. This indicates solar panels on roof areas facing due east or west are expected to achieve around 90% of the annual energy yield of panels facing 20 degrees west of north. This means a wide range of Yarrabah's roof areas are likely to be suitable for solar PV.

Consideration of optimal or seasonal tilt would be required for any fixed, ground-mount PV facing to the north. However, due to Yarrabah's land constraints, a design that uses east and west facing rows of solar panels is recommended to minimise the land requirements of the central solar farm.

The forecast seasonal nature of north-facing, rooftop PV generation is shown in Figure 20.

[45] Using Cairns airport solar data.

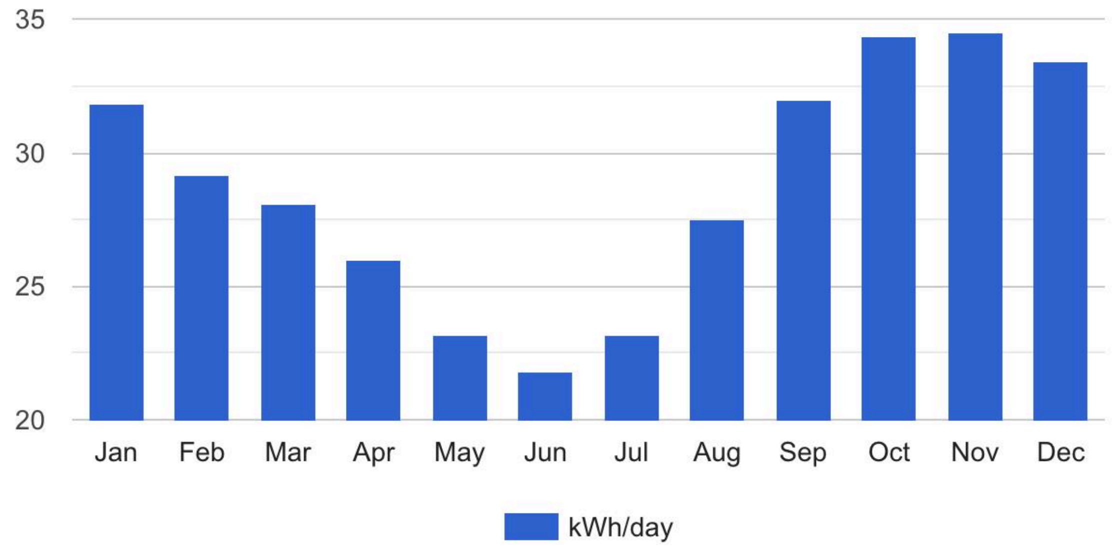

Figure 20 Forecast average daily generation for 6 kW of rooftop solar in the region[46].

The Solar Quotes website forecasts annual generation of 10,448 kWh for a 6 kW PV system. Assuming the PV rating is DC, this gives an energy yield of around 1,741 kWh/kW$_p$/year[47].

Solar PV performance is highly reliable with minimal maintenance requirements. PV panels degrade over time, but they come with 25-year warranties guaranteeing a minimum performance level. This is typically 80% of rated power output under standard test conditions. Thus, a rooftop 6.6 kW$_p$ PV array facing north with no shading is forecast to generate 1,443 kWh/kW$_p$/year in its first year and will have annual output anticipated to decline from 9.5 MWh per year to 7.6 MWh per year over 25 years. Typically, installed PV systems will degrade less than the warrantied amount, as most warranties include a safety margin.

An inverter is required to transform the DC solar PV output to AC power. Typically, inverter replacements are scheduled every 10 years. Other 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 hail, animal or other damage.

As rooftop solar PV is installed behind-the-meter, the generation that is consumed on site during sunlight hours is offsetting the energy imported from the grid. This makes rooftop solar PV more cost-effective for sites with larger daytime loads. Excess generation exported to the grid receives the much lower feed-in tariff rate.

Rooftop solar PV systems are considered an important component of the Distributed Energy solution for Yarrabah given that there are more than 380 Council-owned residences that

[46] www.solarquotes.com.au/location/yarrabah-4871-qld/

[47] The methodology, tilt and the DC/AC ratio for this estimate is not documented on the Solar Quotes website. In addition, the GHI monthly data displayed is about 3 to 7% higher than Cairn's. The Solar Quotes reference is BoM weather station Clohesy River which the BoM website indicates was closed in June 2000 but appears to be still reporting GHI data.

currently do not have solar PV systems fitted, there is limited suitable land available for the development of large-scale ground-mounted systems, and the installation of behind-the-meter solutions can provide electricity bill relief for low-income families.

8.3.2 Solar thermal and heat pump hot water systems

Being located in the tropics, Yarrabah does not have a very high, annual direct normal irradiance. The average daily DNI is around 19 MJ/m^2 though the resource would have significant seasonal variation. Larger, concentrating solar thermal technologies are unlikely to be suitable for the town's loads.

Hot water is a significant energy consumer for households. Heating 200 litres of water to around 60°C consumes more than 10 kWh with an electric resistance element. Solar thermal and heat pump hot water systems can both reduce annual electricity required by around 70 to 80% depending on usage patterns and daily hot water use.

Yarrabah has adequate direct sunlight for flat-plate solar hot water systems to achieve high annual contributions. However, it requires the tank to be sized for the daily consumption and the electric booster to be operated and/or controlled appropriately. The electric resistance booster for solar hot water systems has a high-power draw making it less optimal for islandable microgrids. The cost of installing solar hot water systems is relatively high and their annual solar contribution can be low for high daily consumption amounts if the tank is not sized appropriately. In addition, the replacement costs of ceramic tanks due to corrosive nature of high chemical content of water needs to be considered.

Electric heat pump hot water systems operate in a manner similar to a refrigerator but pump heat from air into the water. Electricity is used to drive a compressor and fan. Typically, residential electric heat pump hot water systems have a co-efficient of performance of between 3 and 4.5. This means that 1 kWh of electricity consumption can be used to deliver around 4 kWh of heat into the water. This high energy delivery is available 24 hours per day and annual contribution is consistent across a wide range of daily consumption amounts.

Heat pump hot water systems can be the more economic option in some tropical areas where households have high hot water consumption. Where a house also has rooftop PV, further cost savings are available by setting timers to restrict boosting to daytime hours. If there is a need for a large amount of hot water overnight, the heat-pump's electric boost could be turned on through a manual over-ride switch.

Another advantage of heat pumps is 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.

The provision of a reliable and adequate supply of hot water is essential for ensuring safe and healthy living conditions for Yarrabah residents. With average occupancy rates of 4.8

persons per household according to 2016 Census data (compared to the National average of 2.6), there is a higher-than-average demand for hot water.

As most hot water systems at Yarrabah are currently connected to the higher-priced tariff 11 Residential tariff, hot water also represents a significant component of the household electricity bill for Yarrabah residents.

Consequently, this study has identified that the replacement of inefficient hot water systems with energy-efficient heat pump units should be considered to optimise the microgrid design and to provide economic benefits for Yarrabah residents.

8.3.3 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.

The weather in Yarrabah is characterised by mostly calm, sunny days punctuated by cyclonic conditions, as is typical in many tropical regions. As a result, the expected capacity factor for wind turbines in Yarrabah is expected to be low.

For Yarrabah, small-scale wind is unlikely to be suitable due to the low wind resource available, maintenance requirements and the need for cyclone protection, e.g., the ability to occasionally lower horizontal axis turbines and towers to strap down to a firm footing.

The Yarrabah Council have expressed interest in demonstrating small, vertical axis wind turbines in the northern beach area.

An assessment of a specialised range of wind turbine sizes, models using horizontal and vertical axis turbines and mast heights suited to the conditions in Yarrabah (i.e., including for lowering for maintenance and in cyclonic conditions) and capable of a broader range of operation to suit the weather extremes was completed. This forecast a range of capacity factors between about 13 and 22 per cent. The highest, wind capacity factor was achieved in the flat, populated area in Yarrabah in the north/south beaches for a 100 kW XANT M21 turbine at 55 metres.

If a build cost of $2,900/kW is assumed, which is ambitious for such specialised technology, modelling using min-E indicates only up to 400 kW of horizontal axis mini wind turbines are installed in an islandable microgrid in Yarrabah, offsetting ~300 kW of solar PV and reducing the size of the battery.

Whilst wind turbines are unlikely to provide any significant contribution to the microgrid solution for Yarrabah, there could be value in incorporating a small wind turbine into the final solution for demonstration purposes, for potential application at other fringe-of-grid communities where environmental conditions are more favourable.

8.3.4 Pumped hydro storage

The use of dams for power generation is widely used in areas with suitable geography and reliable rainfall. Large hydro power 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.

Local examples of large-scale hydro-electric systems in Far North Queensland include the 66 MW Barron Gorge power station near Cairns and the 88 MW Kareeya power station near Tully. The two systems rely on large water storage reservoirs at Tinaroo Dam on the Atherton Tablelands and Koombooloomba Dam near Ravenshoe.

Hydro power generation is unlikely to be cost-effective for a Yarrabah due to the small load, seasonal nature of rainfall and the relatively low hydraulic head that is available, contributing to low levels of forecast annual power generation. Where hydraulic head is the term used to describe the vertical distance the water is falling.

Modelling using the min-E model suggests a mini-hydro plant with 6-hour energy storage could be a direct substitute for the battery energy storage in the hybrid solar PV and diesel plant. A pumped hydro power storage, capable of delivering 2 MW for 6 hours, would require construction of two large 50 ML reservoirs with a vertical height difference of about 100m. This would be challenging in a populated area with environmental, heritage and land constraints. The anticipated costs, required approvals, and constructability are the main barriers to pumped hydro storage being deployed in Yarrabah.

8.3.5 Micro Hydro

There are numerous creeks and streams at Yarrabah that could potentially provide a source of micro hydro energy for the Yarrabah microgrid. The original water supply for Yarrabah was sourced from Reeves Creek however this system has been moth-balled in lieu of a more reliable system of bore pumps. This system is discussed further in Section 13.

Flows from Reeves Creek tend to be inconsistent during the dry season and are affected by turbidity during the wet season (December to April).

An assessment of the capacity of the Reeves Ck system to contribute to the microgrid was undertaken based on the volume of water flows and difference in elevation (head) between the existing weir and water treatment station (~ 70 metres). The calculations based on head and losses with various assumptions in "penstock" or pipe run down the hill found estimated generation of 5 to 8 kW per pipe run down the hill.

Micro hydro is unlikely to be cost-effective for a Yarrabah islandable microgrid due to the seasonal nature of rainfall and the relatively low head that is available, contributing to low levels of power generation.

Modelling using min-E did not include run-of-river using micro hydro turbines as the amount of power generated from a potential plant was not significant enough to impact on the assessment. However, a run-of-river micro hydro system may still be worthy for further assessment to meet local power requirements for the water treatment plant.

8.3.6 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.

Yarrabah does not have sufficient local bioenergy resources or a large enough load to make bioenergy viable. An exception to this may be biodiesel production from waste cooking oils but the quantities involved are not likely to be large.

Whilst there is currently no agricultural activity in Yarrabah likely to generate sufficient biomass for local generation purposes, the area to the west of the Murray Prior Range in and around Gordonvale supports broad-scale sugar cane farming activity.

MSF Sugar operates the Gordonvale Sugar Mill and the Tablelands Mill at Arriga near Mareeba. Bagasse from the sugar mill is currently used to generate electricity at both the Gordonvale and Arriga mills. Excess bagasse could be utilised at Yarrabah if it were economical to purchase and transport to site. All bagasse produced by MSF Sugar is currently utilised within its own operations.

The Gordonvale mill is approximately 40 km from Yarrabah by road.

8.4 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, and
- 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, other generators and whether it is an isolated or an islandable microgrid.

The most appropriate energy storage for an islandable microgrid in Yarrabah is a grid-forming, battery energy storage system (BESS). 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.

A variety of battery types exist. As lithium-ion is widely used, it is likely to be the preferred choice for Yarrabah. A central battery, co-located with the solar farm and standby synchronous generator, is more cost-effective than distributed batteries that are orchestrated to support the microgrid in island mode.

8.5 Diesel generation

Typically, in existing isolated microgrids, diesel generation is on 24-hours per day. The diesel generation regularly ramps up and down to cope with load fluctuations. Adding some VRE generation, increases the diesel generation's load fluctuations and this is manageable provided it is within the acceptable ramp rate of the diesel generation. As the VRE power fraction increases beyond a certain point, risks to power quality emerge and to manage this some form of energy storage is typically used.

Diesel generation could also play a primary generation role for an islandable microgrid operating in island mode. However, as islandable microgrids are a relatively new development and are often designed as a greenfield development, more cost-effective approaches with high renewable energy fractions are feasible. This includes designs where diesel-off operation occurs for the majority of the time the microgrid is in island mode. The diesel generator is only occasionally required, mainly after a day with extensive clouds. At night when the battery depth-of-discharge reaches certain set points, the diesel generator would be auto-started and operated at its maximum efficiency to recharge the battery to the required state-of-charge for that period.

The cost of generating electricity with diesel generators is relatively high due to:

- the low efficiency of internal combustion engine generators (~20 to 40% depending on loading), and
- the high and fluctuating cost of the fuel, diesel at $1.00-$1.70 per litre.

For example, just the fuel cost of generation for a plant averaging 4 kWh per litre with delivered diesel at $1.00 per litre is $0.25/kWh. Actual costs are much higher than this due to the need to factor in the capital costs of the generator as well as its other operation and maintenance costs including fluctuations in the cost of fuel.

8.5.1 Generator efficiency

The diesel generator is expected to only be required to be used occasionally, when the battery state-of-charge reaches specific set points for the time. The typical efficiency of a small, diesel generator is shown in Figure 21.

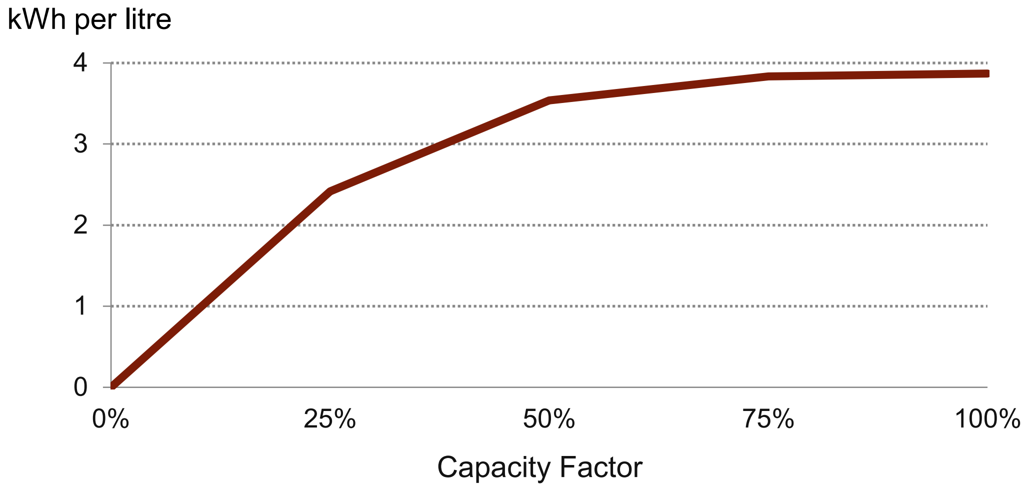

Figure 21 Typical efficiency curve for small, diesel generator at various loadings

When operational, the diesel generator is run at peak efficiency at its optimum loading to recharge the battery, i.e. it is not required to load follow and vary its output with the associated efficiency decrease.

8.5.2 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.

8.5.2.1 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 Yarrabah 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 Yarrabah microgrid back-up generator.

8.5.2.2 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.

The technology is at the early commercialisation stage. Ergon Energy Network is investigating options for reducing diesel fuel use in diesel power stations at Thursday Island and Bamaga through an Expression of Interest which closed in June 2021. Ergon Energy Network indicated that they expected the options that may be submitted include renewables, energy storage, hydrogen or biofuels[48].

Horizon Power is exploring hydrogen and fuel cells as options to assist meet their goal of no new diesel generators after 2025. The Denham Hydrogen Demonstration project is demonstrating a relatively small amount of dispatchable generation capacity and is expected to produce more than 220 MWh per year from a 100 kW fuel cell. Further details

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48 www.ergon.com.au/network/help-and-support/about-us/news-hub/media-releases/regions/general/ergon-kickstarts-next-stage-of-renewable-revolution-in-remote-fnq

are provided in Appendix F. While the Denham total project cost of $8.9 million includes a new 704 kW solar farm, 348 kW electrolysis unit and other equipment, this demonstration project highlights that this is currently an expensive option, so hydrogen generation has not been analysed for this study.

8.6 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.

8.6.1 Microgrid Control Functionality Required by the Yarrabah Microgrid Controller

- Manage microgrid UPS mode - Control seamless grid separation and re-synchronisation based on pre-determined operating modes, state of energy storage devices and available solar PV energy, upstream 22 kV feeder events, and Ergon Energy 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 Ergon Energy 22 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 Ergon Energy 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.

8.6.2 Central or Distributed Control

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 Yarrabah, 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 – the Energy Knowledge Hub - with a high-capacity communications link to the Ergon Energy Network SCADA system and throughout the community microgrid DER devices.

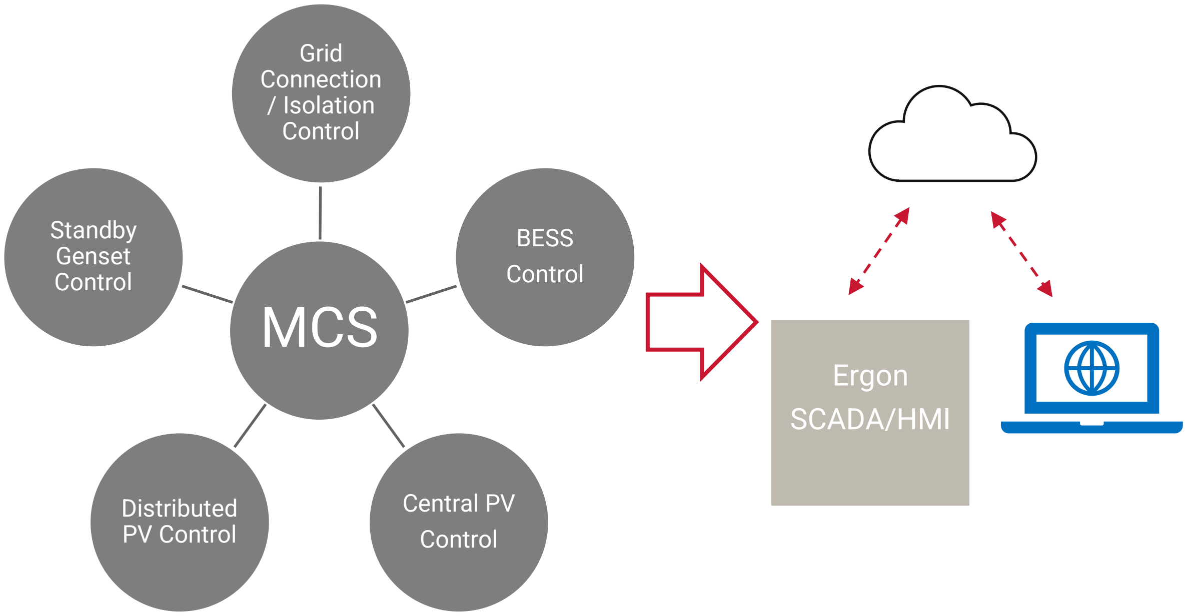

Figure 22 Diagram of the centralised master controller with communications link

8.6.3 Required Features of the Yarrabah Microgrid Master Control (MCS) System

- A microgrid MCS, to be located at the future Yarrabah Energy Knowledge Hub, with UPS power supply, robust high-capacity communications links, and display screens for control and education purposes.
- Connected/interfaced to Ergon Energy Network SCADA system, ability to receive control signals from SCADA, and pass back status information.
- Connected/interfaced to Ergon Energy Network 22 kV circuit breaker (CB) at boundary of Yarrabah community microgrid and able to remotely open/close this CB as required by microgrid control algorithm, in conjunction with Ergon Energy Network SCADA control signals.
- Connected/interfaced to retail market systems for energy pricing optimisation.
- Connected to BESS Grid Forming Inverter to manage grid baseload voltage and frequency, and grid fault levels and protection systems, particularly in grid separation mode.
- Central controller to be connected to and to control all microgrid DER devices to deliver functionality listed above.
- Central controller to be connected to all Yarrabah smart home energy interface units at residential and commercial premises for data gathering and control signaling.
- Central controller to be connected to all EV chargers within the microgrid to optimise EV charging at times of renewable energy availability.
- Distributed control gateway devices located and connected to each DER device that is connected to the microgrid, connected to master controller to accept control signals

and communicate data and status, and able to operate independently in accordance with prescribed algorithms when not able to communicate with master controller.

8.6.4 Microgrid 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[49] 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 (Voltage Frequency) droop control and Angle droop). The most appropriate control mode for the Yarrabah 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 1.25 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.

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

8.6.5 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.

8.6.6 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.

8.7 Yarrabah Microgrid Control Challenges

In any implementation phase, the following will require further investigation:

- Given the Yarrabah 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?
- Will the microgrid require high-capacity optical fibre links to the Ergon Energy Network SCADA and network switches, and optical fibre links to microgrid DER devices, to manage high speed data transfer for microgrid management?
- What is the existing capability of the Yarrabah communications networks? What communications augmentation is required?

9

Distribution Options

9 Distribution Options

9.1 Network Options

According to its Distribution Asset Planning Report 2020[50] Ergon Energy Network has no current plans to reinforce or augment the existing distribution feeder assets that service Yarrabah.

The area located adjacent to the Bruce Highway in the Cairns southern corridor between Edmonton and Gordonvale is identified for future residential and industrial development[51]. Should this development occur it is likely that additional reinforcement of the electricity distribution network would be required along this corridor including establishment of a new zone substation in the Gordonvale area. This infrastructure is unlikely to significantly impact the electricity supply at Yarrabah.

To improve redundancy of the existing power supply network at Yarrabah using traditional methods would entail duplicating the existing distribution feeder between Gordonvale and Yarrabah.

This could be achieved via a combination of overhead and underground 22 kV powerlines and could be constrained by:

- Width of the existing road reserve
- Vegetation proximity
- Location and width of existing easements through Wet Tropics World Heritage Area, or the need to establish an alternative route
- Environmental considerations and approvals

Any new overhead powerlines would be subject to similar environmental and weather exposure conditions as the existing powerline.

These options would be unattractive from a number of perspectives, including environmental, cost, and exposure to seasonal weather conditions that may result in minimal improvement in network reliability at Yarrabah.

These options also do not address community-access issues associated with the impact of road closures across the Yarrabah range resulting from cyclones and other weather-related events.

Alternatively permanent standby generation could be established at Yarrabah with sufficient capacity to power the whole community if grid supply is interrupted.

[50] Ergon Energy Network Distribution Annual Planning Report 2020

[51] The Cairns Plan 2016 Version 3

Generation capacity capable of meeting current maximum demand of 1.85MVA would be required including sufficient diesel-storage capacity in the event that roads were cut for an extended period of time.

These options have not been assessed in the Yarrabah microgrid feasibility study.

9.2 Network Studies & Modelling for Microgrid Connection

As part of the microgrid design, a load flow study has been completed in order to determine the power transfer limits between Yarrabah and rest of the distribution network, and also any constraints on the distribution network within the community. For further details on the existing distribution network refer to Section 6.

The load flow assessment was conducted utilising a Power Factory model of the Yarrabah Spur, and time series load data supplied by Ergon Energy Network. From the time series load data, a peak load and light load scenario was developed, with loads apportioned to distribution transformers based on their rating.

The study assessed the maximum generation that could be installed in the community without exceeding voltage or thermal limits. Based on advice from Ergon Energy Network, the line loading was limited to less than 50% and the voltage was limited to between 0.95p.u. to 1.05 p.u.

The study assumed that generation and storage (e.g. solar PV and battery) would be co-located behind the same connection point, and therefore only the net generation – that is the total generation minus any power consumed by battery charging – has an impact on the existing network. This means that the 'maximum generation' assessed in the study refers to the maximum power exported into the distribution network, the installed capacity of the plant may be larger so long as the power export to the distribution network is limited at the point of connection.

Two generator locations were assessed, one connected adjacent to the sewerage ponds (SS7450 in Figure 23), and another near SS6303 on Sawmill Road. Under both scenarios, the line between SS2336 Koombal Park and SS583192 Yarrabah Rd Regulator is the limiting constraint with thermal overloading exhibited with generation >1.5 MW (shown in Figure 23 as *thermal line constraint 1*). With the generation connected at the sewerage ponds, there is also thermal overloading on the line between the sewerage plant and workshop road (shown in Figure 23 as *thermal line constraint 2*).

With a generation level of 1.5 MW, network voltages were maintained within the prescribed limits using voltage control mode for the generation. It was assumed that the generator has reactive power capability meeting the automatic access standard of Clause S5.2.5.1 of the National Electricity Rules.

Therefore, the maximum net generation of the microgrid which meets the voltage and thermal limits without the need for any network augmentation is 1.5 MW.

Figure 23 Potential microgrid connection points

10

E-Mobility Strategy

10 E-Mobility Strategy

10.1 Overview

The maturing of e-mobility technologies over past decade now presents opportunities for communities like Yarrabah to leapfrog conventional transport technology options, and shift towards innovative, affordable, equitable and environmentally friendly alternatives. Such an approach could provide a pathway for remote and regional communities to reduce social disadvantage.

The potential integration of e-mobility into a future Yarrabah Microgrid has been considered as part of the microgrid feasibility assessment, including the detail of the types of e-mobility vehicles that are likely to be of most benefit to the local community; how these transport options would integrate and support a microgrid; and importantly, how the delivery of e-mobility in Yarrabah could provide broader social, health, environmental and economic benefits.

Transport is a path to opportunity but is usually a priority for larger population centres. Yarrabah Aboriginal Shire Council intends to be at the forefront of the technology change and the e-mobility strategy aims to support this ambition in delivering long-term and meaningful change for the local community.

10.2 Local Mobility Context

The linear nature of the Shire, and the linear provision of services, means that all residents are required to travel to one or more services. There is no public transport in Yarrabah. The difficulty in physically accessing services is compounded by limited internet (no NBN). Accordingly, poor transport builds in another layer of disadvantage to residents that are already among the most disadvantaged in Australia as Yarrabah is in the decile 1 ratings in each of the Socio-Economic Indexes for Areas (SEIFA) of: relative disadvantage; advantage and disadvantage; economic resources; and education and occupation.

The e-mobility strategy responds to the needs of all the community, including[52]:

- 31% of households that do not have a motor vehicle
- 20% of the population that walk or ride to work
- 23% of the population aged 10-19 years of age who lack licenses
- Seniors who do not or should not drive (4% of the population).
- Adults who cannot drive due to disability or lack of driver's license (approx. 15% of the population)

[52] Australian Bureau of Statistics, *2016 Census of Population and Housing, General Community Profile, Catalogue number 2001.0.*

- Drivers whose vehicle is temporarily unavailable.
- People who want to walk or bike for enjoyment and health.
- Households with low incomes that want or have to minimise transportation expenses

It is clear there is significant need for an improvement in the community's mobility options. Through the implementation of the e-mobility strategy, there is an opportunity for Yarrabah to become a knowledge-sharing showcase of self-reliant, sustainable transport in a regional and indigenous community, to support the rollout of similar programs in other communities across Australia.

10.2.1 Connections to Surrounding Region

There are currently no public transport services between Yarrabah and the surrounding region, including Cairns and Gordonvale. Local residents are reliant on driving or walking across Yarrabah town, and due to this lack of accessibility, are often isolated from employment, education, and health services and opportunities, as well as other essential services.

Despite these challenges, there are also a number of emerging opportunities. The Department of Transport and Main Roads has recently completed constructing a 165-metre jetty outside Yarrabah town[53].[i] This jetty will provide an ideal opportunity to link the Yarrabah community with Cairns via water, over a much shorter distance than the current road access over land. There is no existing ferry service, however, this is a key consideration as part of the e-mobility strategy.

[53] https://www.tmr.qld.gov.au/projects/yarrabah-jetty-design-and-construct

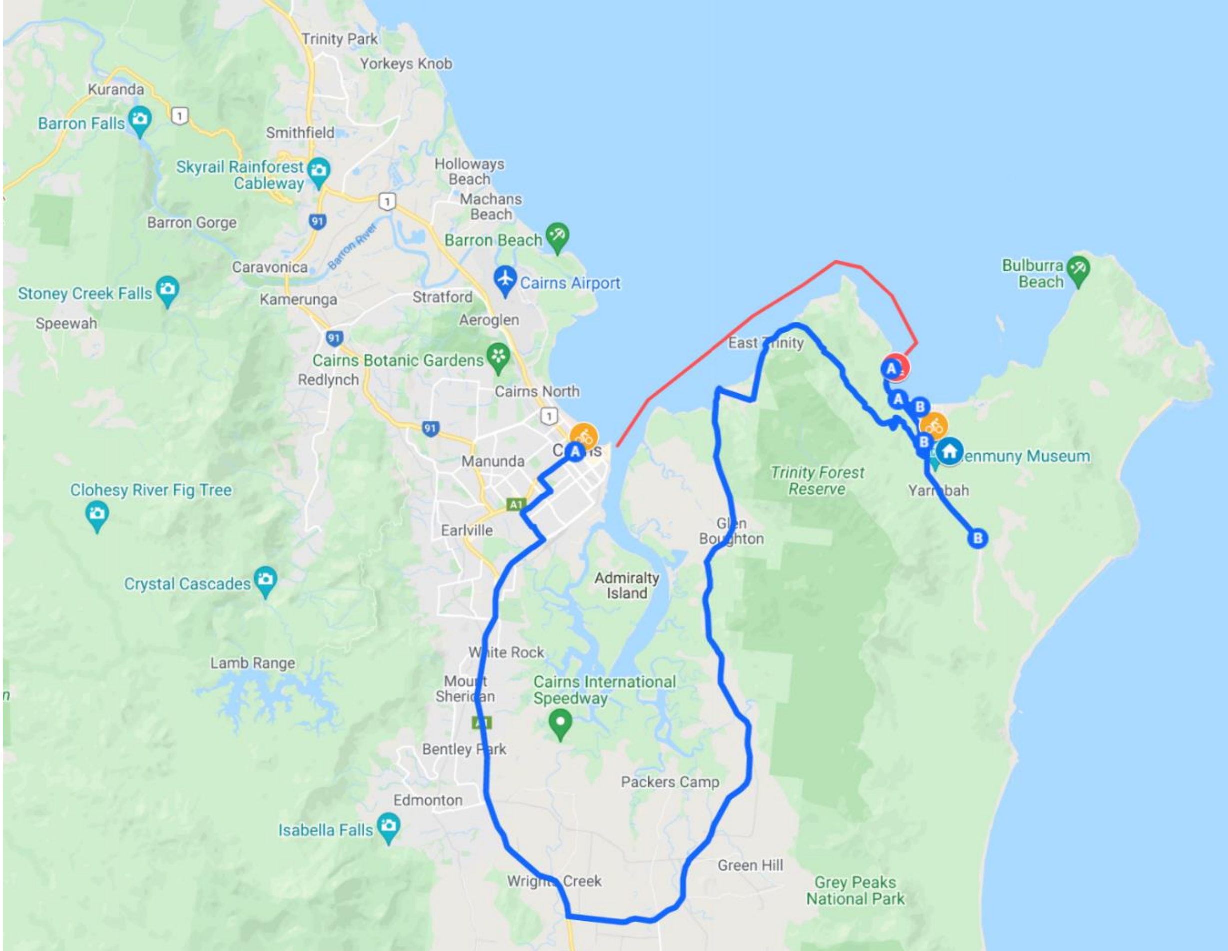

Figure 24 Map of Yarrabah and potential connections to the surrounding region

10.3 Suitable E-Mobility Vehicles

A broad range of potential e-mobility vehicles that would be suitable for deployment in and around Yarrabah have been considered. This includes:

- Micro-mobility i.e. electric bikes, scooters and other micro-devices
- Electric cars
- Electric buses
- Electric trucks
- Zero-carbon emission ferries, and
- Electric agriculture, including biomass synergies.

10.3.1 Micro-mobility

The availability of micro-mobility devices has expanded rapidly in recent years, with prices falling in line with improvements in battery technology. These improvements have enabled the electrification of various forms of micro-mobility, catering to differing needs, including: bikes, trikes, scooters and skateboards. This also includes mobility devices for the elderly and persons with disabilities.

Yarrabah is an ideal location for the deployment of micro-mobility devices, particularly for travel within the community. Yarrabah is relatively flat, and already has some infrastructure in place to support the use of these devices, including Yarrabah Aboriginal Council's recently constructed separated footpath along Backbeach Rd. Further enhancements to this infrastructure could improve the safety of using micro-mobility devices throughout the community. Potential infrastructure (separated paths/lanes) for micro-mobility, including possible dedicated parking locations, and a charging/maintenance facility at the proposed Energy Knowledge Hub are shown in Figure 25.

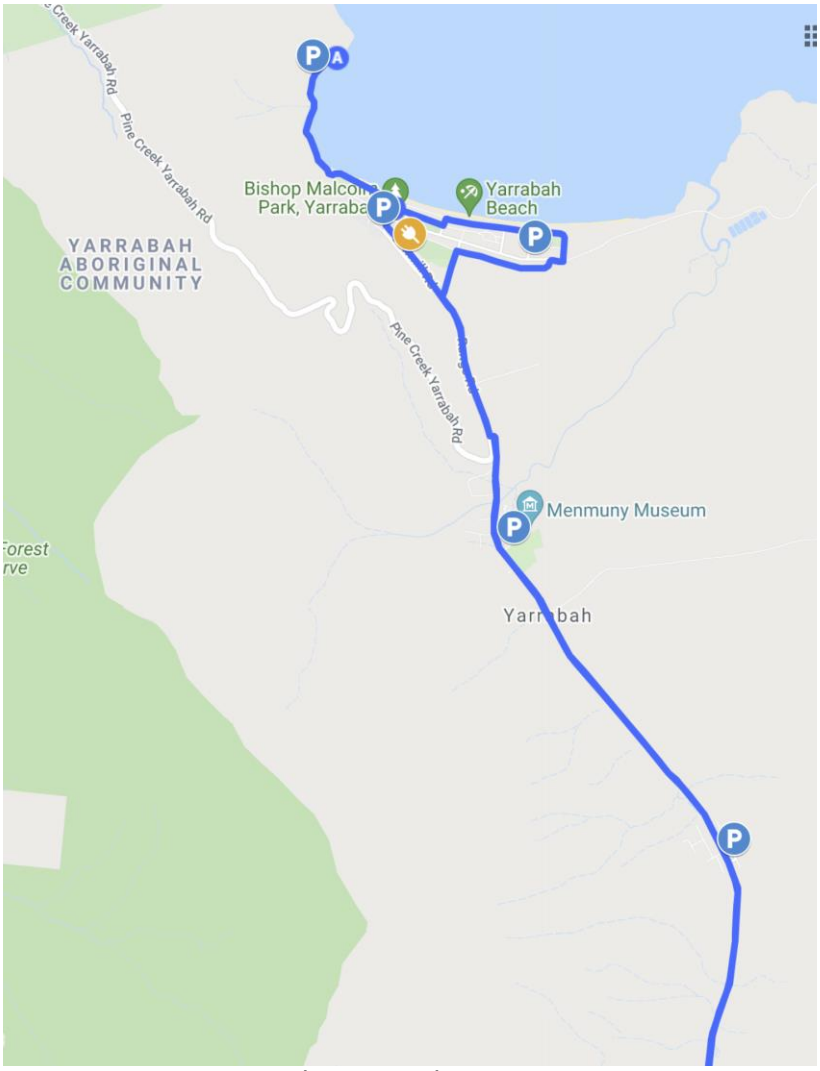

Figure 25 Potential infrastructure for micro-mobility in Yarrabah

Support for the introduction of micro-mobility in Yarrabah would provide an affordable alternative to private car ownership, reduce local emissions, and reduce costs for the community. These micro-mobility devices would not need to be privately-owned, but could form part of a shared, community fleet – available to members who sign up to access the devices, complete the appropriate safety training, and then are provided with the ability to unlock and lock devices. This could be accessed through a Mobility as a Service program (see Section 14.4.2)

A shared micro-mobility fleet would provide the additional benefit of supporting local employment through the charging and maintenance of the devices, as well as the redistribution of devices throughout the community each day to meet local demand. As outlined in 14.3.2 and 14.3.3, ideally a central location would be established to maintain and charge the devices, as well as securely store as required. This could be established at the proposed Energy Knowledge Hub.

Whether it be private or shared devices, it is critical that the local community have the opportunity to learn about how micro-mobility devices work, how to safely use them, and how to safely interact with them when using other transport modes i.e. walking, cycling a normal bike, and driving a car. These safety and awareness campaigns would be critical to a successful deployment. An e-mobility day was held in Yarrabah on the 18th of May 2021, involving Cr Kenneth Jackson, Mayor Ross Andrews, Cr David Baird, Leon Yeatman (CEO), Cr Lucresia Willett to showcase to the community different e-devices, including micro-mobility (see Figure 26). Regular, similar events could form part of this safety and awareness campaign.

Figure 26 Yarrabah Aboriginal Shire Council testing an electric bus, bikes, and scooters

10.3.2 Electric cars

There are now more than 12 million electric cars around the world, and this continues to increase significantly each year[54]. In some countries, the sale of petrol/diesel cars will start to be banned from 2025, and in cases such as the UK, will start in 2030[55]. Given Australia is

[54] https://www.iea.org/reports/global-ev-outlook-2021

[55] https://theicct.org/sites/default/files/publications/update-govt-targets-ice-phaseouts-jun2021_0.pdf

an importer of cars, it is expected that even without policies to support the adoption of EVs today, in the late 2020's, local electric car uptake will start to become significant.

This substantial change in the composition of the local car fleet is set to deliver a range of benefits, including cleaner air, lower fuel costs, lower maintenance costs, more reliable vehicles, and importantly, the ability to support the use of renewable energy and the stability of the electricity grid.

While there are currently more than 350 electric car models available around the world[56], only a small proportion of these are being imported to Australia. The upfront cost of many of these vehicles means that they are currently not affordable for many in the community; although, for fleet vehicles that are regularly driven, they can make economic sense due to the lower operating costs. For example, a petrol vehicle consuming 8 L / 100 km at $1.30 per L equates to more than $10 per 100 km. An average electric vehicle consumes around 17 kWh per 100 km. When charged on Ergon Energy Retail's flat electricity tariff at $0.2176 per kWh, this would equate to $3.70 per 100 km. With the average vehicle travelling around 13,000 km per year, this equates to almost $1,000 in fuel savings each year, before considering the lower maintenance costs due to the little to no servicing that electric cars require.

With more Australians buying electric vehicles, the availability of charging infrastructure is also being used to support so-called EV tourism. EV owners look for destinations where they can get a low-cost or free charging. Many businesses are adopting the 'linger-and-spend' model, where they allow visitors with EVs to charge for free at a relatively slow rate, in exchange for shopping at their business – whether that be for food, clothes or art. Given the cost of the electricity is low, this is more than offset by the amount of money the EV visitors spend while they wait for their vehicle to charge. By having EV chargers publicly available, this also promotes the community as 'EV-friendly', forward-thinking, and is likely to attract more tourists to visit. Potential siting locations for EV chargers have been assessed for Yarrabah as shown in Figure 27.

[56] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales

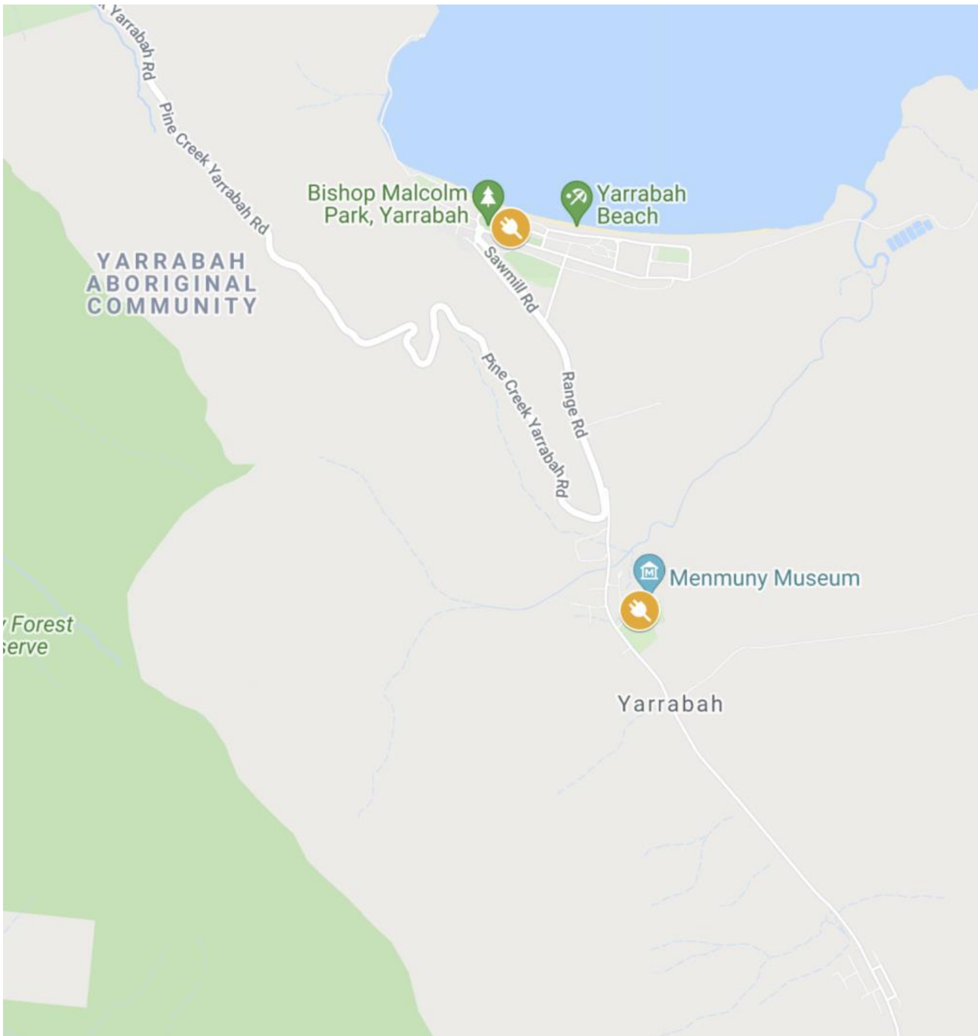

Figure 27 Possible siting locations for EV charging infrastructure

10.3.3 Electric buses & vans

In addition to electric cars, bus fleets around the world are now starting to be electrified. Cairns has been home to one of Australia's first electric buses – running between the city and Kuranda. This bus was brought to Yarrabah for the e-mobility showcase on the 18th of May, 2021 (refer to Figure 26).

While most electric buses at present are focussed on city applications, a number of smaller buses and large vans are emerging. For example, Ford Australia plans to introduce a large electric van in mid-2022[57], with a driving range of over 300 km, and the ability to be fitted out as a shuttle bus for up to 14 passengers. An Australian company, SEA Electric (see Figure 28), is already offering different shuttle bus options, similarly with room for up to 14 passengers[58].

Smaller shuttle buses / vans are expected to be more suitable for the Yarrabah community, and more affordable than a larger city bus. It is anticipated that at least one shuttle bus

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57 https://www.ford.com.au/future-vehicle/e-transit/

58 https://www.sea-electric.com/products/sea-vans-buses/

would be required to service the local community – particularly those that cannot use any shared micro-mobility options that may become available. Additionally, at least a second shuttle bus could be used to provide a transfer option for residents between Yarrabah and Gordonvale and/or Cairns. With these vehicles generally having a driving range of around 300 km, it is expected this would be more than sufficient for use in the local community and would also support up to 3 return trips to Cairns, of 100 km each, with the ability to extend this driving range with charging between return trips.

The provision of these services would further reduce the reliance of Yarrabah residents on private vehicles, and provide the opportunity to access health, education, employment, and other services located in the broader Cairns region. It is envisaged that these services would complement a potential future ferry service, and that the shuttle used within Yarrabah could be used to also move tourists arriving at or departing from the Yarrabah Jetty to and from the centre of town and/or tourism destinations.

Figure 28 SEA Electric's 14-passenger, electric shuttle, with up to 300 km driving range

10.3.4 Electric trucks

Like buses, trucks are now starting to be electrified. The key opportunities at present include electric rubbish trucks[59] (see Figure 29) and electric dump/tipper trucks[60] – two types of trucks that are already in use in the Yarrabah community.

The existing diesel vehicles in Yarrabah could be planned to be replaced with electric equivalents over the coming years, and in addition to fulfilling Council transport duties, during downtime, could be parked and used as "batteries-on-wheels" to support the

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59 https://www.sea-electric.com/products/refuse-ev/

60 https://thedriven.io/2020/12/23/act-government-launches-first-sea-electric-tipper-truck/

microgrid. Assuming both a dump truck and rubbish truck were purchased, combined these two vehicles could store up to ~400 kWh – enough energy to power up to 10 average homes for a full 24 hours, or with smart energy use in the community, up to 30 houses overnight[61].

An additional benefit of transitioning to electric trucks is the lower noise they produce during operations, particularly during early morning rubbish pickup services.

Figure 29 An example of one of SEA Electric's rubbish trucks, with up to 230 km driving range

10.3.5 Zero carbon emission ferry to Cairns and Fitzroy Island

As shown in Figure 24, the opportunity to link Yarrabah and Cairns by water would significantly reduce the travel distance, and also likely the travel time. A ferry link would provide a convenient, scenic opportunity for residents and tourists to travel between the two communities. With ferries already travelling between Cairns and Fitzroy Island, an additional link could be added to Yarrabah to increase awareness of the local community among tourists, as it continues to develop additional tourism attractions.

Given the pressure of climate change on the Great Barrier Reef, it is important that a clean, zero emission solution be pursued for this ferry link. Internationally, a number of alternatively powered marine vessels are emerging as viable alternatives. New Zealand will soon launch the country's first electric ferry travelling across Wellington Bay using a 550kWh battery and twin electric motors. At 19m long, this ferry can carry 135 passengers and is designed to travel at least 75 km on a single charge at an operational speed of up to 20 knots[62] - see

[61] Assumes each house uses an average of 20 kWh per day; and that with smart energy use at least 13 kWh of this energy could be met directly using solar during daylight hours, with less than 7 kWh required for overnight energy requirements.

[62] https://www.meridianenergy.co.nz/news-and-events/new-zealands-first-electric-passenger-ferry-set-to-launch

Figure 30. This development expands on the several electric ferries that are already in operation in the northern hemisphere[63,64].

A return trip between Cairns and Yarrabah is approximately 30 km by water. An electric ferry, like the one in Wellington, could perform two return trips without a charge, and could be topped up on each return trip to extend operations throughout the day. Adding in Fitzroy Island would extend a return trip to 60 km, which would require a charge after each return trip. A 300 kW to 1 MW charger, most likely located in Cairns, would be required for topping up the battery. Lower rate chargers could be used if installed at multiple stops along the journey.

A ferry equipped with solar panels could also top up charging during operations[65]. Alternatively, other options, such as hydrogen[66] and hydrogen-derived ammonia ferries, could also be explored – noting these technologies are less mature in their development for marine applications.

The delivery of a zero-carbon emission ferry would firmly place Yarrabah and Cairns on the global map as a leader on marine decarbonisation. It also presents a major opportunity for kick-starting a Queensland-based zero-carbon emission ferry manufacturing sector, with associated employment growth.

Figure 30 New Zealand's first electric ferry

63 https://www.bbc.com/news/business-50233206

64 https://www.electrive.com/2021/03/02/worlds-largest-electric-ferry-yet-goes-into-service-in-norway/

65 https://soelyachts.com/soelshuttle14/

66 https://www.incatcrowther.com/ships/ferries/commuter/ic17212

10.3.6 Electric agriculture, and related regional biomass synergies

There are substantial synergies between the deployment of e-mobility and the use of local biomass resources. MSF Sugar has already established a green energy power plant in the region, turning sugarcane bagasse waste into renewable electricity[67]. With e-mobility increasing the demand for local electricity, an increase in the number of vehicles operating using electricity can improve the business case for the expansion of this existing facility, and/or the launch of an additional facility near the Gordonvale plant.

Additionally, there is the opportunity for MSF sugar to explore how it can start to transition some of its agricultural machinery to e-mobility alternatives. With major manufacturers, like John Deere[68], starting to launch electric farming equipment, it is important that these alternatives be considered as part of a broader e-mobility strategy for Cairns, and North Queensland, which includes farming operations (see Figure 31 as an example of an electric tractor). This presents significant opportunity for farmers to reduce their dependency on imported fuel, reduce emissions, and in the process, reduce fuel and maintenance costs[69].

Figure 31 Monarch electric tractor that can operate autonomously without a driver[70]

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[67] https://www.msfsugar.com.au/tableland-green-energy-power-plant/

[68] https://www.deere.co.uk/en/agriculture/future-of-farming/

[69] https://www.allelectricvehicles.com.au/blog/7-reasons-why-you-should-use-an-electric-tractor-on-your-farm/

[70] https://www.monarchtractor.com/

10.4 E-mobility and microgrid impacts

The increasing electrification of transport is a trend occurring internationally. It is expected that over the course of the next few decades most land transport applications will be electrified, and even some marine and air applications will also be electrified[71]. This is in line with achieving net zero emissions by mid-century[72,73,74]. As part of this transition, it is important to understand the energy requirements of e-mobility vehicles, and importantly, how electrified vehicles can support the stability of a microgrid by operating as “batteries-on-wheels”[75,76].

10.4.1 Microgrid considerations

An indicative estimate of the long term, potential energy and power implications that the increased use of electricity for transport purposes could have is provided in Table 10.

As shown, in total it is expected that if this e-mobility plan were to be implemented in full, up to 2,550 kWh in electricity generation would need to be planned for each day to support the projected e-mobility fleet. This is about a 12% increase in the average daily load, so a manageable daily energy increase.

In terms of peak power implications, this could draw a maximum of 320 kW during the day, or 50 kW overnight – noting that these power rates could be significantly reduced through smart charging and time-of-use tariffs, where the charging schedule for each vehicle is optimised throughout the day to stabilise the microgrid.

With the introduction of bi-directional charging infrastructure, a total of up to 1,390 kWh in energy storage could be accessed through the combined e-mobility fleet. This would ultimately be dependent on the availability of suitable infrastructure, and vehicles that support bi-directional charging.

It should also be noted that it would not be necessary for all e-mobility vehicles to be charged in Yarrabah. In particular, the ferry should be charged in Cairns where the ferry is likely to be berthed overnight.

The modelling of microgrid options in Section 15 has at this stage not considered the impact of potential future e-mobility uptake due to uncertainties involved with future deployment.

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71 https://www.iea.org/reports/global-ev-outlook-2021

72 https://www.energy-transitions.org/wp-content/uploads/2020/09/Making-Mission-Possible-Full-Report.pdf

73 https://global-uploads.webflow.com/612b0b172765f9c62c1c20c9/615a513770739cc6477e67f4_Castles%20and%20Cars%20Rewiring%20Australia%20Discussion%20Paper.pdf

74 https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

75 https://stories.uq.edu.au/research/2021/batteries-on-wheels/index.html

76 https://www.transportenvironment.org/discover/batteries-wheels-role-battery-electric-cars-eu-power-system-and-beyond/

Approximate vehicle fleet	Average useable battery size	Average daily energy requirements	Ability to act as "batteries-on wheels"
500 micro-mobility devices	200 kWh (500 x 0.4 kWh)	100 kWh (500 x 0.2 kWh)	N/A
50 electric cars	2,500 kWh (50 x 50 kWh)	750 kWh (50 x 15 kWh)	Up to ~750 kWh per day
Cairns electric shuttle bus	90 kWh	120 kWh (4 return trips)	Limited
Yarrabah electric shuttle bus	90 kWh	20 kWh	Up to ~40 kWh per day
1 electric rubbish truck	280 kWh	40 kWh (280 kWh; once per week)	Up to ~250 kWh per day
1 electric dump truck	100 kWh	20 kWh	Up to 50 kWh per day
1 electric ferry	550 kWh	~1,500 kWh (6 return trips; charged at Cairns instead of Yarrabah)	Limited; in emergencies up to ~300 kWh
Total	3,810 kWh	2,550 kWh	Up to ~1,390 kWh
Total without ferry	3,260 kWh	1,050 kWh	Up to ~1,090 kWh
Total without ferry and cars	760 kWh	300 kWh	Up to ~340 kWh

Table 10 Estimated potential energy requirements by e-mobility vehicle type

10.4.2 Siting infrastructure

In planning the microgrid, it is important to not only consider the energy and power implications of encouraging greater use of e-mobility vehicles, but also the integration of e-mobility charging infrastructure into the microgrid. It is recommended that charging infrastructure be sited as near-to microgrid generation infrastructure as possible to minimise grid infrastructure upgrades.

In most cases, there is a high degree of flexibility in co-locating e-mobility charging infrastructure where it is best suited for the microgrid, as the vehicles can be moved to where this infrastructure is located, as long as there is secure parking space.

11

Energy Policy and Regulatory Environment

11 Energy Policy and Regulatory Environment

11.1 National Electricity Rules and Microgrids

11.1.1 Defining Microgrids

Essentially a microgrid is an electricity network that can provide localised generation and storage located close to consumers. As discussed in Section 7 of this report, the US Department of Energy defines a microgrid as:

> *'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 [main] grid'*[77].

The International Council on Large Electric Systems (CIGRE) has defined microgrids in a consistent manner[78]. Microgrids can range in size from a few buildings, such as a retirement village, to entire precincts, towns and even regions. The small electricity network for isolated power systems used for remote towns and islands is usually described as a mini-grid. However, some also describe an isolated power system's network as a microgrid.

An islandable microgrid maintains its connection to the main grid and uses this connection occasionally, frequently or regularly, depending on its design, control system and requirements. Islandable microgrids can be designed to operate independent of the main grid for hours, days, weeks or more.

Typically, a microgrid operates in island mode when there is:

- transmission and/or distribution line outages due to weather or other events, or
- issues balancing supply and demand on the main grid, such as peak demand periods with generation shortfalls requiring network companies to impose a rolling blackout regime, or
- maintenance on main grid network infrastructure upstream of the area requiring feeder lines to be de-energised.

A microgrid could also be designed to island nearly all the time and only rely on the main grid when special events cause demand to increase beyond local generation capacity or if the local microgrid generation is not operational due to maintenance or failure.

Microgrids can also be designed to be entirely stand-alone and self-sufficient allowing for the main grid connection to be physically removed. However, physically removing the main grid connection, makes the system become described as an isolated power system with its

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[77] www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

[78] CIGRE Working Group C6.22, Microgrids 1 Engineering, Economics and Experience, 2015.

own network and it is no longer, according to the US Department of Energy definition, a microgrid.

For the purposes of this report, the term 'isolated microgrid' means there is no physical connection to the main grid, so all generation is always local.

The term 'islandable microgrid' refers to a microgrid that retains its main grid connection but is designed and installed to be able to temporarily operate in island mode, as the main grid is either not available or a switch has been opened to disconnect from the main grid temporarily, e.g., following an extreme weather event or when line maintenance is required.

Islandable microgrids can increase electricity reliability for fringe-of-grid towns because energy generation is closer to where electricity is used, which reduces reliance on long power lines and the connection to the main grid. This is particularly attractive for fringe-of-grid communities and regions where distances between the closest main grid substation to customer loads can be vast. Customers at the end of long feeder lines are vulnerable to outages that may occur because of lightning strikes, fires, wildlife, vehicle impacts, cyclones, and other weather events. Electricity infrastructure rebuilds of these long lines can take days or weeks, which results in prolonged outages.

Where it is feasible, network operators will enact contingency plans such as the deployment of mobile generation equipment to mitigate the impacts, however site access conditions can impact the viability of these plans.

A microgrid can use localised renewable energy sources such as solar and wind. Backup generators, battery energy storage systems, inverters and smart control systems can optimise operation while maintaining power quality. Microgrids are attracting increased interest, particularly as the installed cost of battery energy storage systems is forecast to reduce over the coming years.

11.2 Regulatory Changes and Ownership

As of March 2022, in the National Electricity Market (NEM), electricity distribution network service providers (DNSPs) generally cannot own and sell electricity from generation assets, including batteries. Although they can own battery assets, they 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 network assets from generation assets (because generation operates in a competitive market).

The exception to this is when DNSPs such as Ergon Energy Network receive an Australian Energy Regulator (AER) waiver to own such assets as part of Stand-Alone Power Systems (SAPS). This is relevant to islandable microgrids such as that proposed for Yarrabah that may occasionally operate independently from the main grid. In island mode, such a microgrid has some similarities with a SAPS.

Historically, SAPS is the term used to a describe a system providing power to one off-grid customer. However, the Australian Energy Market Commission's (AEMC) definition[79] states:

> *'(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.'*

The regulatory frameworks governing SAPS is undergoing changes as described in the AEMC reports:

- Review of the Regulatory Frameworks for Stand-alone Power Systems, Oct 2019', and
- Updating the Regulatory Frameworks for Distributor-led Stand-alone Power Systems, May 2020'.[80]

These have recently culminated in new Rules published by the AEMC. These mean that a DNSP in the NEM, such as Ergon Energy Network, will be allowed to include not only the network but also the generation assets of SAPS and, potentially, isolated microgrids in their regulated asset base, where they are a more efficient alternative to traditional grid infrastructure. As noted above, this requires a waiver from the AER.

These rule changes acknowledge that new power systems may offer cheaper and more reliable power than main grid supply for some regional customers and areas – which is particularly relevant to Ergon Energy Network. The drivers for this are high power line operation and maintenance (O&M) costs relative to the loads serviced and, increasingly, extreme weather and natural disaster events.

Although the new rules have not been published at the time of writing, they will be implemented in a staged process beginning in August 2022. They will only apply to new DNSP-led SAPS (existing microgrid will be unaffected) and will operate on an opt-in basis, because some states may need to make amendments to their legislation.

It is expected that a waiver 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.

This change will allow DSNPs to own, operate and control both distribution and generation assets in SAPS and, potentially, in an isolated microgrid. Distribution businesses will also have the choice to contract a third party to operate generation assets. The South Australian

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

80 The Statues Amendment (National Energy Laws) (Stand-Alone Power Systems) Act was passed in March 2021 following the reviews by the AEMC of distributor-led stand-alone power systems. In March 2021, the AEMC noted a final rule change package will go to Energy Ministers for approval in mid-2021.

Parliament passed legislation in 2021 to allow the South Australian Minister to make rule changes relating to SAPS. Further consultation on changes to SAPS rules to accommodate changes to the National Electricity Rules for a wholesale demand response mechanism closed in April 2021 and it is publicly stated that the final rule change would be going to Energy Ministers for approval in mid 2021, however this is yet to occur.[81]

As a result of these changes, DNSPs are increasingly assessing some of their customers to determine whether they should be physically disconnected from the network and provided with power through a SAPS. While in the initial phase, this is being considered at the individual customer level (e.g. a single home or a pump). Over time this may transition to a small collection of customers or to a larger isolated microgrid servicing a whole area.

As part of their capital investment decisions, DNSPs will be considering whether to retain their power lines, replace them, increase their capacity, supplement them with a renewable energy/battery system to defer an upgrade, or to retire the line completely and install SAPS.

Among other factors, these assessments would need to consider the age of the power line, line capacity, load growth forecasts, O&M costs of line, exposure to extreme weather events, replacement cost of line, and length of line. Thus, the regional DNSP business models are changing from being power line companies only to power line companies with a mix of SAPS and, potentially, isolated microgrids where fringe-of-grid locations are physically disconnected from the main grid.

11.2.1 Proposed model for SAPS operation

The AEMC has proposed the model shown in Figure 32 for the electricity and financial flows between stakeholders in a SAPS. This is provided here because it is potentially relevant to the island mode operation of the Yarrabah microgrid. In summary, for a SAPS:

- 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 (Australian Energy Market Operator). 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 waiver or exemption is provided, they can be incorporated into their Regulated Asset Base and

[81] energyministers.gov.au/publications/stand-alone-power-systems-legislative-amendments-%E2%80%93-consultation-revised-national

unregulated revenue earned in the wholesale market can contribute to the funding of these assets.

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

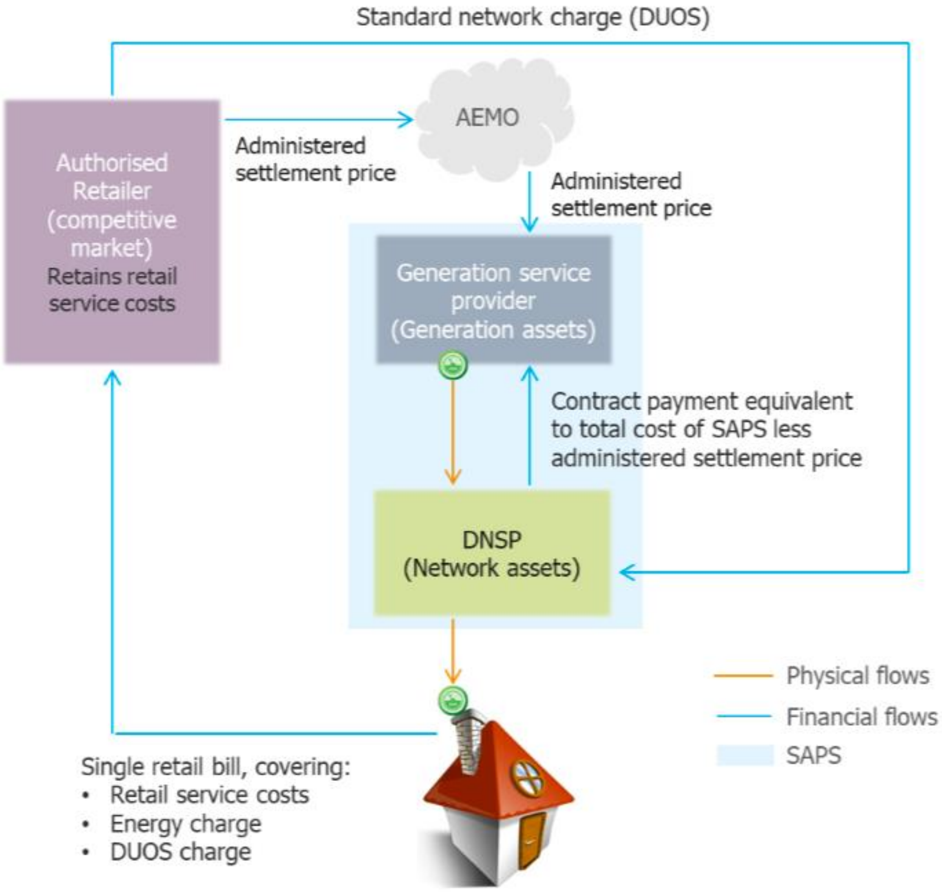

Figure 32 Proposed model for SAPS operation[82]

11.2.2 Islandable microgrids

Islandable microgrids, such as proposed for Yarrabah, are connected to the main grid most of the time and are likely to be islanded for relatively short periods of time each year, (such as when a line may be de-energised for routine maintenance work or following a cyclone).

Currently, in emergency situations for selected locations, such as Mallacoota (Victoria), where the feeder may be down for brief periods, the owner of the generation assets (in this case Ausnet) simply receives no income for the generated electricity and the retailers receive the electricity for free.

[82] AEMC, 2020, 'Updating the Regulatory Frameworks for Distributor-led Stand-alone Power Systems – Final Report', page 20, May 2020.

However, the increasing uptake of microgrids, which could be islanded for extended periods of time (more that 2 weeks), this approach may not be commercially sustainable. This would especially be the case where a microgrid is servicing customers on a very long feeder and may be used by the DNSP to justify reduced maintenance expenditure on that feeder (because the microgrid can be used as backup). In this case the microgrid could be operating as a SAPS for extended periods.

Unfortunately, the proposed SAPS model described above does not apply to islandable microgrids. This is because such microgrids are sometimes connected to the NEM and so do not qualify as a SAPS, and under the draft rules, the owner of the microgrid generation assets is unable to register as a Market SAPS Resource provider where the microgrid is not considered a SAPS.

One possible solution would be to change the definition of a SAPS to include islandable microgrids. If this were to occur, a hybrid approach could be appropriate. With such an approach, the customers on the microgrid would be treated as normal grid-connected NEM customers most of the time. When the microgrid is islanded, the SAPS rules could apply. From the customers' point of view there would be no change, the retailer would pay the settlement price determined by AEMO, the microgrid generator would receive that settlement price, and the DNSP would receive the standard network payments from the retailer as per usual. As above, where the DNSP owns any generation assets (including a battery), it would require a waiver from the AER. The regulatory bodies are currently examining this issue.

Of course, where a single retailer services all the customers in a microgrid area, and that retailer enters into a PPA with the owners of the central generation assets, it may be possible to avoid the need for AEMO to determine a settlement price because it would already be set according to the PPA. However, we note that in Yarrabah there are a couple of customers that are not with Ergon Retail. For these customers, their retailer would have to pay the settlement price determined by AEMO.

There are two additional complications with this hybrid approach. They are that:

I. the network charges included in the existing tariffs assume the customers are connected to the upstream transmission and distribution networks and so may differ to those required for a microgrid, and
II. the existing tariffs also include other energy charges such as those related to ancillary services, as well as the impacts of distribution or transmission losses.

However, given that Yarrabah is expected to be isolated for relatively short periods of time, and that these differences are likely to be a small proportion of the tariff, it seems reasonable that they could be ignored.

In summary:

- The Yarrabah microgrid is an islandable microgrid, and as such is connected to the main grid most of the time; and would only be operating as a Stand-alone Power System (SAPS) occasionally.
- Thus, it is not classified as a SAPS and so the AEMC's proposed rules that would cover payment of the microgrid generators for electricity they supply to customers would not apply.
- Because the microgrid when islanded is not connected to the NEM, the microgrid generators would receive no payment at all for the electricity they produce.
- The only possible exception to this is where a retailer that services customers within the microgrid has entered into a PPA with the microgrid generators and so can pay them according to the PPA, for at least the electricity used by their customers within the microgrid. This may be affected by the two complications described above.

11.3 Outlook

11.3.1 Drivers

The key drivers of the outlook for islandable microgrids include a range of environmental, community and technical factors.

11.3.1.1 Environmental

The increasing incidence of main grid outages caused by extreme weather events is leading to:

- Increases in calls for improving the resilience of supply, including via microgrids[83] and
- An upsurge in interest from impacted communities in backup battery systems[84]

Increasing network repair costs from climate change are likely to place upwards pressure on electricity costs over the longer term[85]. In 2017, Cyclone Debbie brought extensive damage to 650 power poles and 800 power lines in the electricity network in Far North Queensland. The works to restore power to 65,000 customers taking two weeks[86].

In 2006, the Innisfail region experienced Cyclone Larry. In 2011, Cyclone Yasi impacted the communities of Mission Beach, Cardwell, Tully, Ingham and surrounds, interrupting

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[83] Total Environment Centre, *Local energy and climate change resilience*, 2019.

[84] Vorrath, S, *Blackout sparks demand boost as consumers seek reliability in solar and battery storage*. One Step Off the Grid, 2016.

[85] www.abc.net.au/news/2020-01-23/power-prices-rise-blackouts-increase-bushfire-season-intensifies/11890646

[86] www.mygc.com.au/power-fully-restored-far-north-qld-two-weeks-cyclone-debbie/

electricity supply to more than 200,000 properties with 700 properties still without power a month later[87].

Although the Australian tropics are more prone to cyclones, storm surges and floods, the 2019-20 bushfire season demonstrated that climatic changes mean that sub-tropical rainforest in southern Queensland is not immune from bushfire risk[88]. In addition to direct system damage caused by extreme events, power lines can cause bushfires, particularly on high wind days. Thus, network companies are now disconnecting some areas of the main grid during high fire risk periods, making firefighting and telecommunications even more challenging.

11.3.1.2 Community

As part of a broader trend of Australian households leading the world in rates of take up of rooftop solar[89], communities are increasingly looking to local generation to meet their electricity demand. Through uptake of solar PV, households have become more aware of the benefits of on-site generation, including electricity bill reduction from reduced consumption from the main grid[90].

People have also been motivated to be less reliant on the main grid supply due to negative experiences with quality and reliability of supply. Large-scale emergency situations have also led to rapid deployments of stand-alone solar and battery systems to restore supply to towns affected by disasters[91].

11.3.1.3 Technical

Recent trends have also changed the economics of power supply by making local generation less costly, even at small scale. These trends include:

- Falling solar PV costs,
- Falling battery energy storage system (BESS) costs,
- Improving battery performance and life,
- Developments in control, metering, and communication technologies, and
- Energy efficiency and smart, controllable loads.

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87 www.abc.net.au/news/2016-02-03/cyclone-yasi-what-happened-in-2011/7067086?nw=0&r=Gallery

88 www.smh.com.au/national/nsw/fires-are-burning-where-they-never-used-to-burn-20190909-p52pnn.html

89 blog.csiro.au/solar-pv-installation/

90 cur.org.au/cms/wp-content/uploads/2019/03/future-grid-homes-household-report-final-1-1.pdf

91 www.pv-magazine-australia.com/2020/02/20/mike-cannon-brookes-5b-solar-and-tesla-to-bring-power-to-bushfire-communities/

As a result, in Australia, it is now generally economical to design greenfield, isolated power systems so that their MWh annual load is predominantly met (i.e. 50%-95%[92]) with solar PV[93] and BESS, while retaining diesel generation for the balance of annual generation. This requires management of supply and demand via smart controllers. In most greenfield 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 a main grid extension or diesel-only generation.

All the trends described above are widely expected to continue over the medium-term, increasing the incentive for substituting long-distance line connections to the main grid with isolated microgrids. In Western Australia, Western Power's Modular Grid strategy[94] is heading in this direction, providing either stand-alone power systems or isolated or islandable microgrids to areas where main grid supply is costly and unreliable. Australia's largest, islandable microgrid is at Kalbarri, on the northern fringe of WA's South West Interconnected System, see case study in Appendix G.

Across Australia, many customers and communities may benefit from improved power reliability from being disconnected from the main grid and the deployment of SAPS and/or isolated microgrids. This would leave the main grid to supply those loads and customers for which centralised supply is the more cost effective and most reliable option. Geographically, this may reduce the distribution network footprint and impact both the AEMO Integrated System Plan and energy sector regulation.

Energy Networks Australia's recent *Network Innovations 2020* report[95] lists several projects with microgrid and islanding capability, including the Jandakot Clean Energy Innovation Hub in Western Australia and the Dalrymple BESS in South Australia. Further details for Australian, islandable microgrid case studies are provided in Appendix G.

11.3.2 Possible Microgrid Operating Modes

Although islandable microgrids are an emerging area of interest, they show promise in a range of types of applications.

11.3.2.1 Establishment of emergency centres

Suitable community building/s can act as emergency centres during extreme events. PV—battery systems, with standby generator back-up as necessary, can provide emergency

92 The optimal mix (instantaneous power proportion and annual energy contribution) of supply from solar PV in an isolated microgrid depends on many factors including: the annual load and its profile, peak and minimum instantaneous loads, load control options and forecasts, the capital costs of solar PV installation, the solar resource at that location, the capital cost of battery installation, the capital cost of diesel (or gas) generator(s) installation, the delivered cost of diesel or gas fuel, the fuel efficiency of the fossil fuel generator(s) across the forecast load curve at that scale, the weighted average cost of capital, and the length of the analysis period.

93 Wind power may also contribute to this mix, where local demand for electricity is large enough to warrant large wind turbines, and where the wind resource is strong.

94 westernpower.com.au/energy-solutions/modular-network/the-modular-network-our-energy-future/

95 www.energynetworks.com.au/resources/reports/2020-reports-and-publications/innovation-report-2020/

power for essential service loads nominated by the local community. For instance, emergency services, communications, vulnerable people and other critical services such as food, health facilities, and fuel bowsers for days or weeks.

While some critical loads already have uninterruptible power supply (UPS) systems (e.g. hospitals), recent bushfire events in New South Wales and Victoria during 2019-20 have highlighted that many institutions which could support the community during an emergency (e.g. community centres, schools do not. In response to the 2019-20 bushfires and storms, the Resilient Energy Collective is installing stand-alone PV-battery systems across 100 locations[96]. These systems are relocatable and will be deployed until main grid supply is reinstated.

11.3.2.2 Self-reliance during grid disturbances

During emergency situations, some regions of the NEM could operate autonomously for short periods of time using existing distributed resources, with suitable upgrades (e.g. energy storage, grid-forming inverters, control systems) to supply pre-identified loads. These regions could be within particular areas as appropriate due to network topology which could feasibly be retrofitted to operate as semi-autonomous small or large microgrids, especially in areas that are more likely to experience outages during bushfires or other extreme events.

11.3.2.3 Remote areas

Many remote areas of Australia have traditionally been supplied electricity either by:

- Isolated power systems utilising diesel or gas generation and a mini-grid, (often referred to as 'off-grid' or, more recently, an 'isolated microgrid'), or
- By long-distance connection to Australia's main grids.

Both approaches have resulted in high electricity supply costs. Typically, most remote consumers do not pay the full cost of supply as various electricity price subsidies exist.

Fringe-of-grid locations tend to suffer from reliability issues to a greater extent than urban locations, while long-distance connections through bushland pose a significant bushfire risk and potential liability to network operators. Vegetation management also adds to maintenance costs, which is particularly relevant in tropical areas where vegetation can grow very quickly.

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96 www.ecogeneration.com.au/mike-cannon-brookes-5b-solar-and-tesla-launch-energy-collective-to-buttress-burnt-out-towns/

12

Microgrid Business Models

12 Microgrid Business Models

The business models that are possible for islandable microgrids that incorporate renewable energy revolve around the different technology configurations. These can be broadly defined into the following three types:

Type 1: Autonomous behind-the-meter. This includes standard residential and commercial-scale DER such as solar PV, batteries and demand response options, such as controlled loads and Demand Response Enabled Devices (DREDs), all operated just for the benefit of the household or business where they are located.

Type 2: Orchestrated behind-the-meter. In this case the DER in the microgrid, or some components of it such as controlled load, can be remotely controlled by a third party to provide an aggregated benefit for the microgrid, a proportion of which may then be distributed amongst the participating households and businesses.

Type 3: In front of the customer meter. These grid-connected, centralised generation and storage assets can be owned by a third party (including a community cooperative) or by the DNSP – subject to the regulatory constraints outlined in Section 11.2.

The business models and financial outcomes of these different configuration types then depend on whether the microgrid's network (the poles and wires) is owned privately or by the DNSP. For Yarrabah, the owner of the 22 kV feeder and local power lines is Ergon Energy Network.

The following also discusses options for ownership of any large-scale generation assets such as solar farms and/or batteries. There are also various business models for ownership and operation of behind-the-meter DER at Yarrabah, and these are discussed in Section 8.2.

12.1 Privately owned microgrid network

While it is highly unlikely that the Yarrabah grid would be acquired from Ergon Energy Network by a private entity, the following discussion is provided for completeness.

A microgrid network that is privately owned is referred to as an embedded network and is connected to the main grid at a single metered connection point, often referred to as the parent meter. Examples can include greenfield urban developments, industrial estates, shopping centres, apartment blocks, retirement villages and caravan parks.

The embedded network operator (ENO) sells electricity to the embedded network consumers (who also have the option to buy electricity from an external retailer). The sale of electricity to customers within the embedded network can be measured using sub-meters.

Some embedded networks have **Type 1** autonomous DER that:

- Reduces the amount of electricity that must be bought through the parent meter, and

- Exports to other customers in the embedded network. In this case, sub-meters can still be used to keep track of customers' electricity consumption and costs if all exported solar/battery electricity is on-sold at the same tariff as customers pay for the electricity that is drawn from the wider grid. Note that this tariff can be different to the tariff paid by the ENO at the main connection point measured through the parent meter.

The embedded network connection point will be managed, by the retailer, as a large customer. Thus, the ENO will pay for electricity according to a tariff that is appropriate for the total load size. Typically, the larger size of the total embedded network load means it will have to use tariffs with a time-based component. These include time-of-use (where the rates are generally higher in the evening) and/or demand charge tariffs and capacity tariffs (where peak loads, annual and monthly, are paid for).

However, operation of the embedded network is more complex if the internally generated solar/battery electricity is on-sold to embedded network consumers at a price that is different to the standard embedded network usage tariff. In this case some mechanism, such as Local Energy Trading (LET), must be used to track who is selling and buying the electricity in real time.

In LET schemes, participating households or businesses can trade electricity with each other through the LET platform by submitting offers to buy or sell electricity at particular prices. This is not a form of Type 2 orchestrated control (as discussed below) because they are not directly controlled by any external operator. Instead, they respond only to price signals provided by other participants in the LET platform.

Type 2 orchestrated DER are also feasible on an embedded network. The simplest option would be for the ENO to remotely control the DER within the embedded network to minimise electricity demand during high tariff price periods (by using local generation, batteries and demand management). This would reduce the costs faced by the ENO in buying electricity at the parent meter, and it will then ideally use some mechanism to reward the DER customers involved.

A more complex option would be where the embedded network customers are aggregated into a virtual power plant (VPP) which can then participate in external markets such as the wholesale electricity spot market or the frequency control ancillary services (FCAS) markets. This would again generate benefits for the ENO, who would then ideally share these with the participating embedded network customers. However, these types of VPPs (Virtual Power Plants) are unlikely to be developed on fringe-of-grid microgrids such as Yarrabah simply because their connection to the main grid is unreliable.

Similarly, a single large **Type 3** renewable energy generator, such as a centralised solar PV--battery system, could be used instead of (and as well as) distributed PV systems, with or without batteries, owned by individual customers. In this case, the Type 3 centralised PV-battery system could be owned by the ENO, who can sell the electricity to the embedded network customers, or it could be owned by another third party who would then sell the electricity to the ENO.

Like **Type 2** orchestrated behind-the-meter systems, **Type 3** central generation systems could also be controllable, and so could be used to decrease electricity demand at the parent meter during high price periods, and even participate in a VPP. A combination of Type 1 and 3 is also possible, with for example, a large, centralised battery being used to capture excess solar electricity generated by customers within the embedded network (before it is exported to the wider network) for use by other embedded network customers.

12.2 DNSP-owned microgrid network

If the microgrid network is owned by the DNSP, then each customer will have their own electricity meter and there will not be a single metered, parent connection point. Under current NEM regulations, full network charges must be paid on all electricity that is exported by customers to the microgrid at the time it is used by another customer, even if they are next door. This issue applies to **Type 1**, **Type 2** and **Type 3** systems irrespective of whether the microgrid is operating in grid-connected or islanded mode. Where Type 3 systems include a centralised battery, under the NEM Rules it is treated as a load and so network charges apply to electricity used to charge it. These charges are avoided if the battery is owned by the DNSP.

There is ongoing discussion regarding the possibility that DNSPs could apply Local Use of System (LUOS) charges (where a smaller network charge is applied) to electricity that is both generated and used within the microgrid. Although Rule 6.18.4 of the NER (National Electricity Rules) states that "retail customers with a similar connection and usage profile should be treated on an equal basis," which would appear to rule out LUOS charges. However, Rule 6.18.1C allows a tariff structure to be changed, as long as:

- The DNSP's revenue from the relevant tariff each year is no greater than 0.5% of its annual revenue, and
- The DNSP's revenue from the relevant tariff, as well as from all other relevant tariffs, each year is no greater than 1% of its annual revenue.

Thus, LUOS charges should be possible but would require a waiver from the Australian Energy Regulator (AER).

In the absence of LUOS charges, **Type 1** autonomous systems on a microgrid would be treated the same as on the main grid. If LUOS charges were able to be applied, any exported electricity that is used by neighbours would be cheaper and could be cheaper still if the retailer component is also reduced. Similarly, the retailer could choose to pay more for exported electricity than their standard feed-in tariff (FiT) to encourage more distributed renewable generation. However, such discounts and mark-ups would reduce revenue to the DNSP and the retailer. In addition, the application of LUOS would require some form of LET to track electricity that is used within the microgrid rather than exported to the main grid.

Type 2 orchestrated DER systems are already being trialled in Australia. Where the network is owned by a DNSP, there seems little reason to develop a VPP on a remote microgrid, with an unreliable connection to the main grid, unless it is being used to provide local network support.

Local Network support can be:

- reducing demand peaks (to reduce the need for network augmentation and to avoid voltage drop), or
- soaking up excess solar export (to reduce reverse power flow and voltage rise).

Network support requirements are very site-specific. According to Ergon Energy Network, there is no need for network augmentation for Yarrabah due to the forecast peak load increase being within the capacity of the existing feeder. It is likely that the centralised battery would be as effective as batteries in a VPP without the additional expense required for orchestration.

Microgrids can include **Type 3** systems in the form of centralised generation/storage owned either by the DNSP or by a third party. As discussed in Section 11.2, under Rule changes proposed by the AEMC, a DNSP can own and operate generation assets such as batteries on an islandable microgrid but only to the extent that they are providing network support.

For isolated microgrids, the DNSP can own generation assets for the purpose of providing electricity (as well as network support) if they have a waiver from the AER.

For islandable microgrids, the financial viability of centralised generation/storage assets is maximised if they participate in wholesale spot ($/MWh) and Frequency Control Ancillary Services ($/MW/hour[97]) markets, which is not allowed under DNSP ownership. Thus, they are most likely to be privately owned. A privately-owned renewable generator and battery will sell electricity into the spot market, most likely through a PPA with a retailer. They could also provide network support through a bilateral contract with the DNSP.

12.3 Power Purchase Agreements

Typically, a Power Purchase Agreement (PPA) is an agreement for a generator, such as a solar or wind farm, to sell electricity to a buyer such as a retailer or a large customer. It commonly defines all the commercial arrangements including the term of the agreement (including possible extensions), penalties for under delivery, metering points, how loss factors are dealt with, payment terms, force majeure, and termination (including provisions for residual value). It may be 'bundled', meaning that it includes the Large-scale Generation

[97] The NEM has eight markets for FCAS, the six Contingency markets to raise or lower the frequency cover the periods Fast (6s), Slow (60s) and Delayed (5 Minutes). Bids are submitted in $/MW/hour but payments are for enabled services provided. For each dispatch interval of the market, the NEM dispatch engine determines a clearing price for each of the eight FCAS markets. Payments are then equal to the MW provided times the clearing price divided by 12 (to convert from hourly to each 5 min dispatch interval).

Certificates (LGCs) produced by the renewable generation, and can even be only for the LGCs. It may also include the provision of ancillary services.

12.3.1 Co-located direct physical supply

For isolated power systems and behind-the-meter projects, the PPA is usually a direct, physical supply of electricity contract with straightforward metering requirements.

For generation projects and loads that are not co--located, network losses, connection points, and regulatory considerations make any PPAs (Power Purchase Agreements) more complex.

12.3.2 Financial

The most basic type of PPA is variously called a financial, synthetic, or virtual PPA. The generator and buyer agree on a PPA strike price ($/MWh) for the electricity. This strike price may change over the time of the agreement and can even differ for various times of the day.

The generator feeds its total net electricity into the main grid with this metered output being adjusted by the marginal loss factor before receiving the relevant spot market price. For the quantity delivered to the grid a ‘contract for difference’ then operates under the PPA, calculating the difference between the PPA strike price and spot market price received for that quantity.

If the spot market price is lower than the strike price, the buyer pays the generator for any shortfall, and if the spot market price is higher than the PPA strike price, the generator pays the buyer any excess to the PPA strike price.

This means that the generator benefits from revenue certainty over the PPA term which assists in securing the finance needed for the project. Similarly, the buyer is guaranteed a fixed price for the wholesale electricity spot price covered by the PPA, and so reduces risk from market price increases and volatility. Note that if the buyer is a customer, then it must still purchase the physical electricity from a retailer. Thus, the PPA is actually a financial hedging contract.

12.3.3 Supply linked

A ‘supply linked PPA’ is where the Financial PPA is wrapped into a supply contract with a retailer that includes coverage of the balance of the customer’s load. In this case, the PPA can be for a different period to the overall supply contract.

12.3.4 Sleeved

A sleeved PPA is like the Financial PPA except that the customer is an electricity retailer, who then on-sells that electricity to one or more of its customers.

12.3.5 Physical

A ‘physical PPA’ is also similar to a Financial PPA. The difference being that the buyer takes title to the physical energy at a specified delivery point on the electric grid, and so the generator and customer must be on the same network. In the Australian NEM, it is preferable that the generator and customer load should be in the same jurisdiction to avoid the complexities inherent in dealing with the different spot prices and loss factors for each jurisdiction as well as any interconnector constraints.

12.3.6 Preferred Energy Arrangement for the Yarrabah Microgrid

EnergyConnect recommends that the owner of the central solar-battery-standby generator asset negotiate a financial arrangement, which could be a PPA, with a suitable 3rd party, such as Ergon Energy Retail to allow a financial value to be placed on the energy produced by the central power assets, and the energy consumed when charging the central battery. To maximise the value of this PPA, in grid-connected mode, some of the central battery capacity could be used to firm generation output in peak demand periods. It may also be possible to provide FCAS[98] when in grid-connect mode. A separate bilateral contract could also be established with Ergon Energy Network for the provision of network support, for example during islanding events, but also during times of high demand while in grid-connected mode.

Ideally, this financial arrangement would also detail financial flows when the microgrid is in island mode. However, as discussed in Section 11.2.2, where a microgrid may be grid-connected some of the time and islanded some of the time, the regulatory requirements are not entirely clear. For Yarrabah there seems to be three options, discussed below.

i) Financial contract is with 3rd party who does not on-sell the electricity to Ergon Energy Retail

In this case, the financial contract/PPA is with a 3rd party such as a consumer or aggregator outside of Yarrabah and covers the terms for grid-connect mode. The contract would include a clause that allows the PV-battery generator to cease providing electricity for main grid services purposes when the main grid is down.

Then, in islanded mode, the approach outlined in Section 11.2.2 could come into effect, (the SAPS rules apply), outside of the financial contract/PPA. The contracted 3rd party would pay the wholesale settlement price determined by AEMO, the owner of the PV-battery generator would receive that settlement price, and Ergon Energy Network would receive the standard network payments from the retailer as per usual.

ii) Financial contract is with a 3rd party who normally on-sells the electricity to Ergon Energy Retail

In this case, the financial contract/PPA is with a 3rd party such as an owner of electricity generation assets or an aggregator. Instead of the contract including a clause that allows for the PV-battery generator to cease providing the electricity when the main grid is down, it

98 Frequency Controlled Ancillary Services, which can be provided anywhere on the main grid, and is called upon to ensure the grid frequency stays within the allowable range.

could be modified so that it caters for islanded mode as well. The islanded mode terms would only apply to the electricity consumed by the Yarrabah microgrid in islanded mode.

There are two sub options:

- The contracted 3rd party would pay the wholesale settlement price determined by AEMO, the owner of the PV-battery generator would receive that settlement price, and Ergon Energy Network would receive the standard network payments from the retailer as per usual, or
- All payments are identical to the situation where Yarrabah is still grid-connected i.e. Ergon Energy Retail pays the 3rd party who then pays the owner of the PV-battery generator as per their contract terms for operating in grid-connect mode or possibly under different terms in islanded mode, and Ergon Energy Network receives the standard network payments.

iii) Financial contract is with Ergon Energy Retail

In this case, again, when the main grid is down, the contract would only apply to the electricity consumed by the Yarrabah microgrid. However, it may be possible to avoid the need for AEMO to determine a settlement price because the islanded mode $/MWh would already be specified in the contract. This approach may have administrative advantages as some main grid outages are only for quite short periods. However, as discussed, the required Rules are yet to be determined by regulation, and so this remains an area of uncertainty.

Typically, main grid outages are a cost for Ergon Energy Network to fix. Ergon Energy Retail loses electricity sales to Yarrabah in an outage, but beyond this it does not have any additional financial incentives to improve power reliability in Yarrabah. Thus, any contract with Ergon Energy Retail would have to be negotiated on purely commercial terms. Larger PV systems, located elsewhere in Queensland, may be able to offer lower contract/PPA strike prices, making negotiation of a Yarrabah contract/PPA with Ergon Energy Retail more challenging.

13

Alignment with Other Utility Services

13 Alignment With Other Utility Services

13.1 Water, Sewage and Energy Nexus

Water supply, sewerage pumping, and treatment processes are amongst the largest electricity consumption activities at Yarrabah. Domestic water supply to residents is unmetered and, as most of the houses are owned by Council, there are no separate water charges levied to recover the costs of providing this service.

Water is pumped and stored in response to community demand, and consequently energy consumption associated with the provision of water reflects the water usage requirements.

Four bores are located along Bukki Road, Yarrabah[99] as shown in Figure 33. The bores are 45 – 60 m deep and have estimated capacity of 25 – 30 litres per second each. Bores 5 and 6 are operational. Bores 2 and 7 are being equipped with new pumps and electrical switchboards and are expected to be operational before the end of 2021.

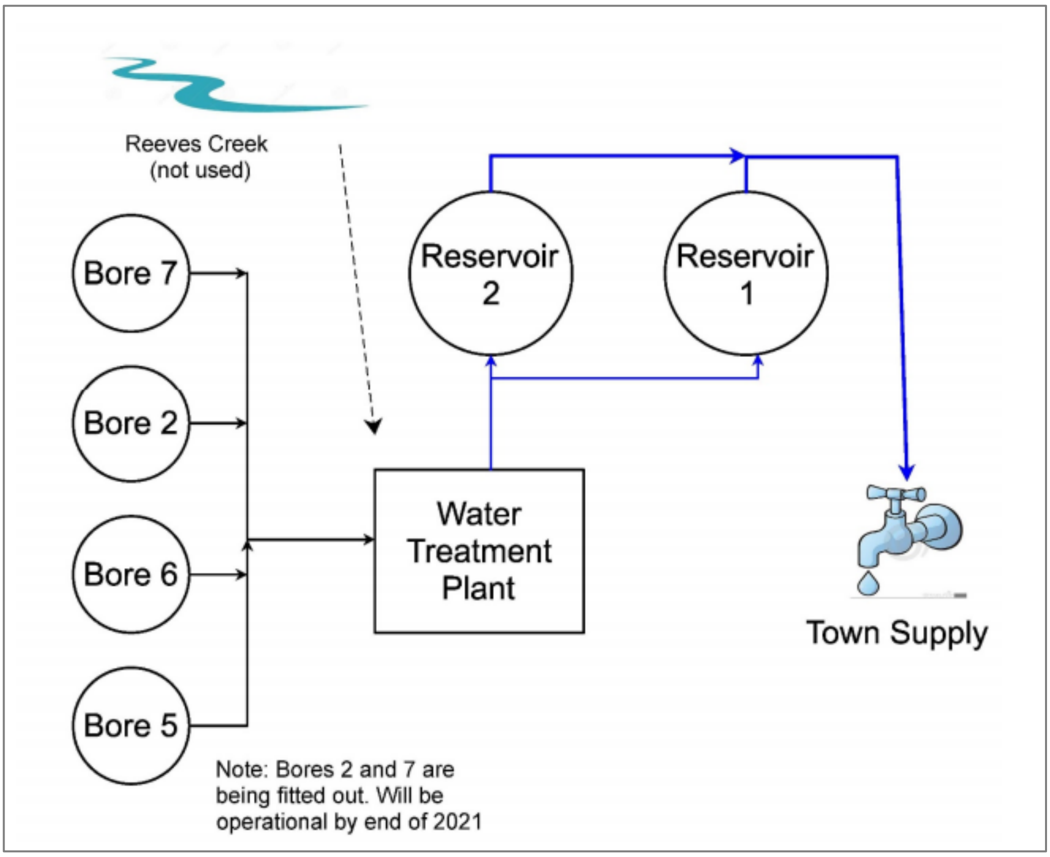

Figure 33 Yarrabah Water Supply System Schematic

Bore operation is controlled by the water level in the reservoirs through the SCADA system. The duty bore is selected by the operator. One bore is usually sufficient to supply the demand.

[99] YASC Drinking Water Quality Management Plan (7 April 2021) page 4

The water treatment plant provides disinfection using liquid sodium hypochlorite. The pH correction system (using caustic soda) is not used. Two marble chip filters have been decommissioned.

Two water storage reservoirs provide storage and gravity distribution to the water supply network. Each reservoir has effective storage of approximately 2.5 ML. The two reservoirs operate in parallel, and the water level controls the bore operation (see Figure 34). There is a level element in one tank only, which creates a problem if that tank is taken off-line for maintenance.

For the 2020/21 period annual energy consumption for the bore pumps, booster pumps, and water treatment station (see Figure 37) was approximately 470,000 kWh. The energy usage for sewerage pumps (see Figure 36 for example) and sewerage ponds was approximately 200,000 kWh for the same period.

The bore field is located at Bukki Road within an area that has previously been planted with pine trees which are mature and potentially millable and is largely void of other native remnant native vegetation. Given the high energy consumption at this site, which is owned and operated by Yarrabah Council, it has been identified as a potential future development site for "behind-the-meter" microgrid assets, which could be configured to offset Council's water pumping costs.

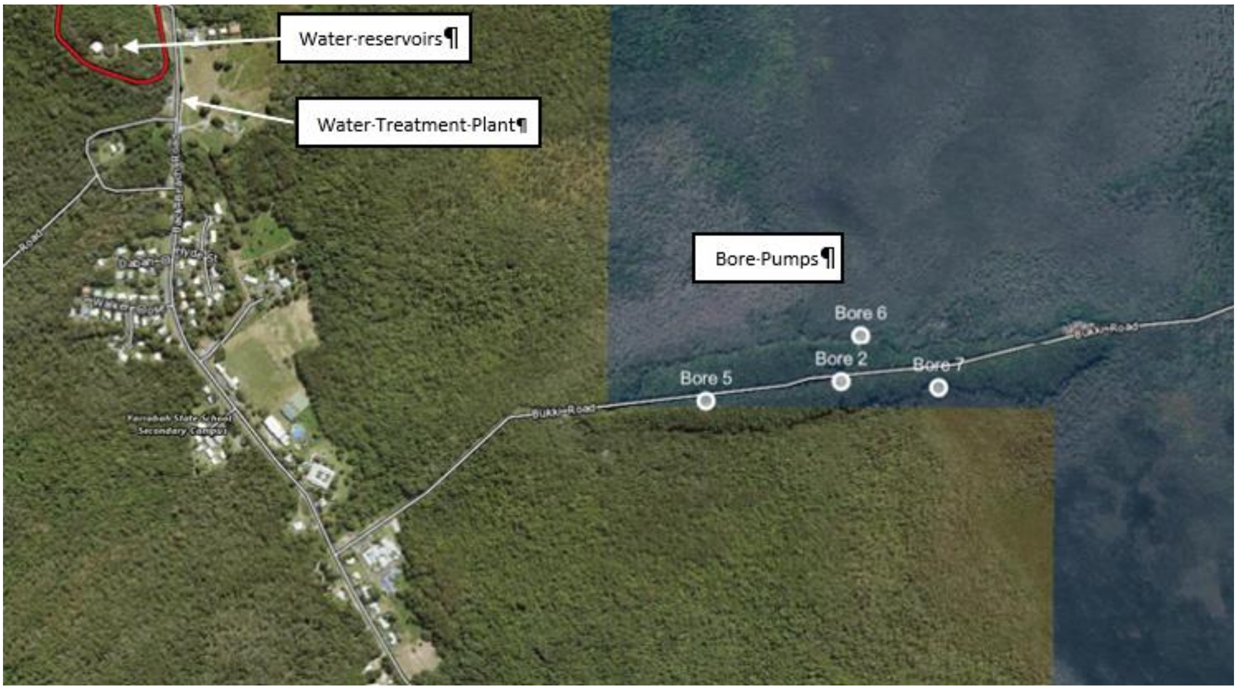

Figure 34 Map of Yarrabah Key Water Supply Infrastructure

There is standby generation installed at all sewerage pumps and bore pumps for emergency requirements in the event of loss of mains power.

Reeves Creek was previously the source of domestic water for Yarrabah but is no longer used due to water turbidity issues experienced during the wet season (see Figure 35).

The existing infrastructure including weir and pipe system could be re-purposed for micro hydro-electricity generation. Preliminary assessments indicate that a 10KW micro hydro generator could be installed on the existing water pipe near the water treatment facility, and that this could produce approximately 70,000 kWh per annum based on 80% availability, covering the power requirements for the existing water treatment facility and providing excess generation to the electricity grid.

Figure 35 Old water intake structure at Reeves Creek - no longer used

Figure 36 Typical sewerage pump station - Yarrabah

The “chlorine shed” consumed 2,550 kWh of energy in the 2020/21 fiscal year with its needs more than adequately met by the proposed 10 kW micro hydro generator.

The total energy cost for the chlorine shed for 2020/21 was $1,127. The use of the micro hydro system “behind the meter” would save this expense and generate $4,445.50 per annum in additional revenue, assuming a feed-in tariff of $0.06583/kWh[100].

[100] Ergon Retail solar feed-in tariff applicable from 1/7/2021

Figure 37 Yarrabah Water Treatment Station

By implementing a modern water metering system, YASC could monitor water demand and proactively address system losses, contributing to an efficient microgrid design by reducing overall energy consumption for water pumping, reducing water losses, whilst saving the community substantial operating costs.

Figure 38 Yarrabah Sewerage Treatment Ponds

The sewerage system in Yarrabah was constructed in 1990 as an upgrade to the previously existing Common Effluent Drain system. The current network is comprised of gravity reticulation mains and rising mains, and 10 pump stations. The treatment plant consists of six sewerage treatment lagoons located on King Beach Road (see Figure 38). Treated effluent is directed to Kappa Creek, situated to the west of the lagoons.

13.2 Telecommunications

Telecommunication and internet access in the Yarrabah Community is quite limited. Despite a landline telephone network installed in the community, mobile telephone coverage and internet services are limited to the main township and some surrounding areas (see Figure 39).

There is no NBN fibre network installed to service Yarrabah and although the area is identified as a NBN satellite service area cost associated with access to satellite service providers currently inhibit uptake.

In general, mobile phone and internet network coverage is unreliable and provision of a reliable communications network for monitoring and control of microgrid components would need to be considered in the final project scope.

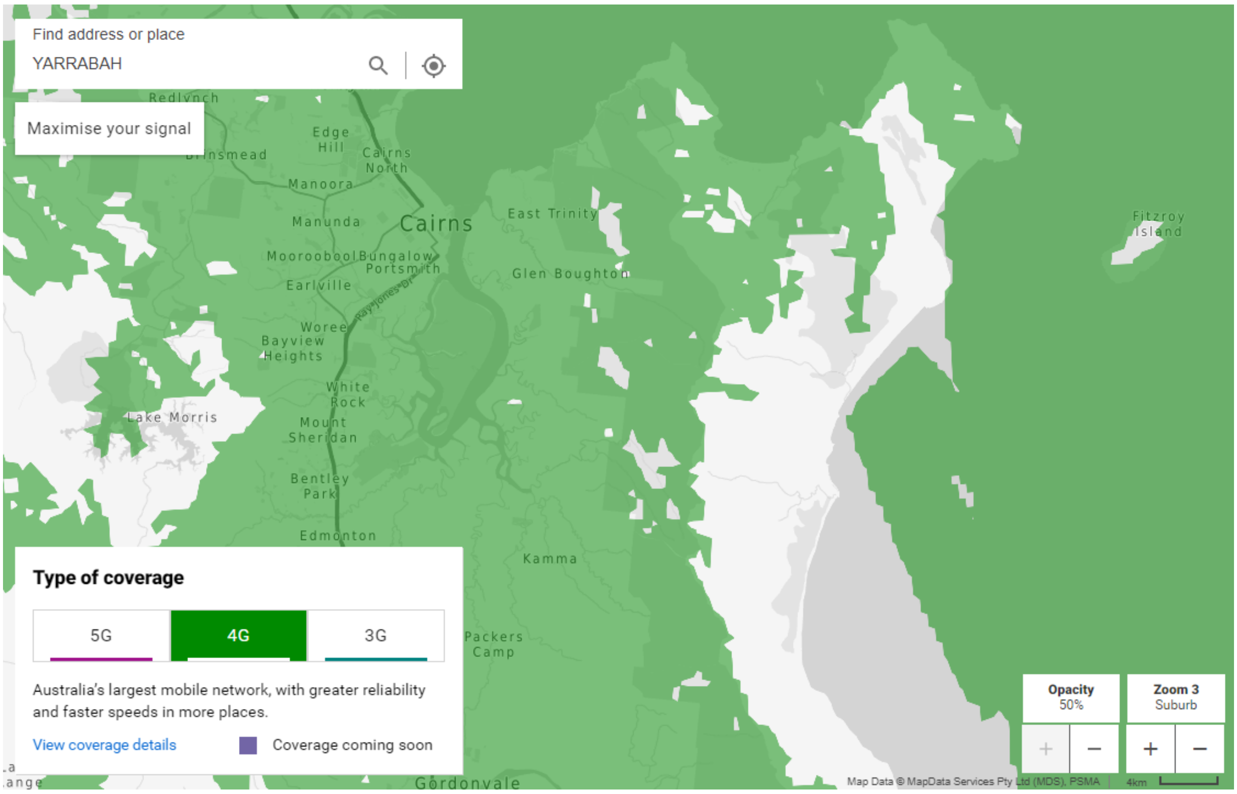

Figure 39 Mobile network coverage around Yarrabah

The availability of reliable telecommunications infrastructure is critical for enabling a wide range of opportunities for Yarrabah. It is particularly important for smart metering, energy efficiency incentives, behind-the-meter solar PV and batteries and demand response options, such as controlled loads and DREDs, and vital if Yarrabah aspires to implement a network of smart charging infrastructure and a shared electric micro-mobility fleet.

Micro-mobility shared devices are typically accessed through a simple smartphone app which requires internet connectivity. Equitable access to smartphones, with internet connectivity, would be another key necessity for enabling fair access to many of the proposed e-mobility services outlined in Section 10.

13.3 Transport

13.3.1 Roads

The Yarrabah community is connected to the surrounding communities of Gordonvale and Cairns by the Pine Creek-Yarrabah Road. This road is managed by the Queensland Department of Transport and Main Roads.

The Yarrabah Aboriginal Shire Council is responsible for road networks within the Shire.

Bitumen sealed roads and gravel roads throughout the Yarrabah Shire are managed by YASC. Sealed roads are in place throughout the township and along the main transport corridor (Back Beach Road) extending south to the Oombunghi community area. Road access is not expected to be a limiting factor for potential microgrid development sites at Yarrabah.

The Ergon Energy overhead powerline distribution network generally follows the established road network.

Council had been undertaking footpath refurbishment works throughout the community and installing concrete pathways adjacent to the main roads to facilitate a safe network for pedestrian traffic.

13.4 Solid Waste

Council provides a weekly household waste collection service. Solid waste is delivered to a waste recycling and disposal facility located at the commencement of King Beach Road, east of the township. Landfill, as a form of waste disposal, does not occur in Yarrabah due to the highly permeable soils and high ground water levels. All waste is transferred outside the local government area for safe disposal at a suitable location.

14

Concept Microgrid Design Options

14 Concept Microgrid Design Options

This section discusses the approach to assessing the options and considerations for the design of a concept microgrid.

14.1 Integrated Assessment of Options

As described in previous chapters, multiple options can be combined into a microgrid solution to increase the reliability of electricity supply for the Yarrabah community. An integrated assessment approach is therefore needed to formulate conceptual design that combines the best mix of options and delivers a solution that takes into consideration costs, operation, and land constraints as well as benefits to the community.

The integrated assessment approach assessed a range of options, consistent with the aims of the study to highlight technologies for a sustainable microgrid, to determine the lifecycle[101], least-cost pathway to meeting the electricity load profile in Yarrabah.

The option of a diesel generation only solution to the town's power reliability issues was not modelled as the Council and community have expressed the preference to demonstrate a microgrid that is predominantly renewable generation and provides benefits in grid-connected as well as islanded mode.

The integrated assessment approach uses the min-E model as described in further detail below.

The assessment considered a range of supply options for electricity generation and storage as well as approaches to reduce and manage the demand for electricity in the community. Supply options take into consideration the relative availability and cost of renewable generation options and their suitability for combination with storage options.

Demand options include embedded generation and energy efficiency measures to manage electricity consumption across residential premises. Simulations using min-E determined a least-cost combination of supply and demand-side measures that can supply electricity to the Yarrabah community during extended (i.e. 6 hours or more) outages at any time of year at the least cost while observing land constraints and community requirements.

14.1.1 min-E model

The min-E model is a least-cost generation and storage simulation tool for a grid-connected network developed by ITP. The min-E model computes the optimal combination of embedded generation technology options and energy storage to satisfy a given electricity load profile over a multi-year period at the least cost.

[101] Overall cost arising for the useful life of an asset from initial design to decommissioning.

Technology cost and performance parameters are configurable to each individual site. The min-E model outputs include the coordinated dispatch of generation and storage on an hourly basis for each simulated year, storage charge and associated operating costs. A scenario-based analysis of multiple min-E runs allows the exploration of flexible demand options and islanded operation.

The min-E model was used to analyse the least cost options to meet Yarrabah's electricity consumption requirements considering the most severe outage in Yarrabah.

The modelling was based on the following parameters and assumptions:

- A 12-month consumption (load) profile constructed using 15-minute interval and outage performance data supplied by Energy Queensland for the fiscal year 2019-20. The data was cleansed to exclude the impact of atypical system-wide events on average and peak loads. Based on this data, a total for main grid outage periods of 20 hours per year was assumed.
- Resource traces for generation and storage options (as considered in section 8) were generated specifically for the Yarrabah site using typical meteorological year data and historical satellite data. Rooftop PV estimates were done using the NREL (National Renewable Energy Laboratory) PVWatts[102] tool, Standalone PEG PV performance was estimated with PVSyst and wind performance estimates from Renewables Ninja[103]which uses the NASA MERRA-2 long term dataset[104].
- PV panels are assumed to have 0.8% per year performance degradation and require an inverter change at 12 years for an assumed lifetime of 25 years.
- BESS are assumed to have a 2.6% storage capacity degradation per year, requiring a replacement of storage modules at 15 years, and an inverter replacement at 12 years for a 25-year lifetime.
- The load balance model was run for the years 2022 to 2032 using build and operating costs for a range of electricity generation and storage technologies to be installed.
- To forecast future electricity demand, an average and peak electricity consumption was determined for each person and household. These parameters were then escalated based on the assumptions that the population increases at 0.5% per year and the number of dwellings increases at 2% per year[105].

[102] https://pvwatts.nrel.gov/ (last accessed 11 November 2021)

[103] https://www.renewables.ninja/ (last accessed 15 June 2021)

[104] https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

[105] Existing Queensland statistics on household electricity consumption were deemed to be not applicable to Yarrabah due to differences in the housing profile. Demand based on survey information collated by Planz and the Missing Link in 2021.

- A total of 428 dwellings[106] was estimated for Year 1, consuming about 91% of electrical demand.
- About 60 recently built dwellings and all future dwellings are assumed to meet energy efficiency standards. Existing dwellings are assumed to have inefficient use of appliances consistent with results of survey data, with space cooling and water heating contributing to 73% of electrical use by dwelling.
- Modelled demand based on the loads metered at SA.1A and SA.16A which are two sectionalised areas of the network which can isolate as the microgrid section of the network.
- An assessment of rooftop orientation and potential solar PV capacity that could be hosted on residential dwellings in Yarrabah was undertaken using satellite images. All rooftops were counted, assessed for suitability, and classified into different orientations. In addition, rooftop space was assessed to identify the capacity of rooftop PV systems in kW that they can hold. Table 11 shows a summary of assessed rooftop orientations for Yarrabah, which is used to generate a PV trace for min-E that considers the diversity of system orientations and their contribution to the microgrid. Table 12 shows a summary of the assessed capacity of residential roofs to host rooftop PV systems. Additional assessment details can be found in Appendix B4.

[106] Estimate by Planz and the Missing Link.

Orientation	Beach Front	Sawmill Rd	Museum	Residential development	Remainder	Total	Percentage
Normal 0° due North	2	0	24	0	13	39	8.94%
Normal 90° due East/West[107]	5	0	18	0	13	36	8.26%
Normal 20° due East	70	35	4	24	9	142	32.57%
Normal 20° due West	79	25	16	51	4	175	40.14%
Flat	29	2	7	0	6	44	10.09%
Total	185	62	69	75	45	436	100%

Table 11 Rooftop orientations for Yarrabah residential and commercial buildings

Orientation	1 (kW)	2 (kW)	3 (kW)	4 (kW)	=>5 (kW)	Total # of roofs
Normal 0° due North	0	1	0	0	24	25
Normal 90° due East/West	0	1	1	1	27	30
Normal 20° due East	1	8	19	17	151	196
Normal 20° due West	0	4	5	5	135	149
Flat	0	0	0	1	27	28
Total	1	14	24	24	363	428

Table 12 Number of residential dwellings that can host specific capacities of rooftop PV systems

14.1.2 Generation and storage options under consideration

A range of design options were included in min-E, to determine the optimal integrated mix of technologies that, when dispatched in coordination, maintain power supply to the community during extended outages at the lowest levelized cost of electricity (LCOE). Under a wide range of scenarios and technology cost sensitivities, min-E consistently showed that the optimal mix of generation includes standalone photovoltaic farms, BESS and a standby generator.

[107] Split into E and W facing panels

Additional options considered that did not feature in the mix either didn't contribute to the microgrid with a net reduction in LCOE (i.e. resulted in a more expensive system) or faced constraints external to the model that made them infeasible. An example of the latter is Pumped Hydro Storage, which can provide a more cost-effective method to store and dispatch electricity than BESS but is not feasible due to geographical and environmental constraints in Yarrabah.

Table 13 shows the generation and storage options considered in min-E scenarios. Indicative capacities for each technology show their resulting modelled size as components of an integrated microgrid system if land or cost constraints are not observed.

Technology	Capacity	Land area	Number of sites	Modelled costs
Solar farm(s)	3.5 MW to 16 MW	0.6 ha / MW 2.1 Ha to 9.7 Ha total	1 to 4	Build: $1,100/kW Fixed O&M: $5.5/kW/y Inverter refurb: $115/kW
Community batteries	1.8 MW / 10 MWh to 2.4 MW / 19.2 MWh	2 to 4 x 20-foot containers	1 to 2	Build: $3,748/kW (6h) Fixed O&M: $48.75/kW/y Refurb: $2,000/kW
Pumped hydro storage	1.7 MW / 10.2 MWh	4 ha including reservoirs	1	Build: $2,800/kW (6h) Fixed O&M: $51.9/kW/y Variable O&M: $0.05/kW
Standby generation	~900 kW	2,000 to 4,000m2	1	Build: $1,500/kW Fixed O&M: $15.31/kW/y Variable O&M: $0.3/kWh
Rooftop solar	Up to 1.5 MW	Existing rooftops	Up to 300	Build: $5,800/house Refurb: $1,500/house
Individual batteries	Up to 1.5 MW	Fitted to existing buildings	Up to 300	Build: $13,500/house Refurb: $13,500/house
Micro hydro	Up to 20 kW	Existing streams and weirs – minimal land impact	1 to 2	Not included in min-E modelling
Small wind	400 kW	2.5 ha per turbine based on 100 kW turbine (includes airflow spacing)	Multiple	Build: $3,500/kW Fixed O&M: $15.31/kW/y Variable O&M: $0.01/kWh

Table 13 Generation and storage options considered in min-E scenarios

Results from min-E provide the basis for the relative scale and coordination of microgrid components. This is useful to reveal indicative relative sizes of generators and storage and consequently their land use. More concrete sizing of the optimal mix of required generation and storage technologies is undertaken in concert with demand side options, as described in the next section.

14.1.3 Demand side options and microgrid component sizing

With the given set of specific and screened technology options, min-E can be employed to consider the effect of demand side measures such as behind-the-meter PV systems and energy efficiency measures on the optimal mix of microgrid technologies.

The following demand side options were formulated as scenarios and simulated in min-E to compute optimal mix microgrid configurations:

a) Base case (centralised solar farm, BESS and standby generator)

b) Base case and energy efficiency program to reduce demand from the main grid

c) Base case and distributed solar PV on residential dwellings

d) Base case and distributed solar PV on community/commercial buildings

e) Base case and distributed solar PV on residential dwellings and community/commercial buildings, and

f) Base case, energy efficiency program, solar PV on residential dwellings and community/commercial buildings

Additional data for modelled demand forecasts can be found in Appendix B.1.2.

Base case configuration

The base case configuration assumes no changes to electricity demand in Yarrabah and it is used to establish a baseline microgrid mix configuration. The min-E model will only build generation into the mix if the cost per MWh is competitive or if the generation source can substantially contribute energy to an islandable microgrid. The base case modelling of a least cost microgrid showed:

- A combination of 3.5 MW PEG[108] solar PV, 1.8 MW / 10.8 MWh battery and 900 kW standby generator can meet the Yarrabah load all the time including the most extreme outages.
- If not constrained in operation, the standby generator operates about 15% of the time that the microgrid is in island mode.

Network modelling studies undertaken using the base case model parameters found it was possible for the system to work as a microgrid, i.e., connected to the main grid with the capability to run in islanded mode during outages. The model was also run to assess the impact of generation from modular pumped hydro and small wind turbines, with the results shown below. Run-of-river hydro for Pine Creek was considered but not assessed by the min-E model as the amount of power from a potential run-of-river hydro plant was not significant enough to impact on the assessment.

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[108] PEG solar is where the PV modules are fixed with the module rows alternately facing east and west. This maximises the amount of solar for a given land area, (around 1.7 MW_p per hectare). Further information is available from: belectric.com/solarplants/peg/

The base case with zero emission power supply was also evaluated. The model min-E was run with base case demand but configured to exclude standby generation (i.e. a zero emission, least cost microgrid is sought). The modelling did not yield a feasible configuration, as results indicated that:

- The central solar PV increases in capacity to offset the standby generation. A combination of over 16 MW solar and 4.3 MW / 19.2 MWh battery is required to supply the Yarrabah load at least cost without standby generation.
- The insight that can be gained from this modelling exercise is that tropical areas such as Yarrabah experience extended periods of low solar radiation during the wet season. These periods lead to a substantial and inefficient oversizing of PV to produce enough electricity to supply the town and charge the BESS during cloudy periods. Conversely in the dry season, the PV farm must be heavily curtailed. Moreover, the BESS inverter capacity also must increase well beyond the highest hourly average load for the community so that sufficient charge can be stored in limited daylight hours to run the system during heavy cloud periods and outside daylight hours.
- In addition, the anticipated land constraints to host such a PV farm are not feasible in Yarrabah and the additional capital costs. I.e., the additional plant cost for the option without standby generation is in the order of $23 million with respect to the base case with standby generation, which only offsets a reduction in annual running costs of approximately $360,000, assuming unconstrained operation for 15% of the year. Thus, subsequent scenario evaluations do include standby generation as part of the generation mix. It is hoped that the technical and economic merits of including standby engines in microgrid configurations can be enhanced by the environmental benefits of zero emission fuels (e.g. biofuels or H2) in the near future.

Base case and demand side measures

Behind-the-meter solar generation and energy efficient appliances have the potential to substantially reduce electricity demand as seen by the microgrid and have the potential to impact on the total size of the system. Furthermore, these measures are installed on existing dwellings and premises and thus can alleviate land requirements for the microgrid. Demand scenarios b) to e) examine different configurations of three demand side options:

- Energy Efficiency
- Behind-the-meter rooftop PV on residential dwellings
- Behind-the-meter rooftop PV on community buildings.

Energy efficiency: Low efficiency air conditioners and hot water systems are replaced by modern split cycle air conditioners and heat pump hot water systems. From 2023, it is assumed there is a replacement program roll-out of 300 high-efficiency, split cycle air-conditioners with an average load of 1.35 kW_e each[109] and 300 heat pump hot water systems (300 litres tank with a coefficient of performance 4 or higher) into dwellings. This measure is due to a substantial proportion of residential demand currently being for space cooling and hot water, and that this demand is met with inefficient appliances.

The energy efficient appliance roll-out drives further reductions in demand growth in Yarrabah relative to the base case with residential and community/commercial solar. As a result, the required capacity of the centralised solar PV is reduced by 57%, standby capacity is reduced by 21% and the battery capacity reduced by 9%.

The potential for energy efficient air-conditioners and hot water systems, to be operated as DREDs to provide short duration, aggregated residential response to peak demand events on the network was investigated. Yarrabah's peak demand profile is not characterised with an extreme peak, rather the profile is for high demand over several hours at a time over a period of multiple weeks. This means that the benefits of DRED appliances such as air-conditioners and hot water systems could only be realised by turning them down for extended periods of time, most likely when they are needed the most. This is likely to result in householders deactivating remote control of their air-conditioners and hot water systems, meaning that using DRED appliances to manage total load is unlikely to be viable. Energy efficiency has a greater impact on average demand levels without loss of amenity. Many heat pump hot water systems come with a timer to control boosting and these could be used to maximise daytime electricity consumption.

Behind-the-meter residential PV: From 2022, it is assumed that there is installation onto dwellings of a total of 1.5 MW_{AC} of generation capacity comprised of 300 behind-the-meter roof-top PV systems at 6.6 kW_p / 5 kW_{AC} each.

The potential for these PV systems to be installed with batteries was explored, with 20% and 50% proportions of installs having behind-the-meter batteries (5 kW / 13.5 kWh each) modelled. Behind-the-meter solar and batteries have a substantial impact on smoothing the average demand profile over the day. However, the costs of installation and maintenance of distributed battery systems would be higher than that of a central battery.

Behind-the-meter PV in community buildings: A further total of 560 kW_p / 400 kW_{AC} of roof-top solar PV on a range of community/commercial buildings was also assumed to be installed in 2022.

The results of the residential solar PV and community/commercial solar PV on the Yarrabah demand growth from the main grid is significant with average consumption falling over the ten years to 2032. As a result, the required capacity of the centralised solar PV is reduced by 40%, standby capacity is reduced by 7% and the battery capacity increased by 6%.

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[109] Sized to cool 60-80m^2 an estimate for average mid-size living rooms that may be common in Yarrabah dwellings.

Optimum design

For scenarios with demand side assumptions b) to e) min-E again computes that the optimal technologies for a microgrid in Yarrabah are a centralised solar array co-located with a battery and standby generator. However, the total size of the microgrid components is significantly impacted by demand side measures. Residential and community/commercial roof-top solar PV and energy efficient appliances reduces the electricity demand growth in Yarrabah and therefore the installed capacity and land requirements of the centralised solar PV, battery and standby generation plant as shown in Table 14. Modelled demand side reduction measures result in additional capital expenditure and maintenance costs for the project, but their impact on the size of microgrid generation and storage sizing is such that their net effect is still a reduction in levelized cost of electricity for the complete solution. Therefore, all measures show the potential to be implemented as a part of an islandable microgrid in Yarrabah.

Description	Energy Efficiency	Residential PV (kW)	Community PV (kW)	Solar farm (kW)	BESS - 6hr (kW)	Standby generator (kW)	Calculated LCOE ($/kWh)
Base Case	NA	NA	NA	3,500	1,800	900	0.18
Base Case + Energy Efficiency	Yes	NA	NA	3,300	1,500	800	0.16
Base Case + Residential PV	NA	1,500	NA	2,000	1,500	650	0.16
Base Case + Residential and Commercial PV	NA	1,500	400	1,600	1,800	650	0.15
Base Case + Energy Efficiency + Residential and Commercial PV	Yes	1,500	400	1,450	1,700	550	0.12

Table 14 Microgrid options design summary

Impact on greenhouse gas emissions of optimal microgrid

It is possible to estimate greenhouse gas emissions reductions for the community resulting from the implementation of the microgrid by computing the annual difference in electricity consumption from the Queensland grid forecasted with and without the microgrid. Using AEMO ISP and openCEM forecasts, it is also possible to estimate the annual rate of emissions in kg/MWh resulting from using electricity from the Queensland grid. Assuming the first year of operation of the microgrid is 2022, and a moderate pathway for decarbonisation for the Queensland electricity grid, Table 15 shows annual forecast annual greenhouse emission reductions due to the reduction in consumption of electricity from the Queensland grid and renewable generation by the microgrid.

Year	Electricity consumption (no microgrid) (kWh)	Net electricity consumption with microgrid (kWh)	Emissions intensity kg/MWh	Emissions saved (Tons)
2022	7,189,720	1,282,175	768	4,537
2023	7,293,311	1,035,876	749	4,684
2024	7,396,901	789,577	729	4,817
2025	7,518,032	672,815	710	4,857
2026	7,639,163	556,053	690	4,887
2027	7,787,399	620,003	671	4,806
2028	7,935,635	683,952	651	4,721
2029	8,068,348	759,272	632	4,616
2030	8,201,061	834,592	612	4,508
2031	8,363,369	922,238	593	4,409
2032	8,525,676	1,009,883	573	4,307
2033	8,525,676	1,009,883	554	4,160
2034	8,525,676	1,009,883	534	4,013
2035	8,525,676	1,009,883	515	3,867
2036	8,549,034	1,012,650	495	3,731
2037	8,525,676	1,009,883	476	3,574
2038	8,525,676	1,009,883	456	3,427
2039	8,525,676	1,009,883	437	3,281
2040	8,549,034	1,012,650	417	3,143
2041	8,525,676	1,009,883	398	2,988
2042	8,525,676	1,009,883	378	2,841
2043	8,525,676	1,009,883	359	2,694
2044	8,549,034	1,012,650	339	2,555
2045	8,525,676	1,009,883	320	2,401
2046	8,525,676	1,009,883	300	2,255
			Total	**96,076**

Table 15 Forecast reduction in GHG emissions due to reduced electricity consumption and the microgrid

Operating considerations

Lithium-ion battery technology is currently the highest performing and least-cost solution for applications that involve daily cycling. However, ITP's experience is that some lithium-ion battery modules are prone to premature failure, meaning a modular design is important to minimise the risk of cascading failure. The proposed BESS is intended to operate for 15 years before replacement. Ten- year warranties are standard, with some vendors able to offer 15-year warranties. A centralised, factory-integrated solution is preferred as this minimises on-site works.

To enable the microgrid to operate with the standby generators turned off, the BESS needs to be grid-forming, and capable of providing sufficient fault current to clear faults. Owing to the nature of inverter-based generation, BESS fault current capability is considerably lower than for synchronous generation of the same capacity and therefore careful protection design is required to ensure fault clearance. One way to overcome this challenge is to oversize the capacity of the BESS and the BESS inverter with respect to the expected peak load in the microgrid. Given that in the optimal configuration (which includes Energy Efficiency, Residential and Commercial PV) the expected load peak will not exceed 1.2 MW, ITP has determined that a grid-forming BESS of at least 1.5 MW can provide sufficient overcurrent to employ conventional overcurrent protection, which is consistent with the optimum design of 1.7 MW.

The BESS should be capable of curtailing excess solar output via frequency shift, as either the primary or secondary form of PV inverter control.

14.2 Assumptions and Design Parameters

The design of a microgrid, and the financial assessment of cost/benefits of the recommended solutions, are impacted by assumptions used for existing and forecast load growth, potential generation output, storage performance and other technical aspects, and the installed costs of the options in Yarrabah. The detail of these assumptions appear in Appendix B of this report.

14.2.1 Design parameters

The design goal of the microgrid was to provide support during extended network outages. Examination of outage load for Yarrabah based on Energy Queensland load data shows 3 outages with a duration over 90 minutes and one outage that lasted approximately 6.7 hours from 9am to 5pm on 26th December 2019. Designing the microgrid to support the load during an 6.7 hour outage during the wet season results in microgrid configurations that can sustain the community for the entire year. Therefore, the design premise of the microgrid is to have the capability to island the town for the entire year.

Hypothetically, if the town were islanded for the entire year, the standby generator would have to run between 1,500 and 2,000 hours, depending on load growth, seasonal variation of renewable generation, and load reduction measures (e.g. energy efficiency and behind-the-meter PV rollout).

14.3 Yarrabah Energy Knowledge Hub

The demonstration value of the Yarrabah microgrid can be significantly enhanced by establishing a multi-purpose interpretive centre. Referred to as the Yarrabah Energy Knowledge Hub (YEKH) in this report, this facility would provide access to information on microgrid technology to local residents, students and technologists from the surrounding region, and act as a hub for other remote communities who can travel to the Cairns and Yarrabah region to experience first-hand how a microgrid works. The facility is expected to provide employment opportunities for local people and provide a much-needed boost to the local economy through its “edu-tourism” value.

It is an educational facility where local experts will share information and knowledge and provide hands-on demonstrations to school children, university students, community members, tourists, representatives from other remote communities and other interested people from outside the community. There is also potential for the facility to serve a secondary function as a cyclone shelter, utilising backup power from the microgrid during natural disasters to improve the community’s climate resilience.

With a significant shortage of housing in Yarrabah, planning for future development of the community has a heavy emphasis on residential usage and there is extremely limited developable land available. To this end, the project team has endeavoured to minimise the land area required and optimise the benefits that can be derived from the sites where microgrid infrastructure is required. To account for land limitations the centre will be a multi-use facility located at the site of the central microgrid energy generation, storage and control systems facilities. A concept plan for the Yarrabah Energy Knowledge Hub is shown in Figure 40.

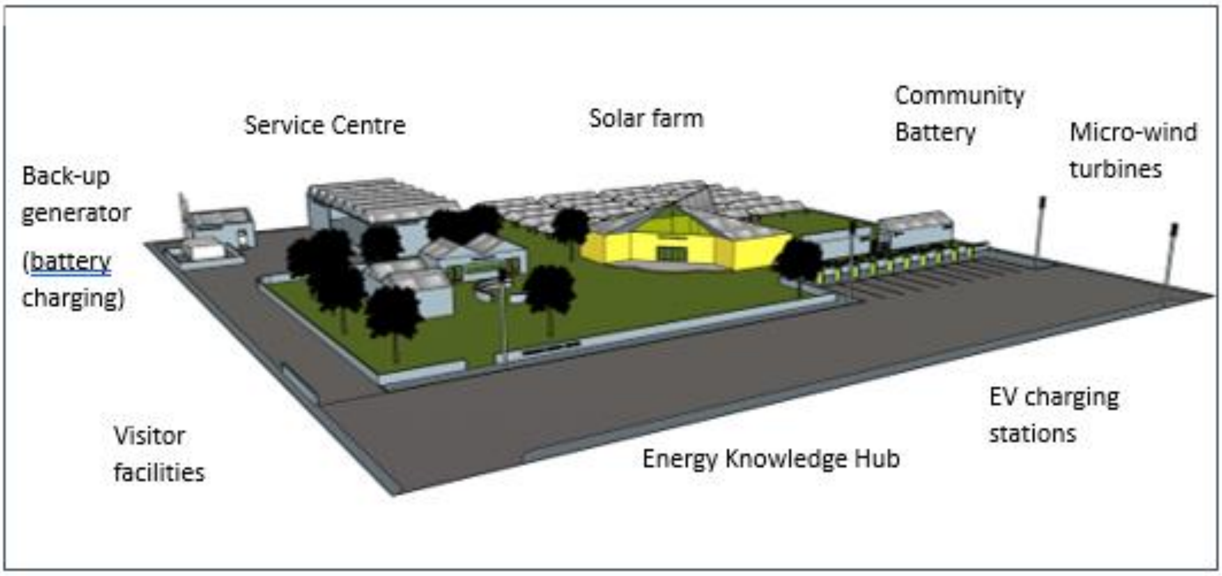


Figure 40 Concept of Yarrabah Energy Knowledge Hub

There are numerous flow-on economic and social opportunities for the Yarrabah community from the implementation of the YEKH.

14.3.1 Tourism

Yarrabah is an idyllic location in North Queensland, with enormous potential to become a tourism destination - as demonstrated in the Mandingalbay Ancient Indigenous Tours feasibility assessments, Yarrabah Cultural Centre visitation number predictions and documentation to support the ferry installation investment.

The YEKH has the potential to attract visitors from the region, other remote communities and further abroad with flow on impacts of visitors providing opportunities to the wider community. While further work is required locally to develop e-mobility infrastructure and other attractions to support a tourism strategy, access to/from Cairns and the surrounding region will be a key enabler of Yarrabah's tourism potential.

14.3.2 Employment opportunities

One of the key considerations in developing the concept of a YEKH has been the provision of local employment opportunities as part of the deployment of these new technologies. It is envisaged that many of these jobs will be co-located around the YEHK to be built in Yarrabah to raise awareness about the local community's proposed microgrid, and associated e-mobility activities. This Energy Knowledge Hub would act as a focal point for employment and provide direct employment opportunities through its establishment and operation as discussed in Section 5.4.

Yarrabah will be the first indigenous community in Australia to develop an energy technology demonstration facility with a particular focus on microgrid applications in remote and fringe-of-grid situations.

The facility will provide the opportunity to educate local children and other members of the community on how their energy is generated, the costs, technologies involved, how it is transported and consumed, and how to be more energy-efficient, via hands-on experiences.

The ***carbon-neutral site*** can be developed and used as the hub for a range of activities and will be an enabler for other commercial activities within the community.

It is envisaged that all buildings constructed on the site would have "demonstration value" for energy-efficiency and appropriateness for community requirements and local conditions, including integrated renewable energy sources such as solar PV on rooftops, battery systems for energy storage, energy-efficient appliances, energy management systems and LED lighting in a building incorporating best-practice tropical design and orientation principles.

The site would also be developed as a working solar farm with community scale battery energy storage systems installed and standby generation for recharging batteries in the event of extended grid supply interruptions or extended periods of inclement weather. The site would incorporate leading-edge technology for monitoring energy production and consumption.

An electric vehicle charging station would be located at the site to encourage and facilitate the development of an e-mobility future for Yarrabah. Electric-powered buses bringing children from other schools in the broader Cairns region for cultural and educational experiences can recharge at the site. Local commuters can charge their electric scooters, bikes and cars while they visit the site for work or to participate in educational and cultural experiences.

The facility could be used as Yarrabah's energy advisory centre, providing advice to residents on energy-efficiency, managing electricity bills, and providing advice on energy-efficient appliances. The local energy advisor could also act as a liaison officer with Energy Retailers and the Network provider. Similar services could also be supported from this site for other services like water and communication.

Apart from being an educational facility, people employed at the facility will be providing an important function for the local community, leading by example in reducing energy wastage, ensuring the reliable operation of local rooftop solar systems, as the central hub for providing maintenance services. Staff could be trained to undertake energy audits within the community and may be able to offer these services to other regional communities on a consultancy basis. In addition, all buildings could be painted / decorated by local artists in appropriate themes representative of the community.

A range of other opportunities may be available for coordinating plumbing and electrical services throughout the community, either via contract management activities, or by employing local tradespeople and trainees to provide the services as required.

The site could form part of the linkage with other key facilities at the community to provide interesting experiences for tourists visiting Yarrabah, linking the new jetty with the redeveloped town centre, and museum and art centre.

It is anticipated that Yarrabah Aboriginal Council would own and operate the site, generating revenue from visitation to the site, and from services provided to the community and beyond.

15

Proposed Business Operating Approach

15 Proposed Business Operating Approach

15.1 Asset Ownership and Management

Extensive investigations were undertaken as part of this feasibility study into possible financing/ funding models for the project assets including the rooftop solar systems, centralised solar farm, BESS, backup generator and microgrid control systems. This in turn required consideration of the intended ownership and management structure for these assets. While various ownership and management models were considered, the preferred options were those that involved YASC maintaining a beneficial or outright ownership interest in the assets.

Following consultation with Council representatives, a preferred ownership and management model was defined to include YASC, directly or through a wholly owned subsidiary, retaining outright ownership of the project assets (except for the community rooftop solar assets – Stage 2d). Through this structure YASC would manage the end-to-end program of works and would be responsible for seeking funding[110] to complete the establishment of the microgrid assets. Furthermore, YASC would retain control of the assets and would be responsible for the ongoing operation and maintenance of the infrastructure.

To support YASC, it is proposed that a special purpose implementation entity (herein referred to as Implementation Entity) is established with the primary objective of performing a Program Management function for the construction phase activities and overseeing the implementation of the operating model for the microgrid. It is expected that this entity would also be contracted by YASC to oversee the ongoing operation of the various components of the microgrid project, beyond construction. A community-based entity (entity comprised of community stakeholder representatives and other specialists) is recommended to ensure that support from community stakeholders is maximised.

The proposed ownership and management structure across both the construction and operational phases has been outlined in Figure 41.

[110] The Queensland Government has established a Working Party with YASC to assist with implementation activities including fund-sourcing activities

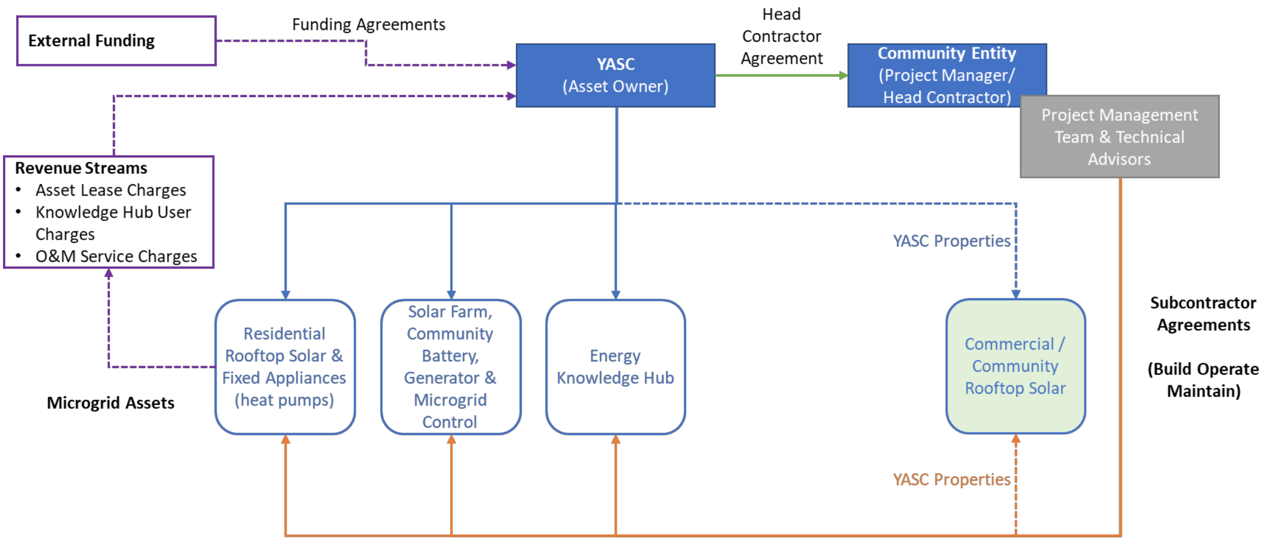


Figure 41 Proposed ownership and management structure

15.1.1 Implementation Entity

The Implementation Entity proposed for this project is expected to take the form of a not-for-profit community organisation administered by a management committee. The management committee is recommended to comprise of representatives of key stakeholder organisations involved in the project, including landholder agencies, YASC, other community groups and other independent specialists. The management committee would oversee the strategic management of the microgrid project and would have a focus of ensuring that the project remains commercially viable into the future.

The corporate structure of the entity may take many forms, with the preferred being:

- Incorporated Association;
- Company Limited by Guarantee;
- Council Owned Entity; or
- Community Trust.

To the extent that a community entity with a similar structure already exists within the Yarrabah community, there may be an opportunity to repurpose or utilise such an entity for the purpose outlined above.

Structure and Charter

It is recommended that the management committee for the entity comprise of between 5 and 7 members and is chaired by a representative of YASC. It is recommended that the committee includes, as a minimum, two independent committee members. The management committee charter would be developed during the establishment phase of the project and would align with the key objectives of the project, as outlined in this Report. Members of the committee would also be appointed at this time.

Operating Arrangement

While the method of engaging the implementation entity by YASC would be determined by the management committee, it is proposed that the entity is engaged under a head contractor type of arrangement. In this role the entity would be delegated responsibility for implementing the entire program of work which includes appointing staff, engaging contractors and other service providers to design, construct, operate and maintain project assets.

Establishment and Construction Phases

During the establishment and construction phase of the project, the entity would be responsible for progressing the project from feasibility study to commissioned infrastructure. This may include tasks such as:

- Establishing head contractor agreements with YASC
- Negotiating lease agreements for central microgrid assets on behalf of YASC
- Appointment of key internal program management personnel, such as Program Director, Program Manager and support staff;
- Management of pre-construction activities, such as technical studies, detailed designs and specifications;
- Assistance with sourcing and managing funding for construction works;
- Overseeing preliminary works and tendering;
- Appointment of project delivery contractors to deliver individual project works;
- Program management of construction works, including monitoring, control and reporting functions; and
- Establishment of the implementation model and structure for the operational phase of the project.

Operational Phases

During the operational phase of the project, the entity would be responsible for implementing the operating model and structure for the commissioned infrastructure and appointing appropriate staff to operate the project assets. The functions that the implementation entity may perform include:

- Establishing head operational contracts and agreements;
- Appointment of operational and management staff, and provision of support to these teams in managing individual assets;
- Sourcing and managing funding for operational activities;

- Establishment of asset management plans and procedures for individual project assets;
- Support to YASC in developing strategic plans related to project assets;
- Oversight of ongoing viability of the collective project assets.
- Engage contractors and develop local capacity to operate and maintain microgrid assets

Program Management Resourcing

The core organisational structure for the implementation entity during the construction phase would likely include the following roles:

- **Program Director** – the Program Director would provide strategic leadership for the entity and would be the primary interface between the entity and YASC. The Program Director would be the appointed accountable officer under the Head Contractor Agreement with YASC.
- **Program Manager** – the Program Manager would directly support the Program Director and would be responsible for operational functions of the entity. The Program Manager would be the primary point of contact for any project delivery contractors and other organisations contracted during the construction or operational phases of the project.
- **Program Support Staff** – program administrators and would be required by the entity. The program support staff would be tasked with direct assistance to the Program Director and Manager.

Additional staff and/or contractors may be appointed to supplement the core team, however, these resourcing decisions would be made by the Program Director in conjunction with the management committee. It is considered essential for effective roll out of this program that the appointed entity have a proven record of successfully working in Indigenous communities, and particularly the Yarrabah community; have local staff who can provide a regular site presence and a committed mentoring role to facilitate ongoing skills transfer to Yarrabah community members.

Funding

YASC, with the assistance of the Implementation Entity and the Joint State Government/YASC working group, would seek grants or other funding for construction works and operational requirements of the project assets. YASC would be the primary applicant for such funding and would direct such monies to the implementation entity in accordance with payment mechanisms in the engagement contract.

It is proposed that the Implementation Entity overheads (for example, program staff, facility expenses would be funded primarily through program/ project management fees allocated in awarded capital grants or other funding, with shortfalls met by in-kind or cash contributions from YASC or through other funding programs. Operational staff would be funded through skills development programs and job creation initiatives.

15.2 Microgrid Operating Approach and Stages

For the purposes of this study, a preliminary concept operating model has been assumed, having regard to the proposed ownership and management structure.

The Implementation Entity, on behalf of YASC, will operate the microgrid assets with the view to generating a sustainable energy supply for the Yarrabah community. The elements of the microgrid will be operated and managed separately, but centrally controlled through the microgrid control system. It is proposed that the central microgrid control system will be located within the YEKH building and/or precinct.

The Implementation Entity will retain primary oversight of the microgrid operating model for the life of the microgrid project, in accordance with the head contractor arrangement held with YASC. As part of this role, the Implementation Entity will engage contractors, procure materials, and recruit and employ staff directly to support the operation and management of the microgrid assets.

A high-level overview of the proposed organisational structure and operating model (for each element of the microgrid) has been outlined below.

15.2.1 Organisational Structure

The organisational structure proposed for the Implementation Entity is shown in Figure 42.

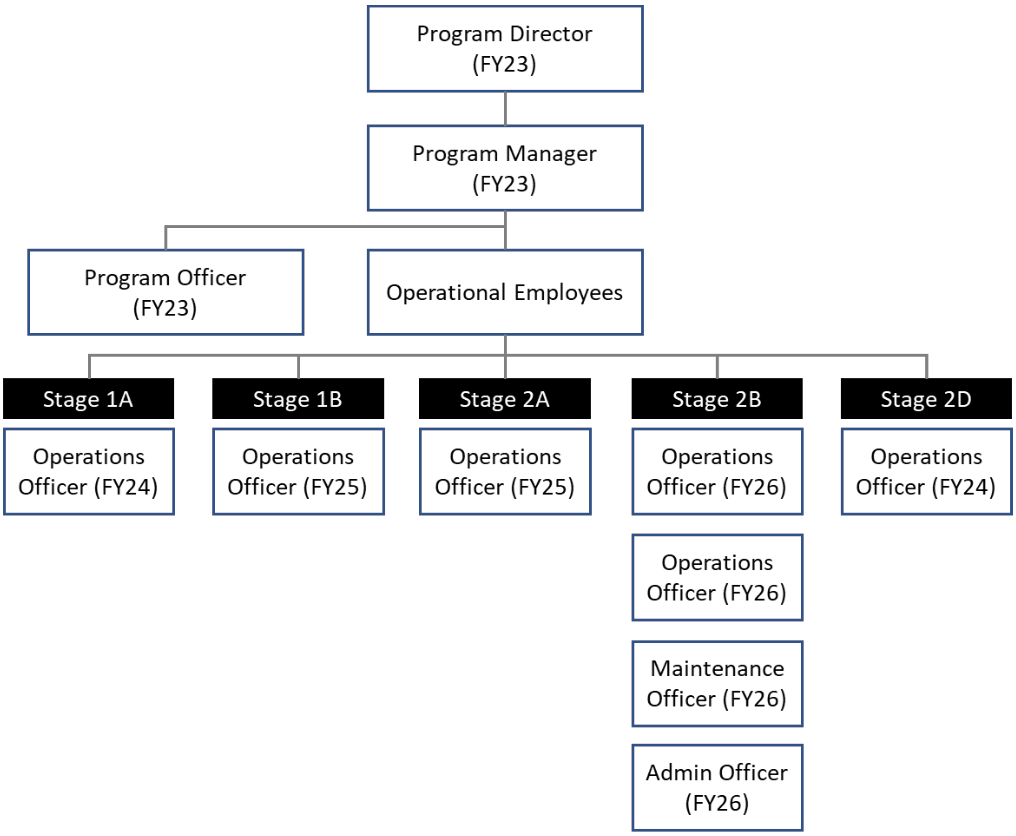


Figure 42 Implementation Entity Organisational Structure

The dates outlined against each operational role reflects the fiscal year in which the role will be recruited and is aligned to the project financial model. Once recruited, it has been assumed that the position will remain for the duration of the project life.

The Program Management team roles and responsibilities have been discussed above. The operational staff recruited will be entry level positions (officers). Through the early years of their employment, it is expected that these personnel will undertake comprehensive skills and training programs through formal training (such as TAFE courses) or through training arrangements with industry partners or contractors. As part of the capital procurement process, a key focus will be on embedding training and development obligations in arrangements for contractors that are appointed to supply and install assets.

15.2.2 Stage 1A Energy Efficiency Upgrades

Following the energy efficiency audit of all Council owned dwellings, a detailed report to YASC will be prepared outlining the potential energy efficiency upgrades required for each dwelling to optimise energy usage. Primarily this program will focus on fixed appliances like hot water systems and air-conditioners but could also include lighting and other equipment. This report will form the basis for the energy efficiency upgrades program. An open tender process will be undertaken by the PMO team to source appliances on a supply and install basis.

Energy audits would also be offered to owners of private dwellings at Yarrabah and a report with findings and recommendations would be provided to the owner. It is envisaged that the energy efficient appliance replacement program would also provide options for the owners of private dwellings.

It is proposed that the audit process will be completed by independent assessors and will incorporate a mentoring component for one or more Implementation Entity employees to upskill in terms of energy management and efficiency.

15.2.3 Stage 1B Rooftop Solar

The residential rooftop solar systems will be procured through an open tender process on a supply, install and maintain basis. The installation program is expected to run for a period of 2 years. During this time, the contractor will have an obligation to provide mentoring/ traineeships to designated Implementation Entity staff. The rooftop systems will each be fitted with a control device that permits remote monitoring and control.

Ongoing, it is expected that Implementation Entity personnel will complete general operation and maintenance activities in relation to the systems, such as general cleaning, troubleshooting, coordination of technical maintenance and monitoring.

15.2.4 Stage 2A – Community Solar Farm, Battery and Generator

For the purposes of the study, once constructed, it is expected that an independent entity will operate and maintain the central microgrid assets on behalf of YASC. This arrangement is expected to take the form of an asset model that shares the risk and profits between YASC and the operator. The operator is expected to be a public or private enterprise operating in the energy generation and distribution space, such as Ergon Energy Network/Energy Queensland Limited. The operator will have right to all energy generated by the microgrid assets and may on sell energy and associated services to energy retailers or wholesalers.

Implementation Entity employees will be responsible for maintaining the site upon which the microgrid assets are located (e.g. waste removal, landscaping, animal control). It is also assumed that a minimum of one employee will undertake a traineeship program with the appointed operator of the microgrid.

The PMO team will administer the terms of the contract between YASC and the operator.

15.2.5 Stage 2B – Yarrabah Energy Knowledge Hub

The YEKH will be established as a multi-purpose interpretive centre providing local residents, students and technologists an opportunity to experience the workings of the microgrid. The YEKH will have a team of up to 4 FTEs (Full Time Employees) focused on managing the day-to-day operations.

General user charges will be levied on individuals attending the YEKH. For larger groups or program providers (groups greater than 20), a fixed group/ events rate will be levied.

15.2.6 Stage 2C – Micro Hydroelectric System and Wind Turbines

The micro hydroelectric and wind turbines established as part of the microgrid are expected to be used primarily for demonstration purposes. These assets will be managed on an as needed basis by staff within the Implementation Entity.

15.2.7 Stage 2D – Community Rooftop Solar

The Implementation Entity will supply staff on a contracted service basis to maintain rooftop PV systems installed on community buildings. The relevant agency/ building owner will be charged a services charge in relation to the maintenance service.

15.3 Economic Impact Assessment of Stages 1A to 2C

PVW Partners undertook the economic impact assessment of the implementation of Stages 1A to 2C as set out above (see Appendix I). It found these stages combined are projected to generate the following construction impacts:

- $5.9 million in output ($4.7 million directly).
- $2.5 million contribution to Gross Regional Product (GRP) ($1.9 million directly).
- $1.5 million in wages and salaries for local workers ($1.1 million in direct wages).
- 17 Full Time Equivalent (FTE) jobs (13 direct FTE).

Once operational, the project is expected to continue to generate a notable impact on the local Yarrabah economy. Stage 1 is projected to generate through household expenditure impacts arising from reduced electricity costs:

- $1.0 million p.a. in output ($0.8 million directly).
- $0.6 million p.a. contribution to GRP ($0.5 million directly).
- $0.2 million p.a. in wages and salaries for local workers ($0.2 million in direct wages).
- 3.5 FTE jobs (3.1 direct FTE).

Stage 2 is projected to generate ongoing operational impacts (including induced tourism activity through the YEKH):

- $2.9 million p.a. in output ($2.4 million directly).
- $1.7 million p.a. contribution to GRP ($1.3 million directly).
- $1.2 million p.a. in wages and salaries for local workers ($1.0 million in direct wages).
- 14.6 FTE jobs (12.9 direct FTE).

A 20-year cost-benefit[111] analysis was undertaken by PVW Partners for a range of discount rates as shown in Table 16. Using a discount rate of 7%, implementation of Stages 1A to 2C yields a net present value (NPV) of $0.5 million and an Internal Rate of Return (IRR) of 7.3%.

Discount Rate	Present Value Costs ($m)	Present Value Benefits ($m)	Net Present Value ($m)	Benefit Cost Ratio
4%	$48.1	$54.8	$6.7	1.14
7%	$40.9	$41.4	$0.5	1.01
10%	$35.7	$32.2	-$3.6	0.90

Table 16 Cost Benefit Analysis of Stages 1A to 2C

[111] Costs included capital and refurbishment, direct operating and overhead costs. Benefits included service revenues, value add from tourism from the YEKH, community cultural and recreation benefit of the YEKH, grid energy savings, solar energy feed-in tariff revenues, greenhouse gas savings, community energy reliability and resilience benefits.

16

Financial Assessment and Business Case

16 Financial Assessment and Business Case

The microgrid will be enabling social infrastructure that will support the establishment of new enterprises and economic development within the Yarrabah community. With YASC unlikely to monetise many of the potential benefit streams arising, the project is expected to be dependent on Government funding for the construction and operational phases, supported by proposed lease charges levied on the operator of the core microgrid assets. For the purposes of the assessment, it has been assumed that Government funding will be sourced for the full capital value of the project of approximately $23.5 million over 3 years, and ongoing operating requirements of approximately $1.5 million per annum (unadjusted for inflation).

Whilst specific project funding sources have not been confirmed at the time of writing this report, discussions have commenced with a range of potential project funders from Queensland State Government and Australian Government agencies and departments.

16.1 Project Cashflows and Returns

While operating cashflows of the project are expected to be marginally positive each year, it is noted that these are not sufficient to cover the amortisation of the infrastructure reflected through annual depreciation charges. As such, ongoing net profit before tax (NPBT) returns to a negative outcome of circa $700,000 annually beyond the construction phase of the project.

The enterprises that will develop in connection with the microgrid infrastructure were not known at the time of completing the study but could be energy or technology suppliers, service providers and educational institutions. The activities associated with these enterprises are expected to generate revenues that could financially support the ongoing operation of the infrastructure. Furthermore, there may be potential for YASC to realise benefits arising from the infrastructure, and supporting services, such as:

- Return on energy savings for residents of Council owned dwellings;
- Contributions from residents for energy efficient appliance upgrades; and
- Expansion of fee for service offerings to external organisations.

For the purposes of this assessment, these benefits were not reflected in the financial model, however, it is recommended that further investigation is undertaken as part of more detailed analyses.

Notwithstanding, for the project to proceed, and based on available information, it is critical for funding support to be secured for the construction phase, as a minimum. Due to the primarily socially focused objectives of this project, this is not an unexpected outcome, yet one that must be considered as part of funding strategies and must be balanced with the broad social and environmental benefits and economic impact arising from such an investment.

16.2 Summary Financial Assessment

The table below outlines the summary financial assessment completed for the 8 years of the project. Detailed financial assessments have been attached in Appendix E. The detailed assumptions underpinning the assessment have been attached at Appendix F.

Financial Summary	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30
Profit and Loss								
Operating Revenue	1,020,000	60,900	690,673	793,471	807,411	821,694	836,334	851,346
Operating Govt Grants	549,393	683,881	840,361	1,422,976	1,442,283	1,461,745	1,481,357	1,501,110
Capital Revenue	12,225,220	7,629,978	3,646,997	-	-	-	-	-
Total Revenue	13,794,613	8,374,759	5,178,030	2,216,447	2,249,694	2,283,439	2,317,691	2,352,456
Less: Direct Costs	(1,514,193)	(672,729)	(1,247,185)	(1,798,157)	(1,825,129)	(1,852,506)	(1,880,294)	(1,908,498)
Less: Operating Expenses	(55,200)	(60,596)	(67,686)	(147,127)	(149,334)	(151,574)	(153,847)	(156,155)
EBITDA	12,225,220	7,641,435	3,863,159	271,163	275,231	279,359	283,550	287,803
Less: Int. & Dep.	(536,167)	(860,872)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)
NPBT	**11,689,053**	**6,780,563**	**2,846,157**	**(745,839)**	**(741,772)**	**(737,644)**	**(733,453)**	**(729,200)**
Cashflows								
Operating Cashflows	(48,422)	7,427	179,179	234,037	273,332	277,788	281,237	285,818
Capital Grants	12,225,220	7,629,978	3,646,997	-	-	-	-	-
Capital Expenditure	(12,225,220)	(7,629,978)	(3,646,997)	-	-	-	-	-
Other Cash Adjustments	31,264	7,070	20,923	26,570	5,170	4,975	5,397	5,202
Net Cashflow	(17,158)	14,497	200,102	260,607	278,503	282,764	286,634	291,019

As noted, this 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 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.

16.3 Funding behind the meter solar PV

Installation of behind-the-meter solar PV systems on houses in Yarrabah would significantly reduce household electricity bills, with excess PV generation contributing to the distributed renewable energy resources needed for the Yarrabah microgrid. The more behind-the-meter solar PV capacity, the less large-scale, central solar PV generation would be required, reducing the land component required for the project.

With Council owning most of the housing in Yarrabah, it is not practical for households to install their own solar PV systems. The upfront cost is also likely to be a significant barrier for households already experiencing financial hardship.

Ideally, the purchase and installation of PV systems could be funded by government grants, which would allow the full benefit of the electricity savings to flow to the households. Whilst not all households will benefit (i.e. If the property is not suitable for a rooftop solar PV system installation) it is the least complex solution for Council and the community. This is important because YASC has expressed a preference for options that do not add to the administrative burden of Council.

Should grant funding not be available for the proposed rooftop solar PV program, then the following four options could be explored in more detail for potential application at Yarrabah. They all involve the property owner (Council) or a 3rd party owning and operating the solar PV systems, and various levels of complexity related to recouping the costs of the solar systems.

1. A solar company (with a retail licence exemption) funds installation and retains ownership of the solar systems, then sells the PV output to the households.
2. Council obtains a retail licence exemption and funds installation, owns the solar systems and sells the PV output to the households. This could be at a reduced tariff compared to a solar installer if Council was not requiring a commercial rate of return.
3. Council pays for the installation and owns the solar systems. If a return is required on the initial capital investment, Council could recover costs over time by adjusting rental values. The rental increase would be offset by reduced electricity bills for households. The increase in rent could be a proportion of the forecast annual cost savings from the solar system.
4. Council pays for installation and owns the solar systems and takes on responsibility for paying the household’s electricity bills, then increases the rent to cover the cost of the electricity bills.

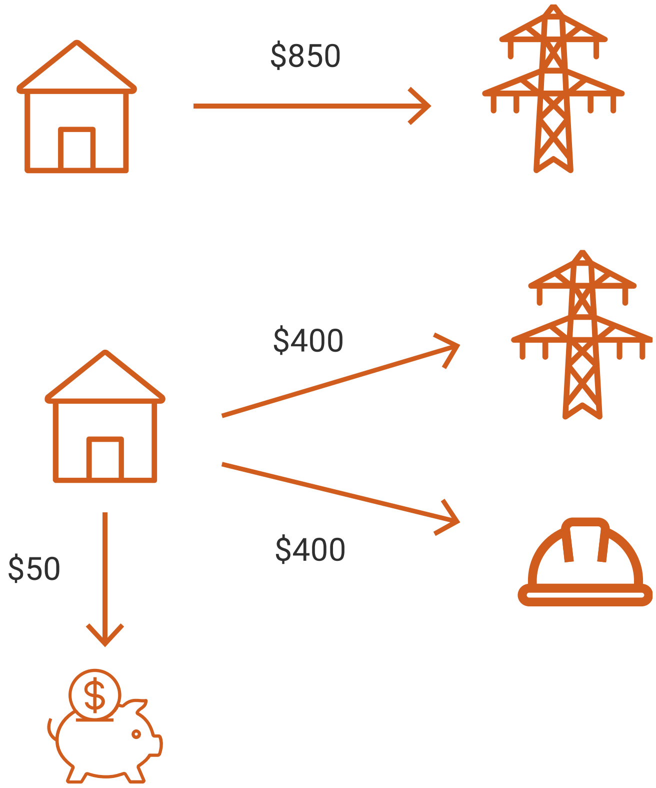
The sourcing of government funding for the installation of rooftop solar PV, as one component of the microgrid, is further discussed in Section 15.

In all four options, the financial benefits are maximised if households have high levels of self-consumption of PV, which is typical of communities like Yarrabah where there are high levels of unemployment and higher-than-average energy consumption during daylight hours.

Each option is described in more detail below. Note that the dollar values shown in the following examples are for demonstration purposes only and do not represent actual household bills at Yarrabah.

1. Solar installer owns the PV systems and sells the electricity to the household

Some solar PV installers offer to install solar PV systems and then sell the electricity to the household. The installer retains ownership of the PV system, and the households retain their existing electricity retailer, and have a second electricity bill from the solar installer. The per kWh cost of electricity from the solar PV systems is less than from their existing retailer and so the household's total bills are reduced. Separate NEM-compliant metering would be required to measure the solar electricity consumed by the tenant and exported to the grid, and to facilitate billing. This option is illustrated below.

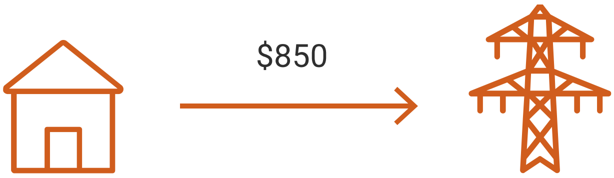


Before – Household paying $850/quarter to retailer

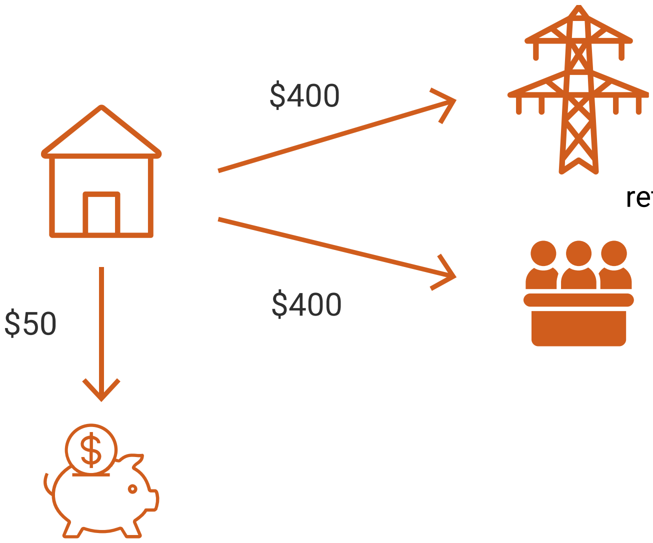
After – Household paying $400/quarter to retailer and $400/quarter to PV installer, and so the PV system is generating $50/quarter savings for the household

2. Council organises installation of the PV systems and sells the electricity to the household

In this option, as well as options 3 and 4, Council would organise installation of the PV systems and would become the owner of the infrastructure. With this option, Council would also sell the PV electricity to the household and would require a retail licence exemption. As for option 1, the solar PV installations would require NEM-compliant metering for solar electricity that is either consumed or exported. Council would be required to establish administrative procedures for billing tenants for the electricity consumed. This option is illustrated below.



Before – Household paying $850/quarter to retailer



After – Household paying $400/quarter to retailer and $400/quarter to Council, and so the PV system is generating $50/quarter savings for the household

3. Council installs the PV systems and recovers costs via rental increases

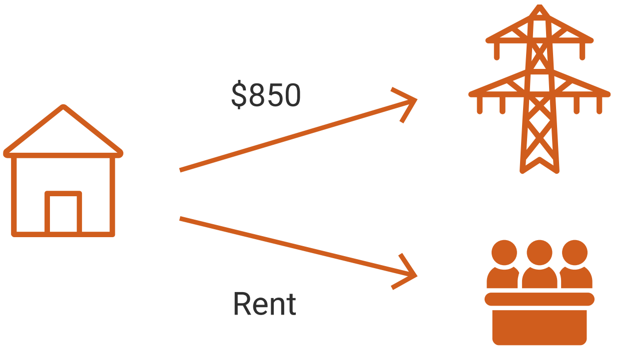
This option is the same as option 2 in that Council would organise installation of the PV systems and would also own them. The difference is that Council would not sell the PV electricity to the household, avoiding the requirement to seek a retail licence exemption. It should be possible to obtain a reasonable value for the solar electricity used on-site from the inverter, and the amount of exported electricity could be obtained from the electricity bills.

Council could either provide 100% of the benefit to the tenant via reduced electricity bills (for example, if the initial project funding were provided via a government grant), or alternatively could consider recovering the installation costs through rental increases (if Council had to raise the initial capital through loans or internal funds).

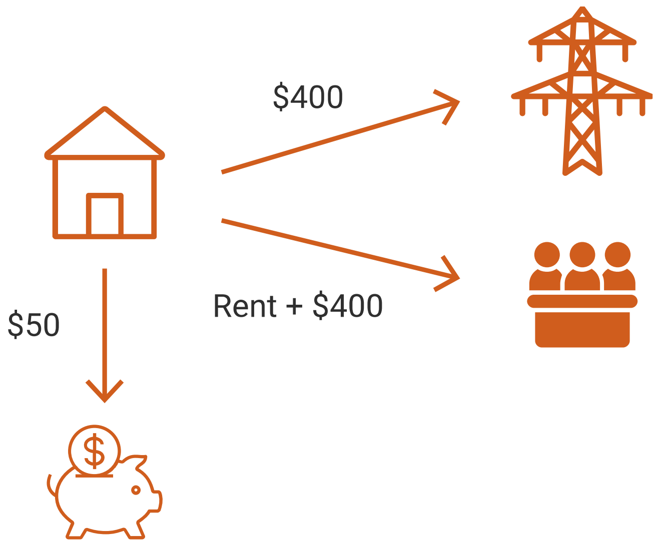
Once the initial costs are recovered, the solar component of the rental charge could be used to cover the cost of the replacement inverter or for other community benefits.

Generally, the increase in rent would be slightly less (10% to 20%) than the household's forecast savings from the solar PV. The total cost of rent plus electricity for a household would be less than it currently is without solar which may assist in gaining community acceptance. This means the household is in front from day one, which increases community acceptance, but it will take slightly longer for Council to recover their costs. However, this approach may cause issues where some households receive a PV system while others do not (because of shading or poor roof quality). In this case, Council could instead put aside some of the PV systems revenue into a general community fund so that all householders receive a benefit. This option is illustrated below.

Given that each household has different electricity consumption patterns, there would be an associated administrative overhead for calculating each customer's inverter and meter readings.



Before – Household paying $850/quarter to retailer and $Rent/quarter to Council



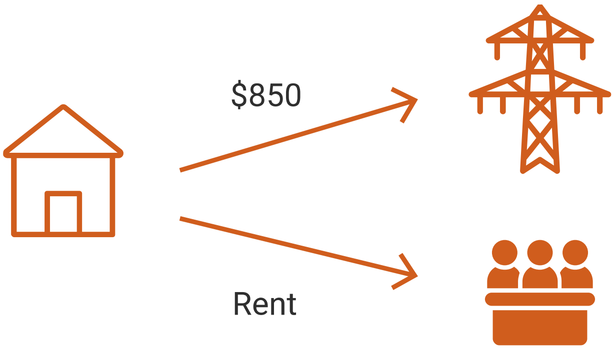
After – Household paying $400/quarter to retailer and ($Rent+$400)/quarter to Council, meaning PV system is generating $50/quarter savings for the household

4. Council pays for the PV systems and takes responsibility for the household electricity bill

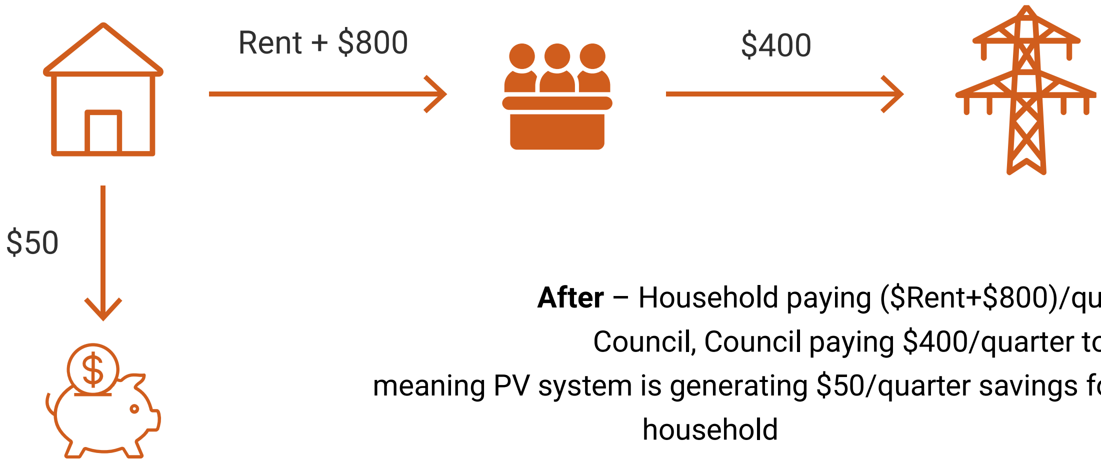
This option is the same as option 2 and 3 in that Council would organise installation of the PV systems and would also own them. The difference is that Council takes on responsibility for paying the households' electricity bills. This means that Council receives the financial benefits of the solar PV systems directly but would need to establish administrative procedures for calculating the costs of electricity and solar system charges from households. The household would receive a rental bill with electricity charges as an itemised line item.

This approach would enable Council to aggregate the financial benefits of the solar installations and distribute the savings more equitably throughout the community via rental reductions or in other ways such as investment in energy-efficient appliances or other community projects. In this option Council would be responsible for future maintenance of the rooftop solar PV systems.

This option is illustrated below.



Before – Household paying $850/quarter to retailer and $Rent/quarter to Council



After – Household paying ($Rent+$800)/quarter to Council, Council paying $400/quarter to retailer, meaning PV system is generating $50/quarter savings for the household

The pros and cons of each option are summarised in Table 17. In each option, Council would need to identify and enlist an appropriate installer. In all options households have an incentive to shift their electricity use to the middle of the day, which is also what is needed to reduce the size of the battery (and standby generation) in a solar-powered microgrid.

Option	Pros	Cons
1	Simplest option for Council as the installer takes on all responsibility for collecting payments from households. Installer also responsible for maintaining systems because if they are not working, they don't get paid.	May be difficult to find an installer willing to do this for customers that may not have a good credit history. Community hesitancy to participate in a voluntary scheme may result in insufficient numbers of households "signing up" hence it may be uneconomical to deploy and not meet target quantity of systems for microgrid needs. 3rd party assets installed on Council residences may result in issues for future access and maintenance.
2	Council retains ownership and control of the process. Creates revenue stream for Council	Council would require a retail licence exemption. Would require NEM compliant metering. Council responsible for maintaining systems because if they are not working, they don't get paid. Additional administrative burden on Council Community hesitancy to participate in a voluntary scheme may result in insufficient numbers of households "signing up" hence it may be uneconomical to deploy and not meet target quantity of systems for microgrid needs.
3	Council retains ownership and control of the process. Council does not require a retail licence exemption. Would not require NEM compliant metering. Creates revenue stream for Council	Council would need access to the customer bills and inverter readings to calculate the savings from the PV systems. Council would need to change the rent of each household either quarterly as the bill impacts change or could adjust each rent by the same amount based on the estimated savings over the year then do an adjustment at the end of each year. Council responsible for maintaining systems because if they are not working, they don't get paid. Complex administrative arrangements
4	Council retains ownership and control of the process. Council does not require a retail licence exemption. Would not require NEM compliant metering.	A change for tenants regarding electricity billing arrangements as they would no longer receive a separate bill Council takes on responsibility for paying the households' bills, and so must implement processes for calculating electricity costs as a separate line item in rental payments. Council becomes responsible for disconnection processes if electricity bill not paid by tenant Council would need to change the rent of each household either quarterly as the bill impacts change or could adjust each rent by the same amount based on the estimated savings over the year then do an adjustment at the end of each year. Council would need access to the inverter readings to calculate the solar benefit. Council responsible for maintaining systems (through the installer). Complex administrative arrangements

Table 17 Options for behind-the-meter solar PV ownership

16.4 Funding the microgrid program of work

It is anticipated that funding for the Yarrabah microgrid program of work will be sourced from Federal and State government funding programs and grants. The project supports existing Queensland government priorities as outlined in section 18.2 of this report.

When completed, the Yarrabah microgrid will also have high demonstration value for other remote and rural fringe-of-grid communities, promoting renewable energy solutions that will contribute to reduced greenhouse gas emissions in line with Federal and State government objectives. The technologies, local ownership and operating models, and economic opportunities showcased by the Yarrabah microgrid will have broad interest to Government and other community-based enterprises.

Table 18 suggests potential funding sources for the various components of the broad program of initiatives envisaged by this project. This summary is preliminary and is provided for guidance only. Further investigation and discussion with State and Federal government departments and agencies is required to confirm potential funding sources.

EnergyConnect also notes that elements of the project may attract external funding, corporate sponsorships or philanthropic donations, however the value of this component is not expected to be material. For example, it may be possible to attract sponsorships of educational displays or financial or in-kind contributions to support the employment of local Yarrabah people through start-up business opportunities at the Energy Knowledge Hub.

Additionally, there may be commercial interest in the development of EV charging stations and other facilities that could be incorporated into the Energy Knowledge Hub campus.

Project Activity	Budget Estimate	Potential Funding Source
Establish the Program Management Office to develop the ownership model and do detailed design and construction planning	$2.6 million	• Queensland Government • Federal Government – National Indigenous Australians Agency (NIAA) Empowered Communities Program
Stage 1A – Energy Efficiency Audits and Upgrades	$2.8 million	• Queensland Government – Aboriginal & Torres Strait Islander Partnerships; Communities, Housing and Digital Economy; Energy & Public Works • Federal Government – NIAA Empowered Communities Program
Stage 1B – Residential Rooftop Solar PV	$2.1 million	• Queensland Government – Aboriginal & Torres Strait Islander Partnerships; Communities, Housing and Digital Economy; Energy & Public Works • Federal Government – NIAA Empowered Communities Program
Stage 2A – Solar Farm, Battery, Standby Generator, Microgrid control	$12.3 million	• Queensland Government - Energy & Public Works • Federal Government – ARENA RAMPP program
Stage 2B – Energy Knowledge Hub	$3.5 million	• Federal Government – Building Better Regions Fund • Federal Government – NIAA Empowered Communities Program • Queensland Government – Building Our Regions Program
Stage 2C – Micro hydro & Micro wind	$0.2 million	• Queensland Government - Energy & Public Works
Stage 2D – Community Rooftop Solar PV	Not included in overall project budget	• Funded by specific State Government Departments e.g. Queensland Education, Queensland Health.

Table 18 Yarrabah program of work and potential funding sources

17

Challenges and Implementation Barriers

17 Challenges and Implementation Barriers

17.1 Challenges

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

Yarrabah 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 current Regulations for grid-connected embedded generators limit flexibility in ownership and operational models and may drive an outcome that delivers sub-optimal economic returns for Yarrabah.
- Yarrabah Council will be reliant on external funding to progress the development of the microgrid and associated infrastructure and operating model. The estimated cost to implement the project is $23.5 million over 3 years with an on-going investment of $1.5 million per annum towards operation and maintenance of the facilities.
- Land tenure and availability are significant issues at Yarrabah and other indigenous communities where there is a high demand for residential development to address housing shortages and overcrowding. This needs to be balanced with the potential socio-economic benefits, including employment opportunities, that can be created by developing energy security projects like the Yarrabah microgrid.
- The development of fringe-of grid microgrid solutions will challenge the traditional energy supply planning and investment criteria and requires a new way of thinking to deliver improved service standards and socio-economic benefits for vulnerable communities like Yarrabah

17.2 Barriers to Uptake

17.2.1 Community Expectations

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

However, it is clear to the project team that the key outcomes expected from the community are:

- Improvement in the reliability of electricity supply – less and shorter-duration outages
- Provide solutions that can reduce the impact of household electricity costs
- Create employment opportunities for locals
- Reduce environmental impacts by utilising renewable energy solutions

As part of the energy-efficiency program proposed to be delivered with the Yarrabah 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 and appliance purchase decisions– with practical examples like turn off appliances when not in use; procure energy efficient and site-appropriate items.
- 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 Yarrabah, 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, invertors, 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.

17.2.2 Regulatory considerations

As noted in section 11 of this report, electricity regulation pertaining to operation and ownership of microgrids is evolving in line with greater understanding and experience of the benefits of establishing local generation and reticulation systems rather than investing in distribution networks for fringe of grid and remote locations.

Current regulation prevents a DNSP from owning generation assets and selling electricity from those assets for grid-connected generation assets. For Standalone Power Supply systems it is possible for a DNSP to be the owner/ operator of generation assets with a waiver from the AER.

This is relevant for Yarrabah where the microgrid would be connected to the Ergon Energy Network grid under normal operating mode and it would be operating in island mode as a

Standalone Power System when the upstream network was unavailable due to fault conditions or to undertake maintenance work.

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

The cost of providing electricity supply in regional areas of Queensland is currently subsidised by the Queensland Government via a CSO (Community Service Obligation) payment to EQL (Energy Queensland Limited). Yarrabah residents currently benefit from the CSO arrangements and no changes to current electricity retailing activities at Yarrabah are anticipated with the development of the microgrid.

This feasibility study has not investigated the impacts of investing in the microgrid on the CSO however it is expected to be minor given the initial capital cost of the project is in the order of $23.5 million and the total CSO for Energy Queensland is approximately $502 million per annum (2021/22 Budget Estimate)[112].

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.

17.2.3 Cost and Funding Considerations

As outlined above, the estimated capital cost of the microgrid is approximately $23.5 million with an on-going requirement of $1.5 million per annum to supplement operational costs.

As a small Council which is predominantly reliant on government funding for capital works and operational activities, this project is currently beyond the capacity of the Council to fund in its own right.

Given that the microgrid project can demonstrate positive economic returns for the community, and also meets several other criteria that align with key Queensland Government priorities, it is anticipated that State government funding would be sought to assist with the development of the project.

Additionally Federal government funding may be available via ARENA's Regional Australia Microgrid Pilots Program (RAMPP) to support this project.

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[112] Queensland Government Budget Paper No. 2 - Budget Strategy and Outlook 2021-22 Table 9.7-Community service obligations and transport services contracts

Funding for the entire program of works and on-going operations would need to be secured in order for the project to proceed.

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 without the 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 a more energy-efficient housing design that can contribute to reduced household energy costs for occupants and also provide a contribution to the Yarrabah microgrid via rooftop solar PV systems. This would need to be considered in budget forecast for the relevant government departments.

Whilst the potential for private investment was considered for this project it was concluded that the project is unlikely to generate the level of commercial returns generally sought by investment funds.

The community comprises mostly younger residents with limited employment opportunities and lower-than-average income. 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.

Employment and training opportunities identified with the development and operation of the microgrid will help to address this barrier,

Additionally, the provision of ‘behind the meter’ renewable energy solutions such as rooftop solar PV could significantly reduce the impact of electricity bills on household budgets over time.

17.2.4 Tenure – DOGIT & Native Title

As identified in section 3.2, in almost all indigenous communities, land for infrastructure development is in limited supply. Status of the resolution of native title claims can limit the capacity or timeliness of determining whether land can be used for community or other infrastructure. Sufficient lead times need to be allowed for consultation with landowners and Native Title holders to address property issues like ownership, access, and operational requirements associated with implementing and maintaining microgrid infrastructure.

It is understood that most vacant land in the Yarrabah area is gazetted as Deed of Grant in Trust (DOGIT). YASC, Traditional Owners and Prescribed Bodies Corporate 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.

17.2.5 Technology-based

It is imperative to ensure that the microgrid is designed to integrate seamlessly with the Ergon Energy Network grid and also to operate in island mode when the grid is unavailable.

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 Network Operating Standards.

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

18

Implementation Pathway and Next Steps

18 Implementation Pathway and Next Steps

18.1 The Opportunity for Yarrabah

There is currently limited economic development opportunity at Yarrabah 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 are currently associated with government services such as health, education, and local government activities.

However, as outlined in Section 15.3 the Yarrabah microgrid project is expected to generate a net positive socio-economic impact of $0.5 million net present value over 20 years to the local Yarrabah economy. The construction is expected to provide a one-off GRP stimulus of $2.6 million to the Yarrabah economy directly and indirectly. Once completed, the project will continue to deliver strong economic impacts for Yarrabah. This includes an estimated $2.1 million per annum to local GRP and 18 FTE jobs on an ongoing basis, increased household incomes and expenditures within the community due to annual household savings of $1.7 million per annum across the community, and ongoing operations.

Through the YEKH, visitation to the region is expected to increase by an estimate of 4,000-8,000 visitors per year, increasing the depth and resilience of the local tourism industry and making the prospect for future short stay accommodation more economically feasible.

18.2 Queensland Economic Priorities

The development of a microgrid at Yarrabah could support the delivery of key Queensland Government priorities including: -

- Local Thriving Communities: assign ministerial and agency leadership
- 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
- Climate Action Plan and Queensland Climate Transition Strategy
  - 50% renewable energy target
- Draft State Infrastructure Strategy

    - Encourage jobs, growth and productivity
    - Enhance sustainability and resilience
    - Develop regions, places and precincts
    - Adopt smarter approaches
- Powering Queensland Plan
    - 50% renewable energy target
    - Decarbonising remote communities program
    - Developing a 10-year energy plan
    - Affordable energy plan

18.3 Proposed Solutions

In assessing suitable alternatives for improving the resilience of the Yarrabah 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 models
- Economic opportunity – revenue generation
- Reliable local energy supply
- Build community resilience and transition from a position of vulnerability
- Create long-term and on-going employment for locals
- Reduce reliance on fossil fuels
- Create a social enterprise business model, not just a technical business case
- High demonstration value for other fringe-of-grid and remote / rural communities

It is intended that the Yarrabah microgrid would be designed and operated as an "islandable microgrid" which will retain the connection to the Ergon Energy Network / Energy Queensland grid for the majority of the year but will be able to switch over seamlessly to operate in island mode for short periods of time, when the main grid is either not available due to an outage event occurring, or in a planned manner when line maintenance may be required.

Technical and economic optimisation modelling using the min-E simulation tool (Refer Section 14.1) resulted in a preferred solution consisting of the following elements:

- A centralised solar farm (1,450 kW) and BESS (1,700 kW / 10,200 kWh) supported by a Standby Generator (550 kW).
- Rooftop solar PV systems installed on approximately 300 dwellings (1,500 kW).

- Rooftop Solar installed on commercial / community buildings (400 kW).
- 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 Energy Queensland grid.

Figure 43 below shows the proposed configuration of the Yarrabah microgrid.

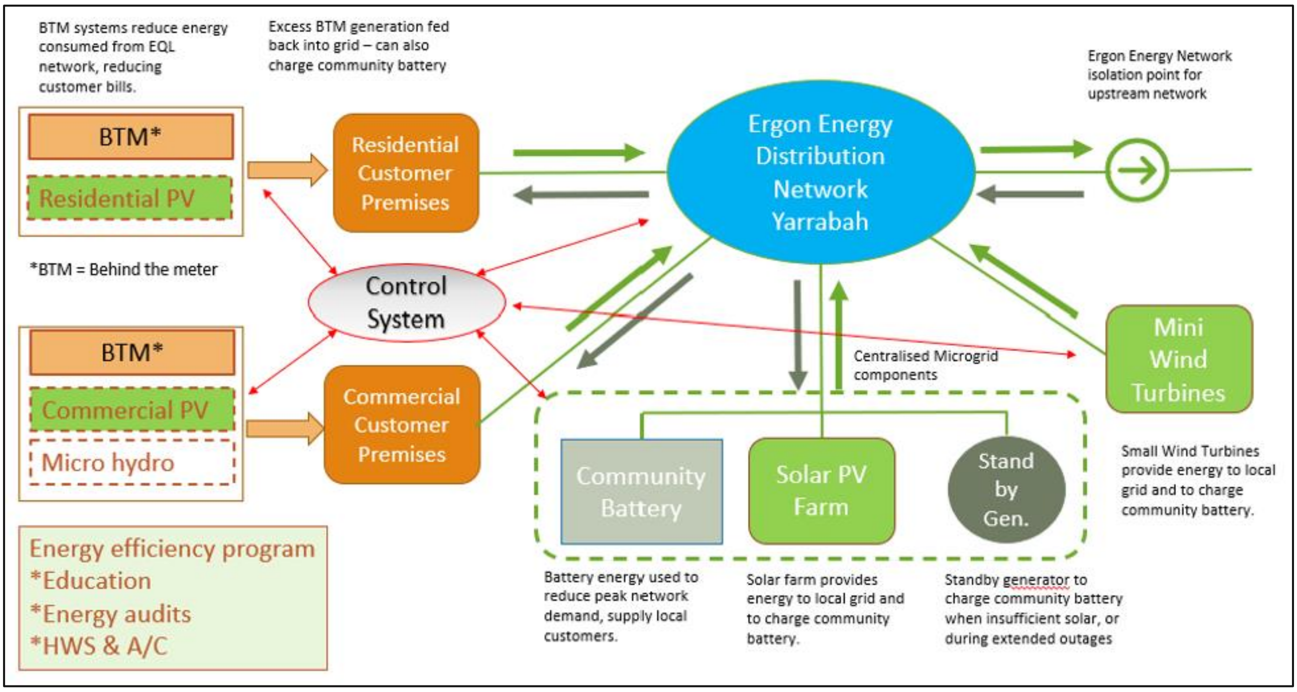

Figure 43 Proposed Configuration of the Yarrabah microgrid

There is also potential for minor contributions to the microgrid Distributed Energy System via micro hydro and mini wind turbines.

Existing disused water supply infrastructure at Reeves Creek could be re-purposed for a 10kW (approximately) micro hydro system.

The wind resource at Yarrabah is unproven and initial assessments indicate that wind power is unlikely to be an economical option at this location.

Whilst the micro hydro and mini wind turbine systems are not essential components of the preferred microgrid configuration, their inclusion may enhance the demonstration value of the facility by having a broader range of renewable energy systems on display at the one site.

Rooftop solar PV systems proposed in this microgrid solution have a number of benefits including:

- Solar is the most economical and suitable technology for renewable energy generation at Yarrabah
- 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 occupants of residences, and this can be a significant saving in large households

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.

Based on data provided by Energy Queensland for the 2019/20 period (15-minute load data and network outage data) and an assessment of expected solar generation constraints due to weather-related factors, the standby generator would be required to operate for approximately 25 hours for the year under normal microgrid operating conditions (excluding disaster events).

18.4 Optimising Demonstration Value

In order to optimise the demonstration value of the microgrid, create employment opportunities for locals and ensure the best use of scarce developable land at Yarrabah, it is proposed to construct an "Energy Knowledge Hub" within the central microgrid facility site.

The Energy Knowledge Hub will be a multi-purpose facility where locals and visitors can learn about renewable energy systems, how they are orchestrated and integrated with the existing electricity grid to create the working microgrid.

The Energy Knowledge Hub will also be a service depot for renewable energy systems installed within the community and will have future potential as a tourism hub and could host electric vehicle charging stations.

Local people employed at the Energy Knowledge Hub will provide a range of advisory services to the community and to other regional and remote communities to establish and promote Yarrabah's reputation as a leader in community-based microgrid energy systems.

Further details on the purpose and scope of the Yarrabah Energy Knowledge Hub are provided in Section 14.3 of this report.

18.5 Microgrid Implementation Plan

To ensure that the full economic and employment benefits are realised it is proposed that the Yarrabah microgrid program of works Stages 1 and 2 could be delivered over a period of 3 years with Stage 3 expected to be completed within a 4-to-5-year timeframe (depending on the uptake of electric vehicles), as outlined below:

Stage 1 – Energy Efficiency and rooftop solar PV systems

- Stage 1a – Energy audits, education, energy-efficient heat pumps and air-con, housing design
- Stage 1b – Rooftop solar PV systems (deployment to ~300 houses)

Stage 2 – Microgrid and Energy Knowledge Hub

- Stage 2a – Solar farm, community battery, standby generator, and control system
- Stage 2b – Energy Knowledge Hub
- Stage 2c – Micro hydro and micro wind turbines
- Stage 2d – Rooftop solar PV – Community and Commercial buildings (~400kW)

Stage 3 – e-Mobility and Transport Resilience – Technology Leapfrogging

- Stage 3a - EV charging infrastructure
- Stage 3b - Electric garbage truck, buses, personal mobility, cars, ferry
- Stage 3c - Mobility as a Service (MaaS)

18.5.1 Stage 1

In Stage 1 a focused energy efficiency program will be delivered in a community-wide program. Local people would be trained to undertake energy audits, provide energy efficiency advice to households and deliver school-based energy-efficiency education programs.

During this stage a program targeting replacement of inefficient appliances including air-conditioners and hot water systems would be delivered and efficient housing design incorporating energy efficiency principles would be developed to support and guide Council, residents and government agencies for future residential developments at Yarrabah.

Rooftop solar PV systems would be deployed to approximately 300 Council-owned dwellings as the initial deployment of renewable energy infrastructure to Yarrabah, providing immediate electricity bill relief to occupants of those residences.

It is anticipated that smart meter installation works would be undertaken in conjunction with the implementation of rooftop solar systems and energy efficiency program deployment throughout the community.

18.5.2 Stage 2

Stage 2 targets the works required to implement the centralised microgrid facilities, including pre-construction activities such as detailed technical design of microgrid components and control systems, site assessment and acquisition, preparing specifications, tender documentation and coordinating tendering processes.

Financial models would be refined at this stage in line with detailed design outcomes to confirm funding requirements and economic benefits.

The development of the Yarrabah Energy Knowledge Hub would be undertaken during this stage also, including all relevant site studies, architectural design and scope of the facility, establishing operating arrangements and future resourcing activities and operating contracts.

Commercial and community buildings would be identified for the required deployment of 400 kW of rooftop solar PV and implementation works would be undertaken in line with agreed outcomes and negotiations with building owners and responsible government agencies.

18.5.3 Stage 3

Stage 3 works will be associated with the anticipated roll-out of e-mobility services within the Yarrabah community. Initial infrastructure considerations will be incorporated into the microgrid design and may consist of initial EV charging infrastructure installed at the Energy Knowledge Hub and other strategic locations within the community.

Financial modelling of Stage 3 works has not been undertaken given the degree of uncertainty regarding the timing and scope of electric transportation services for the Yarrabah community. The development of an e-mobility strategy for Yarrabah would be required to assist in modelling the future economic benefits to the community.

18.5.4 Implementation Model

Section 15 of this report outlines in detail the proposed asset ownership and operating model for the Yarrabah microgrid. In essence, a community-own and operate model is preferred. Yarrabah Aboriginal Shire Council would be the Asset Owner and a new Community Entity consisting of community stakeholders and independent specialists would be established to manage all implementation and operational activity.

The Community Entity would be responsible to Council under formal contract arrangements 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 Community Entity and its Operating Charter is considered a priority activity to progress the implementation of the Yarrabah microgrid project.

Figure 44 shows the ownership / management model.

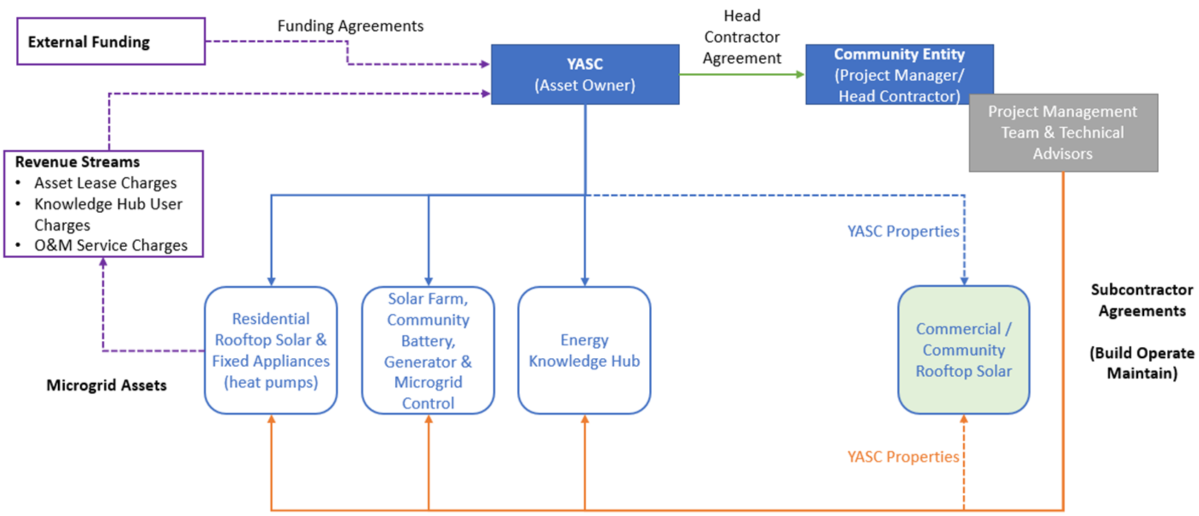

Figure 44 Proposed ownership & management model

18.6 Next Steps

Key stakeholder groups have regularly been engaged and consulted throughout the course of this feasibility study. This activity culminated in a presentation to Queensland Government ministers, department heads and other government representatives with the full Yarrabah Council in attendance, at Parliament House in Brisbane on 20th October 2021.

The Yarrabah microgrid proposal received overwhelming support from the Minister for Energy and Public Works, the Honourable Mick de Brenni; Minister for Tourism, Industry Development and Innovation, the Honourable Stirling Hinchcliffe (who is also the Queensland Government champion for Yarrabah); and Speaker of the House and Member for Mulgrave electorate, the Honourable Curtis Pitt.

A key outcome of this presentation was the establishment of a Working Group co-chaired by Minister Hinchcliffe and Mr Pitt, with representation from Yarrabah Aboriginal Shire Council, Energy Queensland, and other government departments and agencies to actively progress the project upon completion of the Feasibility Study.

The initial Working Group meeting was convened on 15th December 2021.

A Draft Implementation Plan / Pre-Development Plan was presented to the Working Group and will be considered when the Working Group reconvenes in late February 2022. The Plan is outlined below:

18.6.1 Objectives/Outcomes

- Continue momentum of the project to facilitate transition from completion of the feasibility study into shovel ready project to start when funds are available in 2022
- Continuation of the program of community and stakeholder engagement
- Establishment of the ongoing project implementation structure and governance arrangements, including appointment of key program delivery resource/s during 2022

18.6.2 Timeframe

- Federal Government RRCRF Funding expires 28th February 2022
- Implementation team March 2022 – Dec 2022 (10 months)
- Assume that governance, resourcing, and funding can be completed in this timeframe

18.6.3 Activities/Tasks for implementation team

- Manage Queensland Government Implementation working group governance, activities, administration, agendas, and working papers.
- Facilitate Yarrabah Council engagement & development of local project champions, engagement with Yarrabah Leaders Forum (YLF)
- Continue community engagement activities & develop project implementation engagement plan

- Establish interim program management structure and governance including appointment of core advisors/ team, develop detailed project implementation plan and budget
- Establish on-going project implementation structure/ organisation (target by 31 August 2022) including create charter, establish governance, structure, budget, and establishment plan. Assist in the appointment of key resource/s and establish on-going support contracts for advisers to implementation organisation
- Commence scoping for detailed land planning and assessments (pre-construction activities) required to transition the project to “shovel ready”
- Coordinate project funding applications and project implementation grant applications for available microgrid programs (ARENA, Building Better Regions Fund, Queensland Government);
- Commence work on coordinating the delivery of detailed pre-construction studies and assessments, such as:
    - Detailed land planning and assessment to host microgrid assets and Energy Knowledge Hub – Prescribed Body Corporate negotiations if required
    - Detailed planning and engagement for residential energy assessments, appliance replacement program, EQL metering upgrade, EQL tariff alignment, design and installation of smart energy interface units, switchboard upgrades if required, Rooftop PV suitability assessment, produce reports
    - Technical design and implementation contract arrangements for residential PV program
    - Technical and regulatory assessment for impact of microgrid system on Energy Queensland network
    - Technical design and implementation planning for Energy Knowledge Hub

18.6.4 Priority Actions for Stage 3 e-mobility

The following activities for short- and medium-term outcomes for potential e-mobility impacting on the microgrid are:

- Establish the necessary telecommunications infrastructure at estimated cost of $3 million to support shared micro-mobility scheme e.g. 4G mobile reception or community WiFi
- Undertake modelling on the potential future energy demand impact on the microgrid design of future deployment of micro-mobility devices, EV’s for Council and private owners, and deployment of electric trucks and buses.

- Identify appropriate sites for charging infrastructure for Council and visitors – particularly during the day
- Co-locate EV charging infrastructure at tourism destinations in/around the Yarrabah community
- Identify appropriate sites for infrastructure for charging shuttle buses, and trucks, overnight, ideally utilising the same infrastructure available to Council and visitors during the day
- Explore infrastructure that could enable electric shuttle buses and trucks to be used as “batteries-on-wheels” to support the microgrid
- Explore feasibility of installing a 300 kW – 1 MW charger nearby the future Yarrabah Jetty
- Expand on the initial assessment to fully model the potential electricity demand from a future electric ferry, and integrate this into the planning of the microgrid

Appendix A. Ergon Energy Network Outages - 4 January 2018 to 6 June 2020

Outage ID	Date	Type	Asset	Description	Outage Reason	Duration (mins)	Yarrabah Impact
18FN0233	4/01/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN0598	13/01/2018	UNPLN	750 Pine Ck Rd Recloser	VEG: Outside Rural Blow-in/Fall-in (NSP responsibility)	Fallen Power Lines	1,152	All customers
18FN0706	16/01/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
17FN17053	18/01/2018	PLN	GS PR1	(blank)	Coordinated M'tce e.g. lines & subs	113	All customers
18FN1103	23/01/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN2239	6/02/2018	UNPLN	750 Pine Ck Rd Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN2700	15/02/2018	UNPLN	750 Pine Ck Rd Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN2816	17/02/2018	UNPLN	132/22KV TRANSF 1	Non EE Transmission fault	Powerlink Fault	81	All customers

18FN3044	20/02/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN3356	24/02/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN3605	27/02/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN3742	1/03/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN3916	5/03/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN4170	11/03/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Manual Reclose - 15 Mins or more No Trigger Found	Protective Device Operated	80	All customers
18FN8224	14/06/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN8247	14/06/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN9051	6/07/2018	FORCD	750 Pine Ck Rd Recloser	(blank)	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	46	All customers
18FN9191	12/07/2018	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers

18FN10010	4/08/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN11462	13/09/2018	FORCD	Sturt Cove Recloser	(blank)	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	133	All customers
18FN14637	27/11/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN14644	27/11/2018	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
18FN15608	10/12/2018	UNPLN	750 Pine Ck Rd Recloser	Wind borne object	Fallen Power Lines	1,439	All customers
18FN16347	26/12/2018	UNPLN	750 Pine Ck Rd Recloser	VEG: Outside Rural Blow-in/Fall-in (NSP responsibility)	Natural Hazard e.g. trees, animals	123	All customers
19FN1307	27/01/2019	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
19FN1643	5/02/2019	FORCD	SA1A Sawmill Rd Sectionaliser	(blank)	Public Safety Isolation - Directed by Emerg Serv Authorised Agent	116	Beyond SA1A Sawmill Rd Sect.
19FN2463	21/02/2019	UNPLN	750 Pine Ck Rd Recloser	HV-Leakage / Pole top fire	Equipment Failure or Malfunction	368	All customers
19FN3534	17/03/2019	UNPLN	750 Pine Ck Rd Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers

19FN3014	11/04/2019	PLN	GS G1.203	(blank)	Coordinated M'tce e.g. lines & subs	437	All customers
19FN8814	7/08/2019	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
19FN10905	6/10/2019	PLN	GS PR166	(blank)	Coordinated M'tce e.g. lines & subs	80	All customers
19FN12849	18/11/2019	FORCD	SA1A Sawmill Rd Sectionaliser	(blank)	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	65	Beyond SA1A Sawmill Rd Sect.
19FN13766	10/12/2019	FORCD	22KV GORDONVALE NO 1 FDR CB	(blank)	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	322	All customers
19FN14439	26/12/2019	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
19FN14444	26/12/2019	UNPLN	22KV GORDONVALE NO 1 FDR CB	HV-Conductor Connection Failure	Equipment Failure or Malfunction	402	All customers
20FN0812	16/01/2020	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN1068	20/01/2020	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN1165	20/01/2020	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Lightning / Storm	<1	All customers

20FN1710	25/01/2020	UNPLN	22KV GORDONVALE NO 2/LTX2 FDR CB	Non EE Transmission fault	Unknown	22	All customers
20FN2446	7/02/2020	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN2761	11/02/2020	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN3667	27/02/2020	UNPLN	22KV GORDONVALE NO 1 FDR CB	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN7752	6/06/2020	UNPLN	Sturt Cove Recloser	Trip & Auto Reclose - No Trigger Found	Transient Fault of Unknown Origin	<1	All customers
20FN7758	6/06/2020	FORCD	Sturt Cove Recloser	(blank)	Public Safety Isolation - NOT Directed by Emerg Serv Authorised Agent	390	All customers

Appendix B. Technical Design Assumptions

B1. Load

Microgrid boundary = Pole recloser ST10 at 52 Stanley Street, Yarrabah

Load downstream of this pole is 7,520 MWh in FY21 according to 15-minute interval data provided by Energy Queensland.

The business-as-usual scenario forecasts load growing by a total of 21.5% over the period to FY32, based on Planz Town Planning projections for 0.5% per annum population growth and 2% per annum residential dwelling growth.

B.1.1 Load Forecast Methodology

Load projections to FY32 were modelled specially for Yarrabah given that occupancy rates, energy efficiency and population growth projections in Yarrabah do not follow broader Australian population trends.

Residential consumption was divided into energy efficient dwellings (new or recently built) or energy inefficient dwellings (older), and furthermore into per person consumption (hot water and appliances) and per dwelling consumption (space cooling and lighting). Per person and per dwelling consumption indices were derived based on an estimated population of 5,000 people and 428 houses (60 of which are assumed energy efficient because they are recently built). New dwellings are assumed to be energy efficient, and population is proportionally distributed across new and existing dwellings. In addition, load forecasts respond to retrofitting higher efficiency cooling and hot water systems to energy inefficient dwellings, with a 39% reduction in the per-dwelling consumption when fitted with a high efficiency DERP enabled air-conditioner and a 67% reduction in the per-person consumption for residents in dwellings where a high-efficiency heat-pump water heater is installed.

Behind-the-meter PV generation is added to the resulting load forecast profile each FY in proportion to the assumed capacity roll out. Simulations include a conservative assumption where 150 systems are rolled out in the first year and another 150 in the second year of operation.

Solar PV Generation

The seasonal nature of forecast rooftop PV generation is shown in Figure 45.

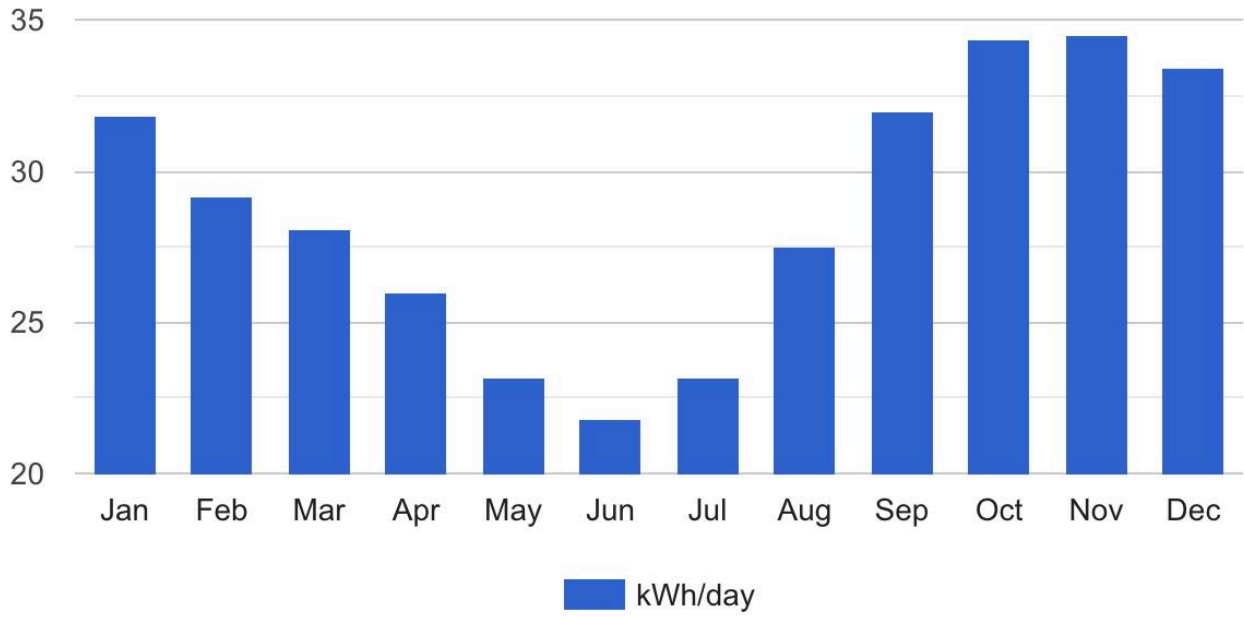

Figure 45 Forecast average daily generation for 6 kW of rooftop solar in the region[113].

The Solar Quotes website reports 10,448 kWh for a 6 kW PV system. Assuming the PV rating is DC, this gives an average yield of around 1,741 kWh/kW$_p$/year[114].

For Yarrabah, NREL's PVWatts Calculator[115] forecasts 1,582 kWh/kW$_p$/year (default losses, 22-degree roof pitch) to 1,654 kWh/kW$_p$/year (optimistic losses, 18-degree pitch) for premium panels with a DC:AC ratio of 1.32.

The Solar Schools website[116] reports the Yarrabah State School's PV array as 55.2 kW. This is the AC (Alternating Current) rating of the inverter and the Department of Education have confirmed the array is actually 73.15 kW$_p$, which is a DC/AC ratio of around 1.33.

The Solar Schools website reports this PV system as having generated 107.5 MWh in the first year of operation, since its commissioning on 6 November 2020. This provides an actual yield of 1,470 kWh/kW$_p$/year.

It is important to note that this is for a specific year which will include periods when the main grid is down and the school's arrays have various orientations. The annual solar resource at Yarrabah can also vary between ~12% below to ~12% above the long term annual average due to the effects of global weather systems such as El Niño and La Niña as well as the number of tropical storms/cyclones in a particular year.

Assumptions for PV output (Year 1):

Ground-mount solar, east-west PEG installation:

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113 www.solarquotes.com.au/location/yarrabah-4871-qld/

114 The methodology, orientation, and the DC/AC ratio for this forecast are not documented.

115 pvwatts.nrel.gov/index.php

116 www.solarschools.net/schools/yarrabah-state-school

- 1,437 kWh/kWp/year
- 1.7 DC:AC ratio
- Assumes 0.5% performance degradation per year, and replacement of inverters at 12 years
- installed cost of $1,100/kW AC (ex GST)

Residential rooftop solar (300 sites):

- 1,443 kWh/kWp/year
- 6.6 kWp with a 5 kWAC inverter (1.32 DC:AC ratio)
- Assumes a distribution of roof pitches (flat and 22.5deg) and orientations (due north, NE 20deg, NW 20deg) and 10% losses due to shading, blocking and soiling.
- Installed cost of $5,400 (ex GST) each, this is based on quotes received from suppliers in Cairns on 30th of June 2021.
- The meter upgrade is not included in this cost as it is usually funded by the retailer with the costs recovered through the metering service charge.

Community building rooftop solar (400kWAC spread across multiple community buildings)

- 1,451 kWh/kWp/year
- One site 120 kWAC (1.4 DC:AC ratio), three sites 85 kWAC (1.4 DC:AC ratio), two sites 13 kWAC (1.4 DC:AC ratio)
- Installed cost of $1,150/kW (GST exc.) assuming flat pitch roofs with easy access and 10% losses due to shading, blocking and infrequent cleaning.

B.1.2 Load forecast results for considered scenarios

The following tables show net load forecasts for the portion of Yarrabah that is covered by the islandable microgrid after applying demand side measurements such as energy efficiency and distributed PV systems (residential and commercial).

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EE retrofit %	0	0	0	0	0	0	0	0	0	0	0	0
Population	5000	5025	5050	5075	5101	5126	5152	5178	5204	5230	5256	5282
Dwellings	428	437	445	454	463	473	482	492	501	511	522	532
Average Consumption kW	853	868	883	899	915	931	948	965	982	1000	1018	1037
Yearly Peak Demand MW	1.51	1.54	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.77	1.80	1.83
Annual Usage MWh	7520	7651	7785	7922	8062	8205	8352	8502	8655	8812	8973	9137

Table 19 Base case load forecast to 2032

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EE retrofit %	0	33	66	100	100	100	100	100	100	100	100	100
Population	5000	5025	5050	5075	5101	5126	5152	5178	5204	5230	5256	5282
Dwellings	428	437	445	454	463	473	482	492	501	511	522	532
Average Consumption kW	853	827	758	687	703	718	735	751	768	785	803	821
Yearly Peak Demand MW	1.51	1.46	1.34	1.22	1.24	1.27	1.30	1.33	1.36	1.39	1.42	1.45
Annual Usage MWh	7520	7286	6686	6059	6195	6334	6476	6622	6771	6925	7081	7242

Table 20 Base case plus Energy Efficiency load forecast to 2032

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EE retrofit %	0	0	0	0	0	0	0	0	0	0	0	0
Population	5000	5025	5050	5075	5101	5126	5152	5178	5204	5230	5256	5282
Dwellings	428	437	445	454	463	473	482	492	501	511	522	532
Average Consumption kW	853	660	467	482	497	512	528	544	561	578	595	613
Yearly Peak Demand MW	1.51	1.41	1.30	1.32	1.35	1.37	1.40	1.42	1.45	1.47	1.50	1.53
Annual Usage MWh	7520	5812	4101	4231	4364	4500	4640	4782	4928	5077	5230	5386

Table 21 Base case + Residential PV load forecast to 2032

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EE retrofit %	0	0	0	0	0	0	0	0	0	0	0	0
Population	5000	5025	5050	5075	5101	5126	5152	5178	5204	5230	5256	5282
Dwellings	428	437	445	454	463	473	482	492	501	511	522	532
Average Consumption kW	853	352	367	382	397	412	428	444	461	478	495	513
Yearly Peak Demand MW	1.51	1.28	1.30	1.32	1.35	1.37	1.40	1.42	1.45	1.47	1.50	1.53
Annual Usage MWh	7520	3094	3222	3352	3485	3621	3761	3903	4049	4198	4351	4507

Table 22 Base case + Residential and Commercial PV load forecast to 2032

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EE retrofit %	0	0	33	66	100	100	100	100	100	100	100	100
Population	5000	5025	5050	5075	5101	5126	5152	5178	5204	5230	5256	5282
Dwellings	428	437	445	454	463	473	482	492	501	511	522	532
Average Consumption kW	853	550	291	229	164	178	193	208	223	239	255	272
Yearly Peak Demand MW	1.51	1.41	1.18	1.09	0.99	1.01	1.03	1.06	1.08	1.10	1.13	1.16
Annual Usage MWh	7520	4912	2554	2008	1440	1565	1694	1826	1962	2101	2244	2389

Table 23 Base case + Energy Efficiency + Residential + Commercial PV load forecast to 2032

B2. Community Battery

Large scale batteries modelled use the following assumptions:

- 85% return trip efficiency and 2.6% degradation per year.
- Modelled power to energy ratios of 1kW/1kWh to 1kW/8kWh in 1kWh increments (I.e., from 1h to 8h of storage)
- Storage assumed effective depth of discharge of 100%, I.e., installed costs include additional kWh to account for operational depth of discharge lower limit of 10%.
- Battery configurations assume installed cost of $550/kW + $450/kWh*hours. For example, a 100kW/300kWh battery has an installed cost of $190,000

B3. Technical Assumptions for Financial and Cost/Benefit Analysis

The following assumptions list technical aspects for project options that have repercussions in downstream financial and cost/benefit analyses.

- All costs are in real dollars for 2021 excluding GST.
- Photovoltaic panels are assumed to have a 25-year life.
- Inverters for PV systems and BESS have an assumed life 12 years for central and community systems. For residential systems it is assumed that inverters have a 10-to-12-year life and are progressively replaced over a 3-year period.
- Assuming 428 households consuming 90% of the town load, average residential consumption is 41 kWh/day (45 kWh/day in March and 35 kWh/day in August).
- Average residential PV exports are estimated to be 9.5 kWh/day per household.

B4. Rooftop Assessment Methodology

An assessment of rooftop orientation and potential solar PV capacity that could be hosted on residential dwellings in Yarrabah was undertaken using satellite images. ITP divided the township into 5 sections:

- Beachfront, for the northern end of town facing Yarrabah beach.
- Sawmill Rd. for the section of dwellings aligned with Sawmill Rd and Stanley Rd.
- Museum: For the section spanning from the Police Station to the Hospital near Bukki Rd.
- Residential Development: for the housing development along Back Beach Rd south of the hospital.
- Remainder: For the remainder of dwellings that are scattered in other parts of the community

All rooftops were counted, assessed for suitability, and classified into different orientations and rooftop spaces for PV panels by ITP staff from satellite images. Gabled roofs are assumed to have a standard pitch of 22.5 degrees. Rooftop orientation categories consider the resulting normal orientation of a panel when installed on a given rooftop, and are divided into due north, east-west, 20 degrees east of north 20 degrees west of north and flat roofs (i.e. no pitch) based on the prevalent orientation of the assessed roofs. Roofs that do not exactly align with each category are assigned to the closest matching category with a tolerance of 5 degrees. Figure 46 shows samples of classified roofs, including those which do not perfectly align with each category.

Due north 0° East-West 90° East of North 20° West of North 20°

Figure 46 Sample classification of rooftop orientations for Yarrabah

Roofs were then assessed in more detail for available space for installation at those orientations. ITP staff inspected roof space in more detail, and for each house identified a potential capacity of rooftop PV to be installed based on available roof area not impacted by shading. The relationship between available rooftop area and resulting rooftop PV capacity in KW for a dwelling is shown in Table 24.

Area (m^2)	Range Area (m^2)	kW System
5	<7.5	1
10	7.5-12.5	2
15	12.5-17.5	3
20	17.5-22.5	4
=>25	>22.5	5

Table 24 Relationship between available rooftop area and viable rooftop PV system capacity

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.

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 47. In very high winds, wind turbines use various protection mechanisms which means no power is produced.

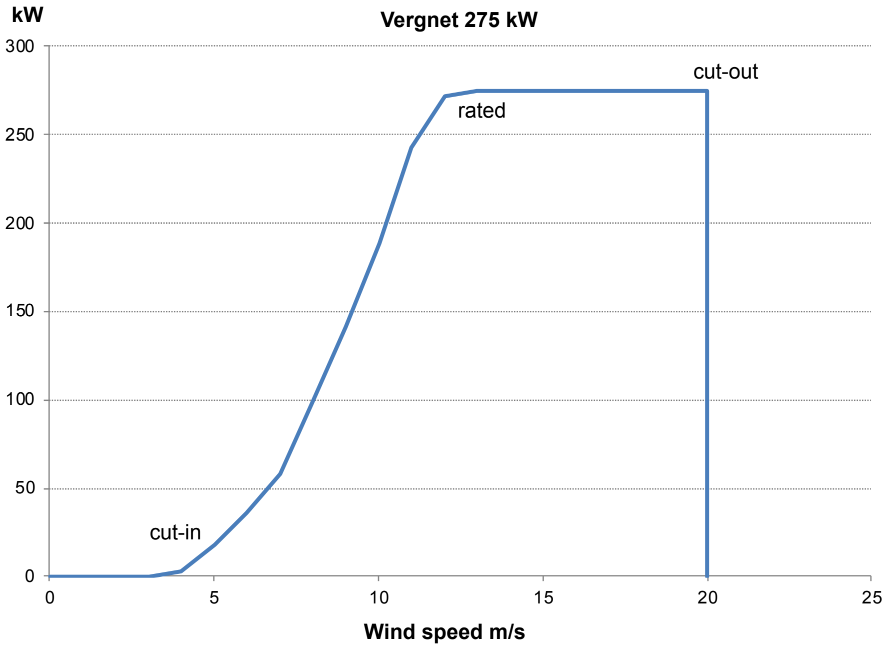

Figure 47 Wind turbine power curve.

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[117] 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.

[117] 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. This study refers to diesel generators as this is what is most appropriate for operating Yarrabah in islanded mode for extended periods during widespread cloud cover.

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 at a later time 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.

D3. Energy Storage in an Islandable Microgrid

Energy storage requirements and design parameters for an islandable microgrid are more complex. This is because the generation and energy storage perform in grid-connected and island mode for different periods of the year.

As Yarrabah is constrained for land and at a low elevation above sea level, pumped hydro is unlikely to be an appropriate storage option. Compressed air, flow batteries and hydrogen storage have high capital and/or running costs at a small scale. In addition, they require specialised operation, maintenance, and parts. High pressure tanks are available for hydrogen storage but costs are relatively high. Underground caverns are order of magnitudes less expensive than hydrogen storage tanks, but not a geological feature in Yarrabah.

Therefore, the most appropriate technology is batteries, with lithium-ion technologies most widely used. Lithium-ion batteries are low-maintenance, scalable, have a high energy density, and are a proven off-the-shelf technology. They are also able to be recycled when replaced.

The battery energy storage system (BESS) is also essential for ensuring power continuity in switching between the two operating modes. In addition, the financial and regulatory aspects of these two operating modes are quite different.

Grid-connected mode

Most of the time, the centralised solar and BESS would not be used to power Yarrabah in island mode, as the main grid would be available. This means the central solar and BESS would be connected to the main grid and are governed by the regulatory requirements of the NEM. Thus, these assets could participate in external markets such as wholesale spot markets and the provision of Frequency Control Ancillary Services (FCAS) or simply provide electricity through a PPA as discussed in Section 12.3.

Wholesale spot markets are where electricity is traded at the wholesale level, which is where retailers generally buy the electricity they provide to customers (apart from the electricity they buy from distributed energy resources). FCAS markets are used to ensure that the frequency of electricity on the main grid is kept within allowed limits.

It is most likely that a centralised solar PV system at Yarrabah will participate in a PPA with a third party, which may specify a minimum amount of electricity to be provided over the year. This will limit any additional participation in spot markets, above what is required under the PPA. In its simplest form, this PPA would involve a third party, such as Ergon Energy Retail, buying the solar output at the time it was generated.

The PPA could also be designed to include the battery and provide higher $/MWh rates in peak demand periods, such as in the evenings. If the battery is included in the PPA, there may also be opportunities to include potential income from participating in FCAS markets.

Energy Queensland are trialling community batteries at five regional locations. These batteries will each have a capacity of 4 MW / 8 MWh. The Talking Energy website[118] states, ‘They will allow the green energy made locally, during the day, to be stored locally, for use

[118] www.talkingenergy.com.au/batteryplan

locally during the evening peak in demand.' The lessons learnt from these trials will be useful for Yarrabah, if a large amount of distributed solar is installed.

Yurika, a subsidiary of Energy Queensland, has delivered a large community battery at Townsville[119]. This 4 MW / 8 MWh BESS was installed at Bohle Plains with the aim of improving the quality of electricity, deferring the need for network investment by reducing summer peak demands, creating more capacity for residential solar and making better use of existing infrastructure.

Island mode

Solar PV inverters are grid-following, meaning they cannot power an islanded microgrid without a separate voltage source. The voltage source can be provided in various ways, but diesel generators and battery energy storage systems are the most feasible options for Yarrabah.

Solar PV generation can operate in parallel with diesel generators on an islanded microgrid to reduce generator loading and fuel consumption. However, PV output can fluctuate rapidly due to passing clouds, and hence generators must be capable of ramping quickly to compensate. Diesel generators have high ramp rates and high tolerance of low loading compared to most thermal generation technologies, but there are limits to their performance and therefore limits to how much PV can be integrated without BESS and/or PV curtailment.

BESS can mitigate instability introduced by PV output volatility and can shift excess PV generation for later use. If BESS inverters are grid-forming and have sufficient capacity to clear faults, the microgrid can be safely operated without diesel generation whenever the BESS has sufficient power and energy available to meet the load. When insufficient power or energy is available (e.g. when the BESS is flat), diesel generation can be dispatched.

If the BESS cannot absorb additional power (e.g. when it is full), solar generation must be curtailed. This can be carried out via active power limits sent to PV inverters, or by configuring the BESS to raise the grid frequency when limits are being reached and configuring PV inverters to curtail their output in response to rising frequency.

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[119] www.yurika.com.au/news/2019/yurika-to-deliver-community-scale-battery-in-townsville

Appendix E. Detailed Financial Statements

PROFIT AND LOSS

	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42
Operating Revenue	1,569,393	744,781	1,531,034	2,216,447	2,249,694	2,283,439	2,317,691	2,352,456	2,387,743	2,423,559	2,552,756	2,496,811	2,534,263	2,572,277	2,610,861	2,650,024	2,689,775	2,730,121	2,771,073	2,812,639
Capital Revenue	12,225,220	7,629,978	3,646,997	-	-	-	-	-	-	3,891,756	427,659	176,692	179,343	-	-	-	-	-	-	-
Other Revenue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Revenue	**13,794,613**	**8,374,759**	**5,178,030**	**2,216,447**	**2,249,694**	**2,283,439**	**2,317,691**	**2,352,456**	**2,387,743**	**6,315,316**	**2,980,415**	**2,673,504**	**2,713,606**	**2,572,277**	**2,610,861**	**2,650,024**	**2,689,775**	**2,730,121**	**2,771,073**	**2,812,639**
Direct Costs	(1,514,193)	(672,729)	(1,247,185)	(1,798,157)	(1,825,129)	(1,852,506)	(1,880,294)	(1,908,498)	(1,937,126)	(1,966,183)	(2,088,519)	(2,025,610)	(2,055,995)	(2,086,834)	(2,118,137)	(2,149,909)	(2,182,158)	(2,214,890)	(2,248,113)	(2,281,835)
Gross Profit	**12,280,420**	**7,702,030**	**3,930,845**	**418,290**	**424,565**	**430,933**	**437,397**	**443,958**	**450,617**	**4,349,133**	**891,897**	**647,893**	**657,612**	**485,443**	**492,724**	**500,115**	**507,617**	**515,231**	**522,960**	**530,804**
Operating Expenses	(55,200)	(60,596)	(67,686)	(147,127)	(149,334)	(151,574)	(153,847)	(156,155)	(158,498)	(160,875)	(163,288)	(165,737)	(168,223)	(170,747)	(173,308)	(175,908)	(178,546)	(181,224)	(183,943)	(186,702)
EBITDA	**12,225,220**	**7,641,435**	**3,863,159**	**271,163**	**275,231**	**279,359**	**283,550**	**287,803**	**292,120**	**4,188,258**	**728,608**	**482,156**	**489,388**	**314,696**	**319,416**	**324,208**	**329,071**	**334,007**	**339,017**	**344,102**
Interest & Depreciation	(536,167)	(860,872)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,017,003)	(1,176,124)	(1,193,231)	(1,200,298)	(1,207,472)	(1,207,472)	(1,207,472)	(1,207,472)	(1,207,472)	(1,207,472)	(1,207,472)	(1,207,472)
Net Profit/ (Loss) Before Tax	**11,689,053**	**6,780,563**	**2,846,157**	**(745,839)**	**(741,772)**	**(737,644)**	**(733,453)**	**(729,200)**	**(724,883)**	**3,012,134**	**(464,622)**	**(718,143)**	**(718,084)**	**(892,776)**	**(888,056)**	**(883,264)**	**(878,401)**	**(873,465)**	**(868,455)**	**(863,370)**
Gross profit %	*89%*	*92%*	*76%*	*19%*	*19%*	*19%*	*19%*	*19%*	*19%*	*69%*	*30%*	*24%*	*24%*	*19%*	*19%*	*19%*	*19%*	*19%*	*19%*	*19%*
Operating expenses %	*0%*	*-1%*	*-1%*	*-7%*	*-7%*	*-7%*	*-7%*	*-7%*	*-7%*	*-3%*	*-5%*	*-6%*	*-6%*	*-7%*	*-7%*	*-7%*	*-7%*	*-7%*	*-7%*	*-7%*
EBITDA %	*89%*	*91%*	*75%*	*12%*	*12%*	*12%*	*12%*	*12%*	*12%*	*66%*	*24%*	*18%*	*18%*	*12%*	*12%*	*12%*	*12%*	*12%*	*12%*	*12%*
Net profit %	*85%*	*81%*	*55%*	*-34%*	*-33%*	*-32%*	*-32%*	*-31%*	*-30%*	*48%*	*-16%*	*-27%*	*-26%*	*-35%*	*-34%*	*-33%*	*-33%*	*-32%*	*-31%*	*-31%*
Revenue Growth		*-39%*	*-38%*	*-57%*	*1%*	*1%*	*1%*	*2%*	*1%*	*164%*	*-53%*	*-10%*	*1%*	*-5%*	*2%*	*1%*	*1%*	*1%*	*2%*	*1%*

CASHFLOW STATEMENT

	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42
Cash From Operations																				
Operating Revenues	1,569,393	744,781	1,531,034	2,216,447	2,249,694	2,283,439	2,317,691	2,352,456	2,387,743	2,423,559	2,552,756	2,496,811	2,534,263	2,572,277	2,610,861	2,650,024	2,689,775	2,730,121	2,771,073	2,812,639
Direct Costs	(1,514,193)	(672,729)	(1,247,185)	(1,798,157)	(1,825,129)	(1,852,506)	(1,880,294)	(1,908,498)	(1,937,126)	(1,966,183)	(2,088,519)	(2,025,610)	(2,055,995)	(2,086,834)	(2,118,137)	(2,149,909)	(2,182,158)	(2,214,890)	(2,248,113)	(2,281,835)
Operating Expenses	(55,200)	(60,596)	(67,686)	(147,127)	(149,334)	(151,574)	(153,847)	(156,155)	(158,498)	(160,875)	(163,288)	(165,737)	(168,223)	(170,747)	(173,308)	(175,908)	(178,546)	(181,224)	(183,943)	(186,702)
Profit/ (Loss) From Operations	**-**	**11,457**	**216,163**	**271,163**	**275,231**	**279,359**	**283,550**	**287,803**	**292,120**	**296,502**	**300,949**	**305,463**	**310,045**	**314,696**	**319,416**	**324,208**	**329,071**	**334,007**	**339,017**	**344,102**
Working Capital Movements	(48,422)	(4,030)	(36,983)	(37,126)	(1,898)	(1,571)	(2,312)	(1,985)	(2,015)	(1,667)	(3,217)	(1,344)	(2,139)	(1,769)	(2,604)	(2,236)	(2,270)	(1,878)	(2,764)	(2,373)
Total Cash From Operations	**(48,422)**	**7,427**	**179,179**	**234,037**	**273,332**	**277,788**	**281,237**	**285,818**	**290,105**	**294,835**	**297,732**	**304,120**	**307,907**	**312,927**	**316,812**	**321,971**	**326,801**	**332,129**	**336,253**	**341,729**
Cash From Investments																				
Capital Grants	12,225,220	7,629,978	3,646,997	-	-	-	-	-	-	3,891,756	427,659	176,692	179,343	-	-	-	-	-	-	-
Assets Purchased/ Capital Expenditure	(12,225,220)	(7,629,978)	(3,646,997)	-	-	-	-	-	-	(3,891,756)	(427,659)	(176,692)	(179,343)	-	-	-	-	-	-	-
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	31,264	7,070	20,923	26,570	5,170	4,975	5,397	5,202	5,213	5,010	5,726	4,969	5,258	5,047	5,503	5,293	5,305	5,087	5,561	5,343
Total Cash From Financing	**31,264**	**7,070**	**20,923**	**26,570**	**5,170**	**4,975**	**5,397**	**5,202**	**5,213**	**5,010**	**5,726**	**4,969**	**5,258**	**5,047**	**5,503**	**5,293**	**5,305**	**5,087**	**5,561**	**5,343**
Total Cash Movement	**(17,158)**	**14,497**	**200,102**	**260,607**	**278,503**	**282,764**	**286,634**	**291,019**	**295,318**	**299,845**	**303,458**	**309,088**	**313,164**	**317,974**	**322,315**	**327,265**	**332,106**	**337,216**	**341,814**	**347,072**
Opening Cash Balance	-	(17,158)	(2,661)	197,442	458,048	736,551	1,019,315	1,305,949	1,596,968	1,892,286	2,192,131	2,495,589	2,804,677	3,117,841	3,435,815	3,758,130	4,085,395	4,417,501	4,754,717	5,096,531
Closing Cash Balance	**(17,158)**	**(2,661)**	**197,442**	**458,048**	**736,551**	**1,019,315**	**1,305,949**	**1,596,968**	**1,892,286**	**2,192,131**	**2,495,589**	**2,804,677**	**3,117,841**	**3,435,815**	**3,758,130**	**4,085,395**	**4,417,501**	**4,754,717**	**5,096,531**	**5,443,603**
Liability Coverage	*-0.04 : 1*	*0.01 : 1*	*0.41 : 1*	*1.47 : 1*	*1.65 : 1*	*1.62 : 1*	*1.57 : 1*	*1.55 : 1*	*1.52 : 1*	*0.54 : 1*	*1.19 : 1*	*1.34 : 1*	*1.32 : 1*	*1.40 : 1*	*1.38 : 1*	*1.36 : 1*	*1.34 : 1*	*1.33 : 1*	*1.31 : 1*	*1.30 : 1*
Current Liability Coverage	*-0.04 : 1*	*0.01 : 1*	*0.41 : 1*	*1.47 : 1*	*1.65 : 1*	*1.62 : 1*	*1.57 : 1*	*1.55 : 1*	*1.52 : 1*	*0.54 : 1*	*1.19 : 1*	*1.34 : 1*	*1.32 : 1*	*1.40 : 1*	*1.38 : 1*	*1.36 : 1*	*1.34 : 1*	*1.33 : 1*	*1.31 : 1*	*1.30 : 1*

BALANCE SHEET

	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
Bank Account	(17,158)	(2,661)	197,442	458,048	736,551	1,019,315	1,305,949	1,596,968	1,892,286	2,192,131
Trade Receivables	1,247,184	755,101	468,151	200,391	203,397	205,884	209,545	212,688	215,878	569,414
Other Current Assets	-	-	-	-	-	-	-	-	-	-
Total Current Assets	**1,230,026**	**752,440**	**665,592**	**658,439**	**939,948**	**1,225,198**	**1,515,493**	**1,809,656**	**2,108,164**	**2,761,544**
Fixed Assets	11,689,053	18,458,159	21,088,153	20,071,151	19,054,148	18,037,145	17,020,142	16,003,140	14,986,137	17,701,769
Other Non-Current Assets	-	-	-	-	-	-	-	-	-	-
Total Non-Current Assets	**11,689,053**	**18,458,159**	**21,088,153**	**20,071,151**	**19,054,148**	**18,037,145**	**17,020,142**	**16,003,140**	**14,986,137**	**17,701,769**
Total Assets	**12,919,080**	**19,210,600**	**21,753,746**	**20,729,590**	**19,994,096**	**19,262,344**	**18,535,636**	**17,812,796**	**17,094,301**	**20,463,314**
Trade Payables	1,198,762	702,650	378,716	73,830	74,938	75,854	77,203	78,361	79,536	431,405
Other Current Liabilities	31,264	38,334	59,257	85,827	90,997	95,972	101,369	106,571	111,784	116,794
Total Current Liabilities	**1,230,026**	**740,984**	**437,973**	**159,657**	**165,935**	**171,826**	**178,572**	**184,931**	**191,320**	**548,198**
External Debt	-	-	-	-	-	-	-	-	-	-
Other Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-
Total Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-
Total Liabilities	**1,230,026**	**740,984**	**437,973**	**159,657**	**165,935**	**171,826**	**178,572**	**184,931**	**191,320**	**548,198**
Net Assets	**11,689,053**	**18,469,616**	**21,315,773**	**20,569,933**	**19,828,161**	**19,090,517**	**18,357,064**	**17,627,864**	**16,902,981**	**19,915,115**
Retained Earnings	11,689,053	18,469,616	21,315,773	20,569,933	19,828,161	19,090,517	18,357,064	17,627,864	16,902,981	19,915,115
Total Equity	**11,689,053**	**18,469,616**	**21,315,773**	**20,569,933**	**19,828,161**	**19,090,517**	**18,357,064**	**17,627,864**	**16,902,981**	**19,915,115**
Current ratio	*1.00 : 1*	*1.02 : 1*	*1.52 : 1*	*4.12 : 1*	*5.66 : 1*	*7.13 : 1*	*8.49 : 1*	*9.79 : 1*	*11.02 : 1*	*5.04 : 1*
Return on Equity %	*100%*	*37%*	*13%*	*-4%*	*-4%*	*-4%*	*-4%*	*-4%*	*-4%*	*15%*
Return on Assets %	*90%*	*35%*	*13%*	*-4%*	*-4%*	*-4%*	*-4%*	*-4%*	*-4%*	*15%*

	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42
Bank Account	2,495,589	2,804,677	3,117,841	3,435,815	3,758,130	4,085,395	4,417,501	4,754,717	5,096,531	5,443,603
Trade Receivables	269,462	241,714	245,340	231,927	236,050	239,591	243,185	246,158	250,535	254,293
Other Current Assets	-	-	-	-	-	-	-	-	-	-
Total Current Assets	**2,765,051**	**3,046,391**	**3,363,181**	**3,667,742**	**3,994,181**	**4,324,986**	**4,660,686**	**5,000,876**	**5,347,066**	**5,697,896**
Fixed Assets	16,936,198	15,912,592	14,884,463	13,676,990	12,469,518	11,262,046	10,054,574	8,847,102	7,639,630	6,432,158
Other Non-Current Assets	-	-	-	-	-	-	-	-	-	-
Total Non-Current Assets	**16,936,198**	**15,912,592**	**14,884,463**	**13,676,990**	**12,469,518**	**11,262,046**	**10,054,574**	**8,847,102**	**7,639,630**	**6,432,158**
Total Assets	**19,701,249**	**18,958,983**	**18,247,643**	**17,344,732**	**16,463,699**	**15,587,032**	**14,715,261**	**13,847,978**	**12,986,697**	**12,130,054**
Trade Payables	128,236	99,144	100,631	85,449	86,968	88,273	89,597	90,692	92,305	93,689
Other Current Liabilities	122,520	127,488	132,746	137,793	143,296	148,590	153,895	158,982	164,543	169,886
Total Current Liabilities	**250,756**	**226,632**	**233,377**	**223,242**	**230,265**	**236,862**	**243,492**	**249,674**	**256,848**	**263,575**
External Debt	-	-	-	-	-	-	-	-	-	-
Other Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-
Total Non-Current Liabilities	-	-	-	-	-	-	-	-	-	-
Total Liabilities	**250,756**	**226,632**	**233,377**	**223,242**	**230,265**	**236,862**	**243,492**	**249,674**	**256,848**	**263,575**
Net Assets	**19,450,493**	**18,732,350**	**18,014,266**	**17,121,490**	**16,233,435**	**15,350,170**	**14,471,769**	**13,598,304**	**12,729,849**	**11,866,479**
Retained Earnings	19,450,493	18,732,350	18,014,266	17,121,490	16,233,435	15,350,170	14,471,769	13,598,304	12,729,849	11,866,479
Total Equity	**19,450,493**	**18,732,350**	**18,014,266**	**17,121,490**	**16,233,435**	**15,350,170**	**14,471,769**	**13,598,304**	**12,729,849**	**11,866,479**
Current ratio	*11.03 : 1*	*13.44 : 1*	*14.41 : 1*	*16.43 : 1*	*17.35 : 1*	*18.26 : 1*	*19.14 : 1*	*20.03 : 1*	*20.82 : 1*	*21.62 : 1*
Return on Equity %	*-2%*	*-4%*	*-4%*	*-5%*	*-5%*	*-6%*	*-6%*	*-6%*	*-7%*	*-7%*
Return on Assets %	*-2%*	*-4%*	*-4%*	*-5%*	*-5%*	*-6%*	*-6%*	*-6%*	*-7%*	*-7%*

Appendix F. Financial Assessment – Detailed Assumptions

F1. Overview

A financial assessment was completed in relation to the project comprising of the establishment of a program management office and Stages 1A to 2C to ascertain its financial viability, and to provide a future looking forecast of the funding requirements. 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.

Note: Outputs of the financial assessment presented in the tables throughout this section may not sum exactly due to rounding differences in source data.

It should be noted that the financial model 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 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.

F.1.1 General Financial Assumptions

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, revenues, depreciation and interest to a pre-tax level. These cashflows are based on the cost of the project in today's (2021) dollars and have been escalated as required for inflation or other factors.

Financial Assessment Assumptions

The key financial assessment assumptions that have been incorporated into the financial model, and the sources of those assumptions (as of 30 November 2021), are presented below. 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.

Input Assumption	Description
Commencement Date of Analysis	1 July 2022
Commencement of Project Activities	1 July 2022
Commencement of Operations	Fiscal year immediately after completion of construction works for each Stage
End of Financial Assessment	30 June 2042
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

F.1.2 Construction Phase

A preliminary concept design cost plan for the project was prepared by ITP as part of the technical option analysis. The assessment performed by ITP 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 pre-implementation 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 2021 terms and escalated at a rate of 1.5% per annum
- No allowance has been made for staging or delayed construction costs.

Capital Development Cost

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

Capital Expenditure Summary	FY23	FY24	FY25
Program Management Office	2,620,000	-	-
Stage 1A - Energy Efficiency Audit & Upgrades	1,413,120	1,434,317	-
Stage 1B - Residential Rooftop Solar	2,088,000	-	-
Stage 2A - Solar Farm, Battery, Generator	6,104,100	6,195,662	-
Stage 2B - YEKC	-	-	3,461,556
Stage 2C - Micro Wind and Hydro	-	-	185,441
Total Capital Expenditure	12,225,220	7,629,978	3,646,997

Collectively, **the total estimated capital cost for the project is expected to be $23.502 million over a 3-year period** (excluding GST).

The capital cost of $2.62 million 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 technical specifications, hydrology studies, land and site assessments, detailed designs and engineering reports, detailed financial and commercial analyses, quantity surveys and PMO establishment. These preliminary works will be required to advance the project to a shovel ready state.

It is noted that the capital costs associated with Stage 2D – Community Rooftop PV (circa $552,000) has not been included in the capital estimate. This is on the basis that these assets will not be owned by YASC and will be funded by various community organisations and Government agencies (i.e., community building owners onto which the PV systems are installed). Notwithstanding, YASC will source these assets and will manage the construction and installation phase on behalf the respective asset owner. For modelling purposes these costs have been treated as operating expenditure with an equivalent cost reimbursement reflected as an offset.

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:

Refurbishment Capital Expenditure Summary	FY32	FY33	FY34	FY35
Program Management Office	-	-	-	-
Stage 1A - Energy Efficiency Audit & Upgrades	-	-	-	-
Stage 1B - Residential Rooftop Solar	-	174,081	176,692	179,343
Stage 2A - Solar Farm, Battery, Generator	3,546,624	253,578	-	-
Stage 2B - YEKC	-	-	-	-
Stage 2C - Micro Wind and Hydro	-	-	-	-
Total Refurbishment Capital Expenditure	3,546,624	427,659	176,692	179,343

Collectively, **the total estimated sustaining capital cost for the project is expected to be $4.33 million** (excluding GST) commencing approximately 10 years after completion of project construction works.

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 later in this Report. The timing of the receipt of grant funds has been assumed to align with the fiscal year in which expenditure is incurred.

F2. 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 (2021) dollars. Operating revenues and costs have been escalated based on a nominal growth rate of 1.5% per annum (unless otherwise stated).

F.2.1 Operational Revenues

Operating revenues for the project are expected to be generated from the following sources:

- Operating - Services and User Charges
- Operating - Government Grants
- Operating - Corporate/ Partner Contributions

The table below summarises the total operating revenues (escalated) generated by the project assets for the first eight years of operation.

Operating Revenue	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30
Services	-	60,900	690,673	741,187	754,343	767,830	781,662	795,854
Grants	549,393	683,881	840,361	1,422,976	1,442,283	1,461,745	1,481,357	1,501,110
Contributions	1,020,000	-	-	52,284	53,068	53,864	54,672	55,492
Total Op Revenues	1,569,393	744,781	1,531,034	2,216,447	2,249,694	2,283,439	2,317,691	2,352,456

These have been discussed in detail below.

Operating Revenue – Services

Services and user charge income generated from the project assets are primarily sourced from the following:

Stage 2A – External Operator Usage Charges

For the purposes of the model, it has been assumed that an external/ independent entity will operate and maintain the central microgrid assets on behalf of YASC. This entity is expected to be a public or private enterprise operating in the energy generation and distribution space, such as Energy Queensland Limited. The operator will have right to all energy generated by the microgrid assets and may on sell these to energy retailers or wholesalers.

The charge levied on the external operator for use of the project assets has been determined based on a gross 5% per annum return on the base capital cost of $12.208 million. This equates to a base amount of $610,410 annually. The terms of such a leasing arrangement, and the final return to YASC will be subject to commercial negotiations as part of the implementation phase of the project.

Stage 2B – General User and Events Patronage Charges

General user charges will be levied on individuals attending the YEKH. For larger groups or program providers (groups greater than 20), a fixed group/ events rate has been applied.

For the purposes of the financial model, the following base assumptions have been relied upon in developing the general user and events charges:

Charge Type	Base Annual Volume	Base Rate ($/ Entry)
General User	1,440	$10.00
Event or Group	120	$200.00

Annual user and event numbers have been escalated at a growth rate of 5% per year.

Stage 2D – Maintenance Charges

YASC (via the Implementation Entity) will supply staff to maintain rooftop PV systems installed on community buildings. YASC will charge the relevant community organisation a services charge in relation to the maintenance service.

For the purposes of the financial assessment, and with details of the specific arrangements for this service subject to further negotiation, a rate of $150/ kW per annum has been assumed as a reasonable benchmark for this service. Based on a total of 400kW for the community rooftop solar systems, this equates to a base charge of $60,000 per annum.

Operating Revenue – Grants

A proportion of the cost to operate and maintain the project assets will require funding via ongoing Government grant or a similar support arrangement. The main costs that such funding will be required to cover, include:

17 Residual cost of operating and maintaining project assets, after considering any other self-generated income streams, such as service charges;
18 Costs of sustaining the implementation entity, where these are not covered by program and project management fees derived through specific capital grant programs; and
19 Costs of employing operational staff to operate and maintain project assets.

The level of funding required to cover operational costs will vary year to year, and will be dependent upon the level of other income generated by YASC from the microgrid assets. As an indication of the expected base annual level of funding required annually through grant programs is as follows:

Stage	Base Annual Grant Amount ($)
Stage 1A	$25,000
Stage 1B	$110,000
Stage 2B	$225,000
Stage 2C	$7,500
PMO	$1,030,000
Total	$1,397,500

These amounts will be subject to annual escalation at 1.5% in accordance with the expected increase in underlying operational costs.

Operating Revenue – Contributions

In accordance with Stage 1A (Energy Efficiency Audit & Appliance Upgrade) an amount of $468,000 of corporate contribution revenue has been reflected in FY23. This relates to an energy efficiency audit program ($368,000) and energy education program ($100,000). It is expected that an organisation such as Energy Queensland or similar agency will contribute funds towards conducting the audit and completing the education program.

An additional source of contribution revenues is expected to be sourced from those community agencies/ organisations that will have rooftop PV systems installed (Stage 2D). YASC will commission, acquire and install the systems and will be funded through contributions from the recipient organisation. The value and timing of these contributions has been assumed to align with the expenditure incurred by YASC.

F.2.2 Operational Costs

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

Employment Costs (Salaries, Superannuation and other On Costs)

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

- Program Management Office staff; and
- Operations and Maintenance staff.

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

Role	Base Annual Salary (Excluding On Costs)
Operations Officer	$60,000
Maintenance Officer	$60,000
Administration Officer	$60,000
Program Director	$150,000
Program Manager	$120,000
Program Support Officer	$80,000

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

On Cost	Rate
Payroll Tax	4.75%
Workers Compensation	2.00%

The FTEs included within the model are summarised as follows:

Role Title	FTE	Commencement
Program Director	1	FY23
Program Manager	1	FY23
Program Support Officer	1	FY23
Operations Officer	6	FY24 to FY26
Maintenance Officer	1	FY26
Administration Officer	1	FY26

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, special program costs (such as energy education program and audit) and overheads have been included as operating costs. These costs are reflected across the following categories:

- Direct Costs - Contractor Expenses
- Direct Costs - Materials & Consumables
- Direct Costs - Facility Expenses
- Direct Costs - Other
- Overheads

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

Program Management Office

Costs associated with the operation of a physical office facility, housing the program management team have been included from FY23. Facility costs, including lease, utilities, computer expenses, insurance and maintenance costs, totalling $62,000 per annum have been assumed. Additional office overheads of $55,200 per annum have been included for the PMO.

It is noted that the PMO has been retained for the duration of the model term. This is on the basis that the PMO team will revert to an operationally focused program management role once the construction phase has completed. This will be to ensure that the targeted objectives of the project are sustained for the life of the project.

It is expected that the PMO may be able to be utilised to manage other similar infrastructure projects on behalf of YASC. While this has not been reflected in the modelled assumptions, this presents a potential upside for YASC in the ability to cover assumed costs.

Stage 1A – Energy Efficiency Audit and Appliance Upgrades

As outlined in the revenue section above, under Stage 1A an energy efficiency audit of approximately 368 dwellings ($1,000 per dwelling) will be conducted during FY23. In addition to this, an energy education program is proposed to be run offering information to dwelling occupants. This program will be once off cost of $100,000 in FY23.

Following completion of the energy efficiency appliance upgrade in FY24, an ongoing maintenance cost of 2.5% of the total capex value has been assumed from FY25 onwards. This rate is inclusive of material costs only on the basis that labour is forecast separately through salaries and wages.

Item	Rate	Unit
Energy Efficiency Appliances - O&M (Variable)	$160	$/ dwelling/ annum

Stage 1B – Residential Rooftop Solar

Following completion of the residential rooftop solar program in FY24, an ongoing maintenance cost of 2.5% of the total capex value has been assumed for the model. This rate is inclusive of material costs only on the basis that labour is forecast separately through salaries and wages.

Item	Rate	Unit
PV System - O&M (Variable)	$145	$/PV system/ annum

Stage 2A – Community Solar Farm, Battery and Generator

The operating and maintenance costs associated with the community microgrid assets have been determined based on industry benchmarks. The expected rates per kilowatt have been outlined below.

The below table outlines the cost basis for direct operating costs associated with Stage 2A.

Item	Rate	Unit
PV System - O&M	$5.50	$/kW
Battery - O&M	$48.75	$/kW
Diesel Generator - O&M	$15.61	$/kW
Microgrid Control Unit - Subscription	$70,000	$/annum
Land Lease, Site Maintenance and Utilities	$170,000	$/annum

Stage 2B – Yarrabah Energy Knowledge Hub

The Yarrabah Energy Knowledge Hub (YEKH) is expected to be a self-sustaining facility with a staff of 4 FTEs. The annual operating, facility and overhead costs associated with operating the YEKH have been outlined below:

Item	Rate	Unit
Operating and Facility Costs	$198,000	$/ Annum
Overheads	$63,000	$/ Annum

Stage 2C – Micro Hydroelectricity Plant and Wind Turbine

Following completion of the construction of the micro hydro and wind turbine in FY25, an ongoing maintenance cost of 5.0% of the total capex value has been assumed for the model. This rate is inclusive of material costs only on the basis that labour is forecast separately through salaries and wages.

Item	Rate	Unit
Micro Hydro - O&M	$2,500	$/ Annum
Wind Turbine – O&M	$5,000	$/ Annum

Stage 2D – Community Rooftop Solar

Following completion of the community rooftop solar program in FY23, an ongoing maintenance cost of 2.5% of the total capex value has been assumed for the model. This rate is inclusive of material costs only on the basis that labour is forecast separately through salaries and wages.

Item	Rate	Unit
Community PV System - O&M	$28.75	$/kW

F.2.3 Non-Operational Costs

Interest Expense

For the purposes of this model and the broader feasibility study, it has been assumed that no external debt or loan facilities will be entered into by YASC for the project. Notwithstanding, in practice, it is likely that a working capital facility may be required to manage cashflows. It has been assumed that such a facility will be provided in the form of a non-interest-bearing loan through YASC.

Depreciation

The financial assessment has assumed a straight-line depreciation method based on estimated effective lives assigned to the various assets categories. The effective lives assigned are as follows:

Asset	Average Effective Life
Buildings	40 Years
Capital Improvements	25 Years
Plant & Equipment	20 Years
Furniture & Fittings	20 Years
Other Depreciable Assets	20 Years
Project Management & Planning (Capital)	20 Years

Appendix G. Case Studies

G1. Western Australia

G.1.1 SAPS and Microgrids

In WA's main grid, the South West Interconnected System (SWIS), there is a focus on strategies to convert isolated farms in fringe-of-grid areas to Stand-Alone Power Systems (SAPS)[120].

In 2016, Western Power, together with Horizon Power and Synergy, undertook a trial of six SAPS that consisted of solar panels, battery storage and a diesel generator. These trials have informed Western Power's current thinking on the evolution of the network toward a modular network of "dynamically-connected"[121] microgrids and stand-alone power systems, as distributed generation becomes more cost effective than centralised generation as shown in Figure 48.

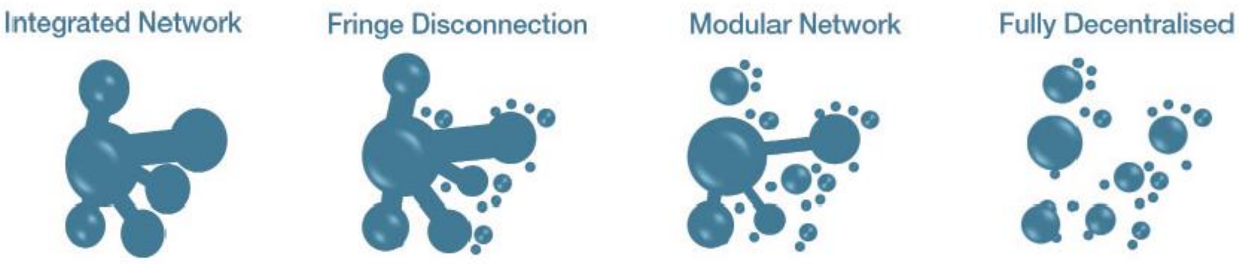

Figure 48 Evolution of the network[122]

This thinking suggests as networks reach end-of-life and require replacement or intensive maintenance, maintaining reliable power supply to individual customers or small clusters of customers in locations where customer density is low is most likely to be cost-effectively achieved through installation of stand-alone power systems. The closer customers are to the main trunk of the network and as they reach a level of energy demand intensity, the value proposition shifts back in favour of using distribution networks as the primary mode of supply. Where large communities are located at the fringes of networks, distributed generation that meets or exceeds peak demand of those customers and exports energy into the broader network is an alternative supply model that could maintain or improve network utilisation. However, this approach often requires network and protection system upgrades.

During 2019 and 2020 Western Power installed another 57 SAPS for consumers on their network, which was expected to save $6 million compared to maintenance of the existing network and result in more reliable supply. During 2020-21, another 100 SAPS will be

[120] In Western Australia, the stand-alone power system acronym commonly used is SPS but for consistency, they are referred to as SAPS throughout this report.

[121] Refers to the ability of the microgrid to transition seamlessly between its two operating modes, grid-connected and islanded mode.

[122] Western Power, *Study into the feasibility of a microgrid at Kalbarri*, 2016.

deployed to fringe-of-grid consumers, again with Synergy as the retailer, and Western Power has identified up to 15,000 consumers that could, eventually, be disconnected from the SWIS (South West Interconnected System) and have power provided from a SAPS.

G.1.2 Bremer Bay

Lead: Western Power

Project Partners: Synergy

Project Timeline: 2005 to Present

Status: In operation

Capex: not published

Location: Bremer Bay is located between Albany and Esperance in WA

Funding: Western Australian Government

Aims: Reduce length of time of outages on feeder

Technologies: Hybrid wind-diesel and control system

Description: Bremer Bay is supplied by the SWIS by a 190 km long feeder from Albany. This feeder has frequent faults due to lightning, vegetation and high winds. For example, there were 300 outages in 2003.

The initial solution implemented to cope with load growth and frequent outages was to disconnect the town from the SWIS in March 2004. Temporary diesel generators where then used to power the town. The second stage was to exchange the temporary diesel generators with a hybrid wind-diesel power system in 2005. The final stage was to reconnect to the SWIS in 2006 with the diesel power station providing power when there were outages on the feeder.

In 2017, Western Power and Synergy completed work on a new Comap control system to allow the town to be powered by the wind turbine and the SWIS. When there is an outage on the feeder, Western Power sends a radio signal to automatically start the diesel generation in the power station. There is still a short power outage while the generators commence operation, as such a seamless transition between grid-connected and islanded mode has not been achieved. However, it does significantly reduce the length of time for the power outage and Synergy has described Bremer Bay as a 'prime candidate to be set up as a permanent microgrid' by the addition of a battery[123].

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123 www.ipsconnect.org/wp-content/uploads/2017/11/Chris-Dowe-Synergy%E2%80%99s-Renewable-Energy-Integration.pdf

G.1.3 Perenjori

Lead: Western Power

Project Partners: Balance Utility Group

Project Timeline: 2016 to Present

Status: In operation

Capex: $1.6 million[124]

Location: Perenjori is 350 km north of Perth and 150 km east of Dongara with a population of around 200 people

Funding: Western Australian Government

Aims: Reduce outages on feeder

Technologies: Distribution level battery

Description : Perenjori is connected to the SWIS by a 75 km 33 kV feeder line that, over 2 years, averaged 11 outages per year, totalling nearly 30 hours per year. A 2.4 MW / 1.1 MWh battery was delivered to site over June 2016 to March 2017 and commissioned in August 2018. In the first two years of operation, the battery has been used more than 300 times avoiding more than 26 hours of outages and eliminating or reducing 85% of outages.

The reasons for the time period between when the battery was installed and commissioned is not entirely clear. However, Western Power indicates 'we learnt a lot through the installation process. It took us longer to integrate the battery into the network than we expected, but we have persevered and it's now working really well.'[125]

G.1.4 Kalbarri

Lead: Western Power

Project Partners: Lendlease

Project Timeline: 2018 to Present

Status: Under construction

Capex: $10 million

Location: Kalbarri is a coastal town 590 km north of Perth with a population of around 1,500 and more than 100,000 tourists visiting each year.

Funding: Western Australian Government

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[124] decmil.com/dmwp/wp-content/uploads/2017/08/Western-Power-Perenjori-BESS.pdf

[125] westernpower.com.au/community/news-opinion/powering-up-the-end-of-the-line/

Aims: Improve reliability of supply at Kalbarri, develop a replicable and adaptable regional power supply model that maximises historical investment in power networks, demonstration of islanding capability.

Technologies: Central battery co-located with existing wind farm, rooftop PV

Figure 49 Kalbarri battery being transported from Perth[126]

Description: Kalbarri has a peak load of about 3 MW and is connected to the SWIS by a 140 km long 33 kV feeder from Geraldton. A combination of high winds and dust, salt as well as moisture on this lines' insulators leads to a large amount of line faults that causes outages in the town, particularly in summer, which is the peak tourist season.

To increase the electricity supply reliability of Kalbarri, Western Power is developing an islandable microgrid that includes the existing Kalbarri 1.6 MW windfarm and about 1 MW in total of residential PV plus a new 5 MW / 4.5 MWh battery. Its primary purpose is to provide network support and allow Kalbarri to maintain power for short periods when the main grid connection fails.

Western Power will also test a 'dynamic connection' where the microgrid can operate either as grid-connected or in island mode when the feeder to the main grid goes down. The windfarm meets 50% of the load more than 30% of the time, which when combined with the PV and battery storage should be able to maintain power for the time needed to repair the feeder when it is has minor damage. At this stage, the intent is to roll out similar projects at other fringe-of-grid locations, assuming the trial proves successful.

Onslow

Lead: Horizon Power

Project Partners: Chevron Australia and West Australian Government

Project Timeline: 2016-2018 (Stage 1) and 2019 (Stage 2)

126 Photo from: www.westernpower.com.au/our-energy-evolution/projects-and-trials/kalbarri-microgrid/

Status: Operational

Capex: $70 million

Location: The town of Onslow is 1,386 km north of Perth and is in the Pilbara region.

Funding: Western Australian Government

Aims: Test grid scale battery to optimise spinning reserve back up and store renewable energy, reduce use of gas and diesel for power generation.

Technologies: Mix of distributed renewables, modular gas generation and battery storage

Description: Horizon Power manages the Onslow isolated microgrid. To reduce reliance on diesel generation, it has upgraded the town's power infrastructure. Stage 1 was completed in July 2018 and consisted of 5.25 MW of gas-fired generators (reciprocating engines) at a new power station site and a new transmission line, zone substation and distribution network extension.

Stage 2 added a 1 MW / 550 kWh battery in May 2019 and a 2 MW solar farm adjacent to the power station in June 2019. The battery energy storage system can be used for load-power shifting, utility transformer and transmission line energisation, microgrid voltage and frequency regulation, active power absorption and dynamic reactive power control.

At Onslow town (about 18 km away), another MW-scale battery has been deployed and consumers were offered either a solar system or a solar and battery system at reduced cost. About 2.4 MW of distributed PV has been installed and about 1 MWh of distributed batteries. These will all be coordinated using SwitchDin devices through a Distributed Energy Resource Management System (DERMS). The DERMS software will optimise dispatch of all the batteries and the gas-fired generators to meet demand at least cost. The DERMS also has control over household air conditioners, in order to optimise the overall system.

In a successful trial in May 2021, the Onslow microgrid was run entirely on solar and battery power for 80 minutes[127]. The intelligent DERMS was integral to the success of the trial, using predictive analytics to maximise the amount of renewable energy in the microgrid while maintaining network stability for all customers.

[127] www.mediastatements.wa.gov.au/Pages/McGowan/2021/06/Onslow-successfully-powered-by-100-per-cent-renewable-energy-in-trial.aspx

Figure 50 Onslow power station[128]

G.1.5 Jandakot Clean Energy Innovation Hub

Lead: ATCO

Project Partners: N/A

Project Timeline: 2018 to 2021

Status: Pilot operational

Capex: $3.53 million

Location: Jandakot, Western Australia

Funding: ATCO and ARENA

Aims: Investigate the role of hydrogen in a microgrid, test microgrid enabled by gas integrated with solar and batteries.

Technologies: Solar PV, lithium- ion batteries, combined with existing gas generator and new hydrogen plant producing 23 tonnes per annum of hydrogen.

Description: Jandakot Clean Energy Innovation Hub is a R&D facility that includes 300kW solar PV, 500kWh lithium-ion battery storage and existing 200 kVA gas generator set up as a microgrid with an electrolyser to produce green hydrogen reticulated into a mini gas distribution network for gas consumption.

[128] Photo accessed from: horizonpower.com.au/our-community/news-events/news/horizon-power-launches-second-stage-of-onslow-microgrid-project/

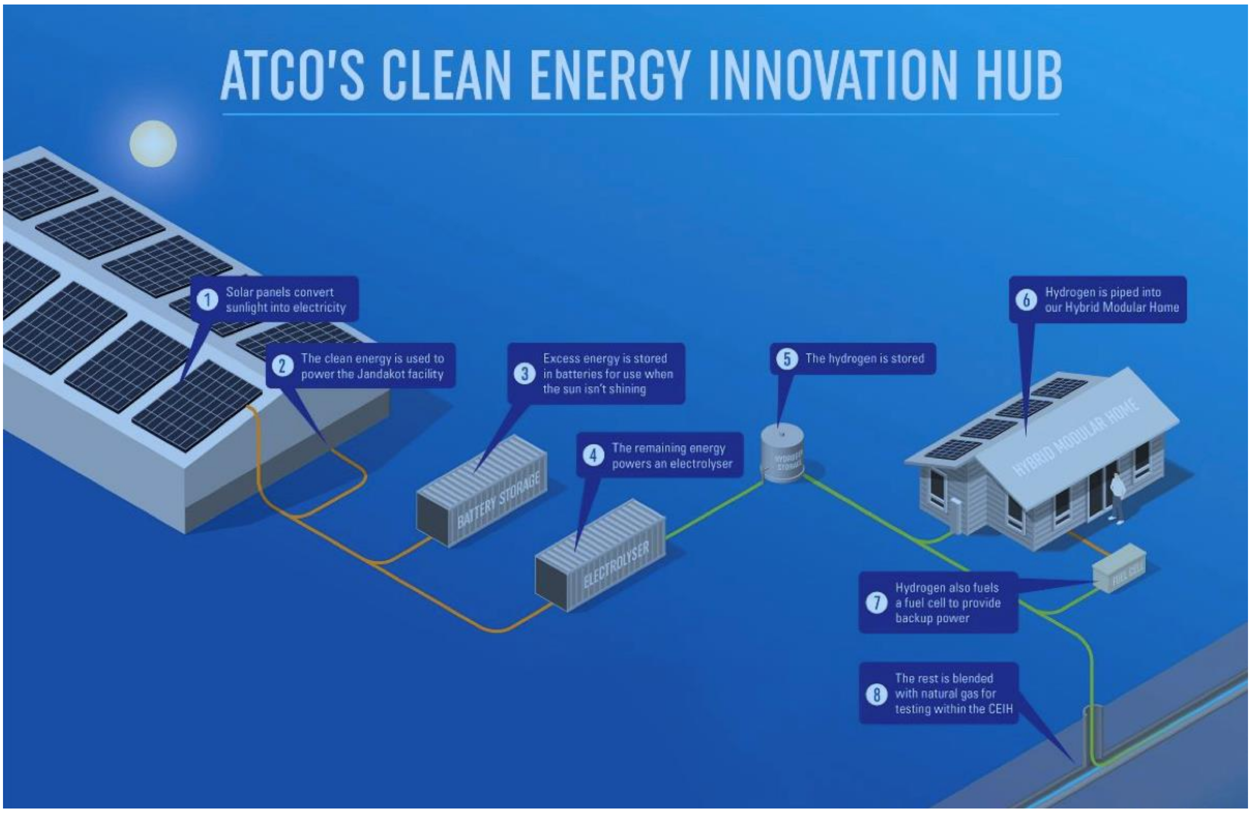

Figure 51 ATCO's Clean Energy Innovation Hub[129]

G.1.6 Granny Smith Gold Mine – Isolated microgrid

Lead: Aggreko

Project Partners: Gold Fields (mine owner)

Project Timeline: Announced February 2019

Status: Installation completed in October 2020

Capex: not published

Location: 740 kms northeast of Perth, Western Australia

Aims: Support off-grid mine operators to decarbonise operations with re-deployable and modular power solutions to suit mine life, use of battery to provide PV ramp rate control and transient voltage/frequency support.

Technologies: Thermal-solar-battery hybrid, power control systems

Description: Aggreko and Gold Fields are nearing completion of a hybrid solar PV system integrated with existing gas fired generation at the Granny Smith gold mine in WA. The system comprises 7.7 MW of solar PV integrated with the existing 27.3 MW reciprocating gas fuelled power station at the mine site and 2 MW/1 MWh battery, with integration via Aggreko's control software platform. Aggreko enters into 5-15 year PPA for MW-scale semi-

[129] Image from: arena.gov.au/assets/2018/07/clean-energy-hub-innovation-report.pdf

permanent solar plants and is also developing redeployable plants in the 100 kW range that they aim to offer for rental for periods as short as a few months.

Figure 52 Granny Smith gold mine solar array[130]

G.1.7 Denham Hydrogen Demonstration – Isolated microgrid

Lead: Horizon Power

Project Partners: Hybrid Systems, division of Pacific Energy

Project Timeline: Announced November 2020

Status: Installation to be completed by the end of 2021 with commissioning expected to start in December 2021.

Capex: $8.9 million

Location: Denham 820 km north of Perth, Western Australia

Aims: Demonstrate the ability to incorporate renewable hydrogen into a microgrid with solar, wind and diesel, to prove that reliable, dispatchable power generation can be achieved. This will be demonstrated by converting excess renewable energy to hydrogen and then using the hydrogen in a fuel cell to provide electricity on demand.

Technologies: solar, electrolysis unit, fuel cell, power control systems

Description: The project is a small pilot plant to prove the concept which may then be expanded, with the learnings transferred to other sites. Horizon Power will design, construct and operate a hydrogen demonstration plant, including a dedicated solar farm to power the

[130] Photo from: www.pv-magazine.com/2020/10/08/there-has-never-been-a-better-time-for-hybrid-microgrids/

hydrogen equipment, to support the commercialisation of renewable hydrogen power generation and conduct a proof of concept trial for possible future services.

The project will produce hydrogen via a 348 kW electrolysis unit and a 704 kW grid-connected solar farm to deliver a minimum of 13 tonnes per year. The hydrogen will provide firm capacity from a 100 kW fuel cell equivalent to the average load of 100 residential houses, around 526 MWh per year (from solar and renewable hydrogen), of which at least 220 MWh will be provided by renewable hydrogen.

Horizon Power will demonstrate the efficiency of hydrogen equipment such as the electrolyser and fuel cell, the ramp rates of hydrogen production and generation in response to reductions in solar generation, and the efficiency and storage capability of hydrogen fuel cells versus batteries.

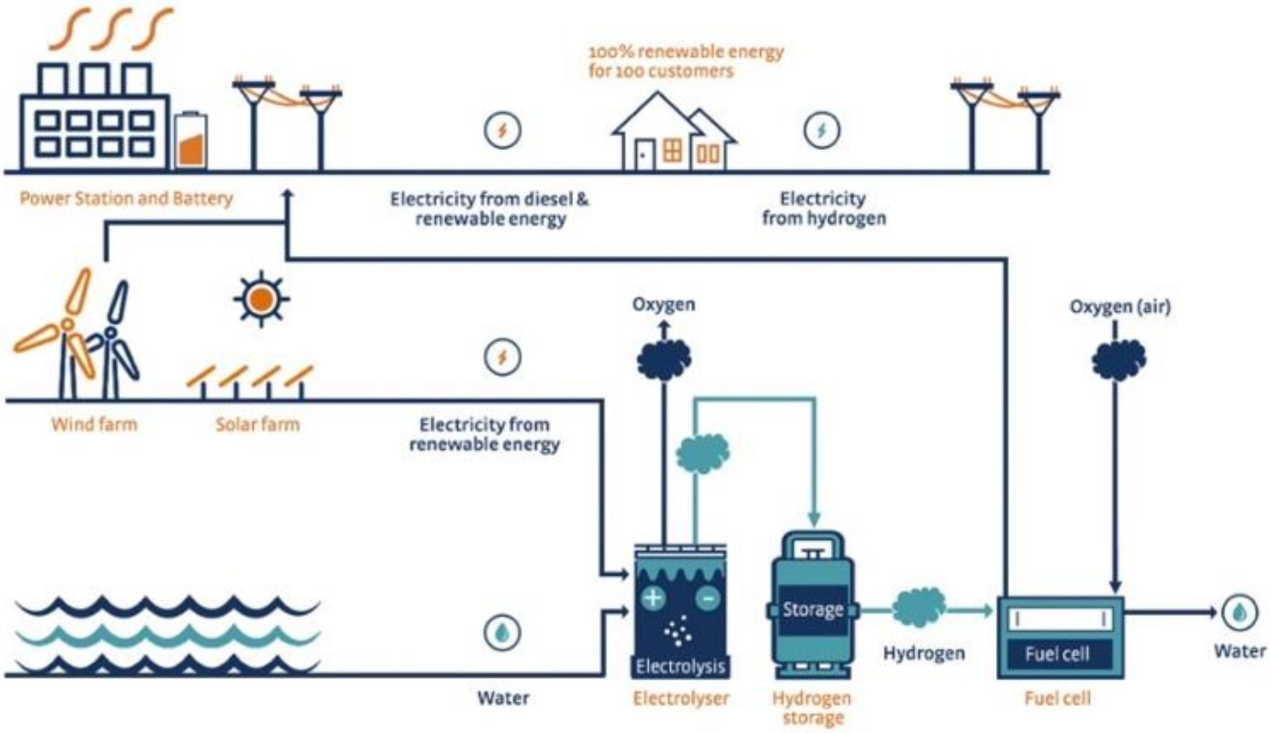

Figure 53 Denham hydrogen demonstration project

G2. South Australia

G.2.1 Dalrymple ESCRI-SA Project

Lead: ElectraNet

Project Partners: AGL and Advisian

Project Timeline: 2017 to Present (Commissioned April 2019)

Status: In commercial operation

Capex: $30 million

Location: Lower Yorke Peninsula, South Australia

Funding: Project Participants and ARENA

Aims: Develop commercial model for provision of regulated reliability and security services and competitive market services; navigating the NEM registration, licencing and connection processes; and largest autonomous regional microgrid for both grid connected and islanded operation with 100% renewables

Technologies: Battery energy storage system using lithium ion rechargeable batteries, inverters, combined with nearby existing wind farm and roof-top solar PV

Description: Dalrymple ESCRI-SA is a 30 MW, 8 MWh large lithium ion battery energy storage system (BESS) developed by **ElectraNet,** AGL and Advisian and is connected to an ElectraNet substation in the lower Yorke Peninsula in South Australia (see Figure 54). The Dalrymple local supply includes significant local renewable energy generation with the nearby 90 MW Wattle Point wind farm and 3.4 MW of roof-top solar PV.

Figure 54 Dalrymple BESS facility[131]

The local maximum demand at Dalrymple is around 8 MW with average demand of about 3 MW. ElectraNet owns the BESS and leases it to AGL to operate. The BESS is used for energy trading and provision of FCAS services, however during time of grid supply interruptions has

[131] Photo from ESCRI-SA Final Knowledge Sharing Report, 2021.

operated in island mode with the Wattle Point wind farm at reduced output until grid supply is restored.

The BESS has two levels of controls, with the first level of control taking precedence over the second level. The first level of control is automated and responds to system events is controlled by preprogramed logic. The second level of control for market trading and charging is controlled by AGL.

Appendix H. International Experiences

An April 2020 study[132] examined the contributing factors to the successful growth of community microgrids[133] 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.

H1. 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

[132] 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.

[133] 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.'*

one of the most effective methods to integrate these and at the same time provide grid operators with more control.

- 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.

H2. European Union (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 battery 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 elevated 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.

H3. 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.

H4. 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.

H5. 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 USA, 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 USA 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 USA 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.

Appendix I. Economic Analysis

Overleaf.

Yarrabah Micro-Grid Economic Analysis

Yarrabah Aboriginal Shire Council

GROWING COMMUNITIES

Regional Economic Advisory

Version	Date	Approved by	Reviewed by
WD v1	23/08/2021	Matthew Kelly	Matthew Kelly
Draft 1.0	30/11/2021	Matthew Kelly	Matthew Kelly
FINAL	9/12/2021	Matthew Kelly	Matthew Kelly

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Executive Summary

Introduction

The EnergyConnect project team (Yarrabah microgrid feasibility study) has engaged Regional Economic Advisory (REA) to provide this economic analysis of the Yarrabah Microgrid project (the Project). The economic analysis provides estimates of economic activity the Project will provide to the local economy and the net socio-economic benefits the Project will provide to the Yarrabah community.

The findings of this Economic Analysis will be used by EnergyConnect and Yarrabah Aboriginal Shire Council (Council) and broader project stakeholders to support funding applications and advocacy efforts to raise awareness of the Project.

Project Overview

The Project includes a range of energy initiatives proposed to be delivered across three stages as follows:

- **Stage 1** Energy Efficiency and Residential Rooftop Solar:
    - **Stage 1a:** Energy audits, education, energy-efficient appliances and fittings, housing design.
    - **Stage 1b:** Residential rooftop solar.
- **Stage 2:** Commercial Energy Generation, Micro Grid and Knowledge Centre:
    - **Stage 2a:** Microgrid infrastructure including solar farm, community battery and backup generator.
    - **Stage 2b:** Yarrabah Energy Knowledge Centre (YEKC) a tourism and educational facility facilitating energy usage and technological awareness.
    - **Stage 2c:** Micro hydro & wind turbines.
    - **Stage 2d:** Commercial rooftop solar initiatives.
- **Stage 3:** E-mobility Solutions (potential electric buses, council trucks, personal mobility, cars, ferries, and charging infrastructure).

The core aim of the Project is to increase resilience and economic opportunity for the Yarrabah community through renewable energy and new technologies. The Project will also serve as a testing ground for end of grid communities and international aid options in the south Pacific.

Quantitative analysis in this report will focus on the combined Stages 1 and 2, while qualitative commentary is provided for the longer-term e-mobility opportunities which will form part of Stage 3.

Key Findings

Economic Impact Assessment

Construction activities associated with the Project are estimated to have a notable impact on the local Yarrabah economy. Stages 1 and 2 of the Project combined are projected to generate the following construction impacts:

- **$5.9 million in output** ($4.7 million directly).
- **$2.5 million contribution to Gross Regional Product** (GRP) ($1.9 million directly).
- **$1.5 million in wages and salaries** for local workers ($1.1 million in direct wages).
- **17 Full Time Equivalent (FTE) jobs** (13 direct FTE).

Once operational, the Project is projected to continue to generate a notable impact on the local Yarrabah economy. Stage 1 is projected to generate through household expenditure impacts arising from reduced electricity costs:

- **$1.0 million p.a. in output** ($0.8 million directly).
- **$0.6 million p.a. contribution to GRP** ($0.5 million directly).
- **$0.2 million p.a. in wages and salaries** for local workers ($0.2 million in direct wages).
- **3.5 FTE jobs** (3.1 direct FTE).

Stage 2 is projected to generate ongoing operational impacts (including induced tourism activity through the YEKC):

- **$2.9 million p.a. in output** ($2.4 million directly).
- **$1.7 million p.a. contribution to GRP** ($1.3 million directly).
- **$1.2 million p.a. in wages and salaries** for local workers ($1.0 million in direct wages).
- **14.6 FTE jobs** (12.9 direct FTE).

Cost Benefit Assessment

The 20 year cost-benefit analysis identified and examined the following costs and benefits:

- **Costs:**
  - Capital and Refurbishment Costs.
  - Direct Operating Costs.
  - Overhead Costs.
- **Benefits**
  - Services Revenues.
  - Value Add from Additional Tourism to the YEKC.
  - Community Cultural and Recreational benefit of the YEKC.
  - Grid Energy Savings.
  - Solar Energy Feed in Tariff Revenues.
  - Greenhouse Gas (GHG) Savings.
  - Community Energy Reliability and Resilience Benefits.

At the selected real discount rate of 7%, the analysis yields a Net Present Value (NPV) of $0.5 million and a Benefit Cost Ratio (BCR) of 1.01 meaning that it is economically desirable and provides a net benefit. The project is somewhat sensitive to the discount rate applied, returning a negative NPV at a 10% discount rate. The project yields an Internal Rate of Return (IRR) of 7.3%.

Under the Base Case scenario (without Project scenario), none of the identified benefits would be captured nor any of the costs incurred. As such, the scenario with the Project provides positive net economic and social benefits. It would be expected that further detailed investigation and optimisation of the Project components through a detailed business case would further improve the net position of the analysis.

Table ES.1: CBA Results

Discount Rate	Present Value Costs ($M)	Present Value Benefits ($M)	Net Present Value ($M)	Benefit Cost Ratio
4%	$48.1	$54.8	$6.7	1.14
7%	**$40.9**	**$41.4**	**$0.5**	**1.01**
10%	$35.7	$32.2	-$3.6	0.90

Note: Totals may not sum due to rounding.
Source: REA

In addition to the costs and benefits included in the assessment above, the Project can be expected to have a broad range of positive impacts which have not been included within the CBA analysis. These include:

- **Improved health, education, and community outcomes:** Improved energy reliability will increase health outcomes, including access to hot showers and cooking and more regular school attendance. Consultation with the local community indicates significant issues relating to the reliability of energy and hot water specifically creating health and hygiene difficulties within the community. Assets such as the YEKC may serve further community purposes such as a community shelter for natural disasters. These notable impacts have not been quantified to avoid double counting energy reliability and resilience benefits.
- **Economic development opportunities:** The project will help unlock a range of additional potential economic development opportunities, including:
    - **Increasing visitation and the viability of further tourist developments** due to the YEKC including future development of short stay visitation accommodation in Yarrabah. As a new tourism experience, the YEKC will support the recovery of visitation and the broader tourism sector post the current COVID-19 pandemic.
    - **Potential E-mobility Solutions** (electric buses, council trucks, personal mobility, cars, ferries, and charging infrastructure) considered in Stage 3 of the Project will be supported by the energy infrastructure.
- **Increase in business confidence:** The Project will see a significant injection into the economy during construction and a notable increase in direct visitor expenditure and disposable household incomes after completion. These injections in the economy may increase confidence amongst local businesses, which may provide the catalyst for additional investment and job creation.
- **Increase in community amenity and pride:** Many aspects of the Project (beyond the YEKC) provide significant community value including employment, recreational, and education opportunities for residents. This in turn will support improved social outcomes and general community wellbeing in Yarrabah.
- **Prototype project for other fringe of grid communities:** The Project will serve to test and highlight the effectiveness of microgrid energy solutions for fringe of grid communities, serving as a potential prototype for other Australian and Pacific region communities.

These impacts are strongly positive and would increase the CBA results, if they were quantified.

Table of Contents

1. Introduction

1.1 Background and Purpose

The EnergyConnect Project Team (Yarrabah microgrid feasibility study) has engaged Regional Economic Advisory (REA) to provide this economic analysis of the Yarrabah Microgrid project (the Project). The economic analysis provides estimates of economic activity the Project will provide to the local Yarrabah and broader Far North Queensland economies and the net socio-economic benefits the Project will provide to the Yarrabah community.

The findings of this Economic Analysis will be used by EnergyConnect and Yarrabah Aboriginal Shire Council (Council) and broader project stakeholders to support funding applications and advocacy efforts to raise awareness of the Project and facilitate its implementation.

1.2 Structure and Approach

The remainder of this report is structured as follows:

- **Chapter 2 Project Overview:** Provides a summary background of the Yarrabah community and economy and an overview of each proposed stage of the Project.
- **Chapter 3 Economic Impact Assessment:** Applies Input-Output modelling to estimate the direct and flow-on economic impacts of the Project during construction and once operational.
- **Chapter 4 Cost Benefit Assessment:** Considers the net socio-economic benefits the Project will provide to the Yarrabah community over a 20 year period.
- **Chapter 5: Opportunities for E-Mobility:** Considers potential additional opportunities to leverage E-Mobility solutions for Yarrabah.
- **Chapter 5 Summary Findings:** Provides an overview of the key findings and recommendations from the analysis.

2. Project Context

The following sections provide a summary of each stage of the Project and a summary profile of the Yarrabah community to provide context for the Economic Analysis.

2.1 Project Overview

The Project includes a range of energy initiatives proposed to be delivered across three stages as follows:

- **Stage 1** Energy Efficiency and Residential Rooftop Solar:
  - **Stage 1a:** Energy audits, education, energy-efficient appliances and fittings, housing design.
  - **Stage 1b:** Residential rooftop solar.
- **Stage 2:** Commercial Energy Generation, Micro Grid and Knowledge Centre:
  - **Stage 2a:** Microgrid infrastructure including solar farm, community battery and backup generator.
  - **Stage 2b:** Yarrabah Energy Knowledge Centre (YEKC) a tourism and educational facility facilitating energy usage and technological awareness.
  - **Stage 2c:** Micro hydro & wind turbines.
  - **Stage 2d:** Commercial rooftop solar initiatives.
- **Stage 3:** E-mobility Solutions (potential electric buses, council trucks, personal mobility, cars, ferries, and charging infrastructure).

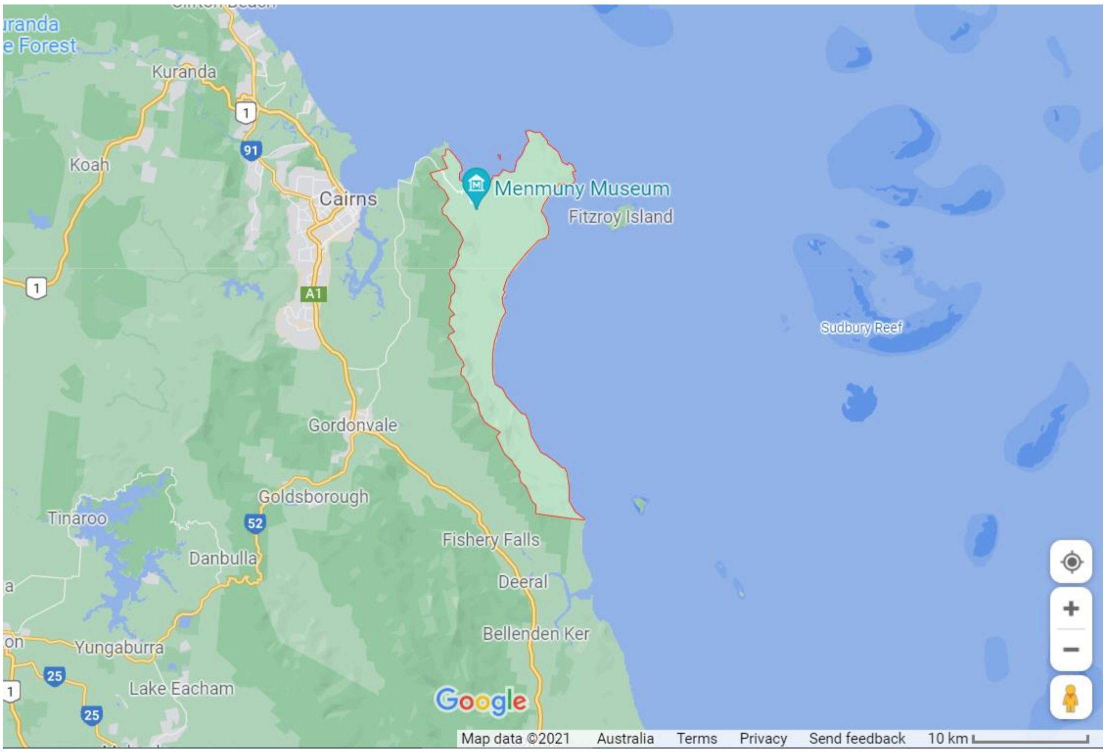
The core aim of the Project is to increase resilience and economic opportunity for the Yarrabah community through renewable energy and new technologies. The Project will also serve as a testing ground for end of grid communities and international aid options in the south Pacific.

Quantitative analysis in this report will focus on the combined Stages 1 and 2, while qualitative commentary is provided for the longer-term e-mobility opportunities which will for a part of Stage 3.

2.1 Socio-Economic Profile

Yarrabah is an Indigenous Shire, located approximately 60km east and southeast of Cairns on Cape Grafton of Cairns in Far North Queensland. The Shire covers an area of 159 km2 and hosts an estimated population of approximately 4,000 persons of which 90% identify as either Aboriginal Australian (85.8%) or Torres Strait Islander (4.2%).

Figure 2-1: Yarrabah Local Government Area (LGA)



Source: Google Maps (2021)

Like many remote Indigenous communities, Yarrabah has experienced significant socio-economic disadvantage, with key issues including overcrowding, high crime rates, poor education and employment outcomes, lack of community, medical and disability services. The initial energy audits undertaken as part of this Project confirms that many houses are overcrowded, with up to 12 individuals living in 3 or 4 bedroom houses.

As of the 2016 Census Yarrabah recorded household incomes approximately 20% below the Queensland average and unemployment is currently running at nearly half of the local labour force. Yarrabah ranks in the bottom decile of Australian LGA's in the Socio-Economic Indexes for Areas (SEIFA) and was ranked as the seventh most disadvantaged LGA in Australia (ABS, 2016).

The main employment sectors in Yarrabah are currently government led:

- Health care and social assistance (28.2% of employment) health outcomes in Yarrabah remain well behind Queensland and national averages (Productivity Commission, 2021).
- Public administration and safety (25.7% of employment), with Council a major provider of essential services to the community.
- Education and Training (23.9% of employment): Public schooling is currently provided in Yarrabah up to grade 10.

Key socio-economic indicators for Yarrabah are presented in the table below, with additional detail provided in Appendix A.

Table 2-1: Yarrabah LGA Socio-Economic Statistics

Indicator	Value	Notes
Population (Jun 2020)	Approx. 4,000	1.7% p.a. growth over five years
Avg. Persons Per Household (2016)	4.8	2.2 persons per household higher than the QLD average
Labour Force (Jun 2021)	736	3.6% p.a. growth over five years
Unemployment Rate (Jun 2021)	47.7%	40.9 ppt higher than the QLD average
Avg. Weekly Household Income (2016)	$1,129	19% below QLD average.

Indicator	Value	Notes
Top Five Employment Sectors (PoW, 2016)	Health care and social assistance (28.2% of employment) Public administration and safety (25.7% of employment) Education and training (23.9% of employment) Other services (8.0% of employment) Retail trade (3.8% of employment)	

Source: QGSO (2021), ABS (2016)

The community's location at the end of the National Electricity Market (NEM) grid has compounded social and economic issues, with frequent service disruptions due to weather events and limited grid capacity.

The Project forms a key component of Yarrabah's broader strategy for economic opportunity and sustainable growth, providing:

- Improved health, social, and economic outcomes through improved energy reliability.
- Reduced household living costs.
- Direct and flow on employment opportunities for residents.
- Economic diversification through tourism opportunities such as the YEKC.

3. Economic Impact Assessment

The following sections provide estimates of economic activity supported by the Project during construction and once operational. Economic impacts are assessed for the combined stages 1 and 2 of the Project.

3.1 Overview and Approach

The following analysis estimates the economic activity supported by the Project through construction and ongoing impacts once operational. The economic impacts are assessed at two geographic levels:

- Yarrabah LGA.
- Far North Queensland Region (Cairns Statistical Area Level 4).

An Input-Output model (including the development of specific regional Input-Output transaction tables) was developed to reflect the economic structure of Yarrabah and Far North Queensland. See Appendix B for further detail on the Input-Output modelling methodology applied.

Input-Output modelling describes economic activity through the examination of four types of impacts described in the table below.

Table 3-1: Economic Impact Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Product	The value of output after deducting the cost of goods and services inputs in the production process. Gross product (e.g. Gross Regional/State Product (GRP/GSP)) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project either directly or indirectly.
Employment	Employment positions generated by the Project (either full time or part time, directly or indirectly). Employment is reported in terms of Full-Time Equivalent (FTE) positions (i.e. full-time person-years).

Source: REA

3.2 Modelling Assumptions

<u>Construction</u>

For modelling purposes, capital expenditure items were allocated to industry sectors represented in the Input-Output model, based on Australia and New Zealand Standard Industrial Classification (ANZSIC) categories as per the assumptions in the table below.

Table 3-2: Capital Expenditure Assumptions

Item	$M	ANZSIC
Pre-Construction and Detailed Planning	$2.6	Professional, Scientific and Technical Services (50%) Heavy and Civil Engineering Construction (30%) Construction Services (20%)
Stage 1		

Item	$M	ANZSIC
1a Energy Education Program	$2.8	Arts, Sports, Adult and Other Education Services (including Community Education) (10%) Construction Services (40%) Retail Trade (50%)
1b Rooftop Solar	$2.1	Electrical Equipment Manufacturing (70%), Construction Services (30%)
Total	**$4.9**	-
Stage 2		
2a Microgrid Infrastructure, including Solar Farm, Community Battery, Generator	$12.2	Electrical Equipment Manufacturing (50%) Heavy and Civil Engineering Construction (30%), Construction Services (10%) Professional, Scientific and Technical Services (10%).
2b Yarrabah Energy Knowledge Centre (YEKC)	$3.4	Non-Residential Building Construction (90%), Professional, Scientific and Technical Services (10%).
2c Micro Hydro & Wind Turbines	$0.2	Electrical Equipment Manufacturing (50%) Heavy and Civil Engineering Construction (30%), Construction Services (10%) Professional, Scientific and Technical Services (10%)
2d Commercial Rooftop PV	$0.5[1]	Electrical Equipment Manufacturing (70%), Construction Services (20%) Professional, Scientific and Technical Services (10%)
Total	**$16.3**	-
Total (Stages 1 & 2)	**$23.8**	-

Note: Totals may not sum due to rounding. [1] Capital cost to accrue to the commercial operator and not Council.
Source: REA

In undertaking Input-Output modelling, it is important to consider both where economic activity occurs and where project labour is sourced from. For the purposes of this assessment, it was assumed:

- Approximately 80% of the direct expenditure on construction-related (i.e. Heavy and Civil Engineering Construction) activity would be sourced from local businesses and labour in Far North Queensland (30% within Yarrabah LGA)[1]. Of this:
    - Approximately 25% of purchases on goods and services (supply chain related activity) made by construction-related businesses sourced from outside the catchment region would be spent within the local economy (i.e., 25% of the Type I flow-on activity associated with non-local construction companies is assumed to represent additional local activity).
    - Approximately 5% of wages and salaries paid to construction-related workers sourced from outside the region would be spent on local goods and services, such as food and beverages (i.e., 5% of the Type II).
- Only flow-on activity of locally sourced education and professional, scientific and technical services (80% Far North Queensland, 30% Yarrabah LGA), retail trade (80% Far North Queensland, 30% Yarrabah LGA), and manufacturing activity (0% local or regional content) is included, as it is not anticipated businesses in these sectors located outside of the region would purchase goods/ services locally.

Operations

Once operational, the Project will generate ongoing economic activity through the following avenues:

- **Direct operational activity** through energy generation and distribution, and operation of the YEKC. Operational turnover for each stage of the project has been allocated to ANZSIC sectors as per the assumptions in the table below[2]. In order to avoid

[1] 100% of activity associated with the energy audit and education programs are assumed to represent local content.

[2] Modelled direct impacts adapted from TLG (2021) estimated direct turnover and gross product.

double counting of benefits, household rooftop PV generation revenues (feed in tariffs) have been included in the household expenditure modelling driver considered in the next section.

Table 3-3: Operational Assumptions (Stage 2)

Item	Turnover Per Annum ($M)	ANZSIC
Project Management Office	$1.0	Professional, Scientific and Technical Services (50%) Administrative and Support Services (50%)
2a Microgrid Infrastructure, including Solar Farm, Community Battery, Generator	$0.6	Electricity Generation (80%) Electricity Transmission, Distribution, On Selling and Electricity Market Operation (20%)
2b Yarrabah Energy Knowledge Centre (YEKC)	$0.3	Heritage, Creative and Performing Arts (80%), Food and Beverage Services (20%)
2c Micro Hydro & Wind Turbines	$0.01	Electricity Generation (100%)
2d Commercial Rooftop PV	$0.1	Electricity Generation (100%)
Total	**$2.0**	-

Source: TLG (2021), REA.

- **Increased household expenditure within the local and regional economies** as a result of decreased electricity costs. Rooftop PV solar installation is projected to generate notable savings to households averaging $1.5 million per annum once fully installed and operational from 2023.

  For modelling purposes, additional household expenditure has been modelled for the Yarrabah and Far North Queensland economies using expenditure categories from the ABS household expenditure survey (ABS, 2016b). Assumptions have been made for household savings rates, local and regional expenditure as reported in the table below.

Table 3-4: Household Expenditure Assumptions (Stage 1)

Item	Total Spend ($M)	Far North Queensland Spend ($M)	Yarrabah LGA Spend ($M)
Annual Savings	$1.7	$1.7	$1.7
Less Household Savings (15%)	$1.4	$1.4	$1.4
Expenditure Items (ANZSIC)			
Ownership of Dwellings	$0.3	$0.3	$0.3
Retail Trade	$0.3	$0.2	$0.1
Food and Beverage Services	$0.2	$0.1	$0.1
Personal Services	$0.1	$0.1	$0.0
Other Services	$0.1	$0.0	$0.0
Telecommunication Services	$0.1	$0.0	$0.0
Road Transport	$0.1	$0.1	$0.1
Rail Transport	$0.0	$0.0	$0.0
Air and Space Transport	$0.0	$0.0	$0.0
Sports and Recreation	$0.1	$0.1	$0.1
Primary and Secondary Education Services (incl Pre-Schools and Special Schools)	$0.0	$0.0	$0.0
Technical, Vocational and Tertiary Education Services (including Undergraduate and Postgraduate)	$0.0	$0.0	$0.0

Item	Total Spend ($M)	Far North Queensland Spend ($M)	Yarrabah LGA Spend ($M)
Arts, Sports, Adult and Other Education Services (including Community Education)	$0.0	$0.0	$0.0
Health Care Services	$0.1	$0.1	$0.1
Heritage Creative and Performing Arts	$0.0	$0.0	$0.0
Electricity Transmission, Distribution, On Selling and Electricity Market Operation	$0.0	$0.0	$0.0
Total	**$1.4**	**$1.2**	**$0.8**

Note: Totals may not sum due to rounding.
Source: ABS (2016b), REA.

- Increased tourist visitation to Yarrabah and expenditure within the local economy by visitors to the YEKC. The YEKC will facilitate additional visitation and broader expenditure within Yarrabah and Far North Queensland that would not otherwise occur. Operating impacts have been based on the following assumptions (TLG, 2021):
- Approximately 6,000 visitors per annum travel to the YEKC[3]:
    - 15% represent local (Yarrabah) visitors. The broader expenditure of these local visitors has been conservatively excluded from the assessment as it is assumed their expenditure will occur in the local economy regardless of the Project.
    - 35% represent Far North Queensland visitors representing new day trip visitation to Yarrabah LGA[4].
    - 30% represent additional intra and interstate visitation to the region. These visitors have been allocated one day trip to Yarrabah LGA[5] and one additional visitor night within Far North Queensland due to the YEKC.
    - 20% represent additional international visitation to the region. These visitors have been allocated one day trip to Yarrabah LGA and one additional visitor night within Far North Queensland due to the YEKC.

TEQ (2021) average Tropical North Queensland local visitor expenditure of $109 per domestic day trip[6] and $214 per domestic visitor night and $125 per international visitor night were split across (TRA, 2021) national average expenditure items and allocated to ANZSIC sectors as per the assumptions in the table below.

Some expenditure items were reduced to avoid double counting of direct turnover generated by the YEKC operations.

Table 3-5: Visitor Expenditure Estimates

ANZSIC	Yarrabah LGA Spend ($M)	Far North Queensland Spend ($M)	Notes
Accommodation	$0.0	$0.2	
Automotive Repair and Maintenance	$0.0	$0.0	
Food and Beverage Services	$0.1	$0.1	Reduced 20%
Gambling	$0.0	$0.0	
Heritage, Creative, and Performing Arts	$0.0	$0.0	Reduced 50%
Rental and Hiring Services (Except Real Estate)	$0.0	$0.0	
Retail Trade	$0.2	$0.1	
Road Transport	$0.0	$0.0	

[3] Visitation is projected to grow from just under 4,000 initially to nearly 8,400 by 2041-42 (TLG, 2021).

[4] These visitors are excluded from the Far North Queensland assessment as they do not represent net new visitation.

[5] Due to the lack of overnight accommodation within Yarrabah, overnight visitors are assumed to return to Cairns resulting in day trip visitation to Yarrabah.

[6] Regional day trip expenditure levels were reduced 30% for Yarrabah day trips due to lack of local expenditure data.

ANZSIC	Yarrabah LGA Spend ($M)	Far North Queensland Spend ($M)	Notes
Water, Pipeline and Other Transport	$0.0	$0.0	
Other Services	$0.0	$0.0	
Total	**$0.4**	**$0.5**	

Note: Totals may not sum due to rounding.
Source: TEQ (2021), TRA (2021), REA

3.3 Model Results

Construction

Construction activities associated with the Project are estimated to have a notable impact on the local Yarrabah economy. Stages 1 and 2 of the Project combined are projected to generate the following construction impacts:

- **$6.1 million in output** ($4.7 million directly).
- **$2.6 million contribution to GRP** ($1.9 million directly).
- **$1.5 million in wages and salaries** for local workers ($1.1 million in direct wages).
- **18 FTE jobs** (13 direct FTE).

Economic impacts during construction are estimated be even larger across the broader Far North Queensland catchment due to the larger supply chains and greater share of local content. Economic impacts for Yarrabah and Far North Queensland are presented in the table below.

Table 3-6: Construction Impacts (Stages 1 & 2, $M)

Impact	Output ($M)	GRP ($M)	Incomes ($M)	Employment (FTE)
Yarrabah LGA				
Direct	$4.7	$1.9	$1.1	13
Production Induced	$1.0	$0.5	$0.3	3
Consumption Induced	$0.4	$0.3	$0.1	2
Total Impact	**$6.1**	**$2.6**	**$1.5**	**18**
Far North Queensland				
Direct	$12.6	$5.0	$2.9	34
Production Induced	$6.9	$3.2	$1.8	19
Consumption Induced	$5.9	$3.4	$1.5	20
Total Impact	**$25.4**	**$11.5**	**$6.3**	**73**

Note: Totals may not sum due to rounding.
Source: REA

Operations

Once operational, the Project is projected to continue to generate a notable impact on the local Yarrabah economy. Stage 1 is projected to generate through household expenditure impacts:

- **$1.0 million p.a. in output** ($0.8 million directly).
- **$0.6 million p.a. contribution to GRP** ($0.5 million directly).
- **$0.2 million p.a. in wages and salaries for local workers** ($0.2 million in direct wages).
- **3.5 FTE jobs** (3.1 direct FTE).

Stage 2 is projected to generate ongoing operational impacts (including induced tourism activity through the YEKC):

- **$2.9 million p.a. in output** ($2.4 million directly).
- **$1.7 million p.a. contribution to GRP** ($1.3 million directly).
- **$1.2 million p.a. in wages and salaries** for local workers ($1.0 million in direct wages).
- **14.6 FTE jobs** (12.9 direct FTE).

Economic impacts once operational are estimated be even larger across the broader Far North Queensland catchment. Ongoing Economic impacts for Yarrabah and Far North Queensland across stages 1 and 2 are presented in the tables below.

Table 3-7: Operational Impacts ($M, Yarrabah LGA)

Impact	Output ($M)	GRP ($M)	Incomes ($M)	Employment (FTE)
Stage 1: Household Expenditure (Stage 1)				
Direct	$0.8	$0.5	$0.2	3.1
Production Induced	$0.0	$0.0	$0.0	0.2
Consumption Induced	$0.1	$0.0	$0.0	0.3
Total Impact	**$0.9**	**$0.6**	**$0.2**	**3.5**
Stage 2: Operations and Induced Visitation (Stage 2)				
Direct	$2.4	$1.3	$1.0	12.9
Production Induced	$0.3	$0.2	$0.1	0.8
Consumption Induced	$0.2	$0.2	$0.1	1.0
Total Impact	**$2.9**	**$1.7**	**$1.2**	**14.6**

Note: Totals may not sum due to rounding.
Source: REA

Table 3-8: Operational Impacts ($M, Far North Queensland)

Impact	Output ($M)	GRP ($M)	Incomes ($M)	Employment (FTE)
Stage 1: Household Expenditure (Stage 1)				
Direct	$1.2	$0.7	$0.3	5.0
Production Induced	$0.3	$0.1	$0.1	0.9
Consumption Induced	$0.4	$0.2	$0.1	1.4
Total Impact	**$1.9**	**$1.1**	**$0.5**	**7.3**
Stage 2: Operations and Induced Visitation (Stage 2)				
Direct	$2.5	$1.4	$1.0	13.2
Production Induced	$1.0	$0.5	$0.2	2.4
Consumption Induced	$1.1	$0.6	$0.3	3.6
Total Impact	**$4.6**	**$2.5**	**$1.5**	**19.2**

Note: Totals may not sum due to rounding.
Source: REA

4. Cost Benefit Assessment

4.1 Modelling Approach

Cost-Benefit Analysis (CBA) is an analytical tool used to inform decisions regarding complex investment projects. A CBA has advantages over other modelling techniques (like an Economic Impact Assessment), in that a CBA seeks to measure not just the net benefits but also the net costs of a project. Equally, through a CBA framework, it is possible to measure multiple costs and benefits derived from a project (as opposed to just the economic components).

This CBA was carried out using a discounted cashflow (DCF) approach to analyse all costs and benefits that would occur if the Project were to proceed. In this sense, two scenarios were considered:

- **A baseline ('without the project') scenario:** Which assumes that the Project does not proceed, and that household energy cost, reliability, and local employment outcomes continue as per current trends.
- **A 'with the project' scenario:** Which assumes the Project (stages 1 and 2 are assessed separately) proceeds, supporting improved energy resilience, local employment, increased visitation, and reduced household living costs.

The CBA considered the effect of real costs and benefits (which excludes inflation) over a period of 20 years (from YE June 2023 to YE June 2052) at a range of real discount rates (4%, 7%, and 10%).

The geographic boundary for this assessment is the Yarrabah LGA.

In a CBA framework, decisions are made based on two criteria, Net Present Value (NPV) and the Benefit Cost Ratio (BCR). The NPV shows the difference between the present value of all future benefits and all future costs. The BCR is calculated by dividing the present value of future benefits by the present value of the future costs. A project is deemed 'desirable' if the NPV is positive and the BCR is above '1'. In general, if the NPV is negative and the BCR is below '1', the Project is deemed as undesirable as the future costs will outweigh the benefits.

4.2 Definition of Costs and Benefits

The following costs and benefits have been considered in the CBA.

Table 4-1: Cost and Benefits

Impact	Description	Value	Timing	Source
Costs				
Capital and Refurbishment Costs	Initial capital and program requirements and longer-term infrastructure refurbishment allowance have been incorporated into the CBA as per the financial feasibility assessment undertaken for this project.	$23.8 million + refurbishment	From 2023, refurbishment as required	ITP (2021)
Direct Operating Costs	Estimated ongoing costs including salaries & wages, contractor expenses, materials & consumables, facility expenses, and other direct costs have been incorporated into the CBA as per the financial feasibility assessment undertaken for this project.	$1.7 million p.a. at full operations	From 2023	TLG (2021)
Overhead Costs	Overhead operating costs have been incorporated into the CBA as per the financial feasibility assessment undertaken for this project.	$0.1 million p.a. at full operations	From 2023	TLG (2021)
Benefits				
Services Revenues	Revenues generated from operating activities costs have been incorporated into the CBA as	$0.7 million p.a. at full operations	From 2024	TLG (2021)

Impact	Description	Value	Timing	Source
	per the financial feasibility assessment undertaken for this project. Grant and sponsorship revenue streams have been excluded from the CBA to account for the societal cost of providing these forms of support.			
Value Add from Additional Tourism	The YEKC will facilitate additional visitation and broader expenditure within Yarrabah that would not otherwise occur. Estimated annual direct value add from broader tourism spend within the Yarrabah community has been included in the CBA as per the drivers developed in section 3.2.	\$0.1 million p.a. initially rising to \$0.3 million p.a. due to projected visitation growth	From 2026	TLG (2021), REA
Community Cultural and Recreational benefit of the YEKC	Museums and similar historical and cultural attractions provide a significant community value including recreational and education opportunities for residents, and an increase in civic amenity and pride. This CBA applies a community amenity and cultural value of the YEKC of \$20 per Yarrabah household per annum[1] projected over the analysis period.	\$0.01 million p.a.	From 2026	Trantor (2008), Museums and Galleries (2009), REA
Grid Energy Savings	Reduction in household energy costs due to PV solar has been included in the analysis as modelled by ITP (2021) at a rate of 21.76c/kwh.	\$1.8 million p.a. at full capacity	From 2024	ITP (2021)
Solar Energy Feed in Tariff Revenues	Benefits from solar energy grid exports have been included in the analysis as modelled by ITP (2021) at a rate of 6c/kwh	\$0.1 million p.a. at full capacity	From 2024	ITP (2021)
Greenhouse Gas (GHG) Savings	Reduction in GHG emissions has been included based on replacing grid electricity (est. 800 grams carbon/kwh) with PV solar (est. 40 grams carbon/kwh). Value of carbon reduction is included @ \$15/tonne.	\$0.1 million p.a. at full capacity	From 2024	Commonwealth Government (2021) ITP (2021)
Community Energy Reliability and Resilience Benefits	The Project will provide significantly improved energy reliability and community resilience due to microgrid and battery infrastructure (e.g. post-cyclones). Increased reliability has been valued at \$25 per additional kwh of energy delivered vs. the base case based on AER (2019) Willingness to Pay (WTP) benchmarks for regional Australia. The project is assumed to provide an additional 3 days (64 hours) per annum of additional energy reliability compared to the base case with associated daily kwh adapted from ITP (2021) estimates.	\$1.7 million p.a. at full capacity	From 2024	AER (2019), ITP (2021)

Note: [1] Previous studies attempting to value the social and cultural amenity of museums include Museums and Galleries (2009) who applied a contingent valuation methodology to estimate a Willingness to Pay (WTP) of \$57 per household per annum (\$2009) to maintain the current levels of cultural services and facilities across the Bathurst Regional Council, Orange City Council and Dubbo Regional Council LGAs. Trantor (2008) estimated a WTP of between \$14.73 and \$19.15 per adult per annum (\$2008) to support the ongoing operations of the Queensland Museum. Respondents were also in favour of funding \$24 million in proposed expansions.

Source: REA

4.3 Costs and Benefits Not Included

The following benefits have not been included and would serve to improve the outcomes of the CBA analysis, if they were quantified.

- **Improved health, education, and community outcomes:** Improved energy reliability will increase health outcomes, including access to hot showers and cooking and more regular school attendance. Consultation with the local community indicates significant issues relating to the reliability of energy and hot water specifically creating health and hygiene difficulties within the community. Assets such as the YEKC may serve further community purposes such as a community shelter for natural disasters. These notable impacts have not been quantified to avoid double counting energy reliability and resilience benefits.
- **Economic development opportunities:** The project will help unlock a range of additional potential economic development opportunities, including:
  - **Increasing visitation and the viability of further tourist developments** due to the YEKC including future development of short stay visitation accommodation in Yarrabah. As a new tourism experience, the YEKC will support the recovery of visitation and the broader tourism sector post the current COVID-19 pandemic.
  - **Potential E-mobility Solutions** (electric buses, council trucks, personal mobility, cars, ferries, and charging infrastructure) considered in Stage 3 of the Project will be supported by the energy infrastructure.
- **Increase in business confidence:** The Project will see a significant injection into the economy during construction and a notable increase in direct visitor expenditure and disposable household incomes after completion. These injections in the economy may increase confidence amongst local businesses, which may provide the catalyst for additional investment and job creation.
- **Increase in community amenity and pride:** Many aspects of the Project (beyond the YEKC) provide significant community value including employment, recreational, and education opportunities for residents. This in turn will support improved social outcomes and general community wellbeing in Yarrabah.
- **Prototype project for other fringe of grid communities:** The Project will serve to test and highlight the effectiveness of microgrid energy solutions for fringe of grid communities, serving as a potential prototype for other Australian and Pacific region communities.

These impacts are strongly positive and would improve the CBA outcomes for the Project case if they were quantified in the analysis.

4.4 Results

The results of the CBA for the Project are highlighted in the following table (Table 4.2).

Table 4-2: Present Values of Costs and Benefits

Discount Rate	Present Value Costs ($M)	Present Value Benefits ($M)	Net Present Value ($M)	Benefit Cost Ratio
4%	$48.1	$54.8	$6.7	1.14
7%	**$40.9**	**$41.4**	**$0.5**	**1.01**
10%	$35.7	$32.2	-$3.6	0.90

Note: Totals may no sum due to rounding.
Source: REA

At the selected real discount rate of 7%, the analysis yields a NPV of $0.5 million and a BCR of 1.01 meaning that it is economically desirable and provides a net benefit. The project is somewhat sensitive to the discount rate applied, returning a negative NPV at a 10% discount rate. The project yields an Internal Rate of Return (IRR) of 7.3%.

Under the Base Case scenario (without Project scenario), none of the identified benefits would be captured nor any of the costs incurred. As such, the scenario with the Project provides positive net economic and social benefits. It would be expected that further detailed investigation and optimisation of the Project components through a detailed business case would further improve the net position of the analysis.

4.5 Sensitivity Testing

Sensitivity testing was undertaken using Monte Carlo simulation, which tests the impact of changes in input assumptions thousands of times based on a defined probability distribution. The simulation tested each of the variables in isolation with all other inputs held constant, with the results reported in the following table in terms of the modelled change in NPV resulting from the variance in the base assumptions at a discount rate of 7%. The final row of the table examines each assumption simultaneously to provide a 'combined' or overall sensitivity of the model findings to the assumptions used.

The sensitivity analysis applied the following variable distributions:

- **Costs:** Maximum 30% higher and lower than the base values.
- **Benefits:** A normal distribution with a standard deviation of 0.2.

The table below outlines the distribution of NPV allowing for a 10% confidence interval, with the '5%' and '95%' representing a 90% probability that the NPV will be within the range outlined in the table.

The table below shows, at a discount rate of 7%, there is a 90% probability the Project will provide an NPV of between -$8.9 million and $9.6 million. Sensitivity testing returned a positive NPV across 53.5% of the 5,000 iterations run in the Monte Carlo analysis. The analysis is most sensitive to capital costs, grid energy savings, and community energy reliability and resilience benefits.

Table 4-3: Monte Carlo Simulation

Cost/Benefit ($M)	NPV ($M) 7% Discount Rate	
	5th Percentile	95th Percentile
Costs		
Capital and Refurbishment Costs	-$3.9	$4.6
Direct Costs	-$2.8	$3.5
Overhead Costs	$0.2	$0.7
Benefits		
Services Revenues	-$1.7	$2.6
Grid Energy Savings	-$4.9	$5.9
Community Energy Reliability and Resilience Benefits	-$4.7	$5.7
Tourism Value Added	$0.0	$0.9
Solar Energy Feed in Tariff Revenues	$0.4	$0.6
GHG Savings	$0.1	$0.8
Community Cultural and Recreational benefit of the YEKC	$0.4	$0.5
Combined	**-$8.9**	**$9.6**

Source: REA

5. Opportunities for E-Mobility

The following section considers future opportunities to establish e-mobility services within Yarrabah as part of Stage 3 of the Project. Identified local opportunities include electric buses, council trucks, personal mobility, cars, ferries, and charging infrastructure.

5.1 The Need for E-Mobility Solutions in Yarrabah

Yarrabah is a linear community stretching for 13 km along Backbeach Rd (one lane each way). The town centre, at the northern end of the Shire, provides many services including: Government Offices, Store, Child Care, Primary School, Health Care and Pharmacy. However, other essential services including: Police, Hospital, Rehabilitation Centre, Aged Care, High School, Pool, Art Centre and Sporting Fields are spread along Backbeach Rd. All new housing is also being provided towards the southern end of Backbeach Road.

The linear nature of the Shire, and the linear provision of services, means that all residents are required to travel to one or more services. There is no public transport in Yarrabah. The difficulty in physically accessing services is compounded by limited (no NBN) internet. Accordingly, poor transport builds in another layer of disadvantage to residents.

Currently, there is no public transport service between the community and Cairns/Gordonvale. Local residents are reliant on driving/walking across Yarrabah town, and due to the lack of accessibility, are often isolated from employment, education, and health services and opportunities, as well as other essential services. A large proportion of the community does not own or have access to reliable motor vehicle transport, including:

- 31% of households that do not have a motor vehicle.
- 20% of the population that walk or ride to work.
- 23% of the population aged 10-19 years of age who lack licenses.
- Seniors who do not or should not drive (4% of the population).
- Adults who cannot drive due to disability or lack of driver's license (approx. 15% of the population)
- Drivers whose vehicle is temporarily unavailable.
- People who want to walk or bike for enjoyment and health.
- Households with low incomes that want or have to minimise transportation expenses i.e. 100% of the population, as Yarrabah is in the decile1 ratings in each of the Socio Economic Indexes for Areas (SEIFA) of: relative disadvantage; advantage and disadvantage; economic resources; and education and occupation.

There remains an ever increasing need to ensure regional towns, and in particular, Indigenous communities, are not left further behind in the transition to a zero emission transport system, and a shift towards more equitable transport pricing models, such as Mobility as a Service (MaaS). In particular, technology leapfrogging - such as the opportunities provided through MaaS - is one of the most cost-efficient and effective ways for remote, regional and disadvantaged communities to reduce social disadvantage.

5.2 The Proposal

Yarrabah presents the ideal opportunity to extend the ongoing MaaS trial at UQ – ODIN PASS – to a different setting to inform TMR's broader ambitions to support the expansion of MaaS across Queensland. The existing infrastructure built to support the MaaS trial in South East Queensland could be leveraged to expand usage to North Queensland, as part of a new trial, with a focus on understanding how MaaS could be used by regional and Indigenous communities, as well as tourists.

Ideally, the MaaS program would also encourage tourists to visit the nearby Yarrabah community, potentially on a zero-emission ferry and/or bus that would link the community with Cairns city, providing access to essential services, while assisting Yarrabah in achieving its ambition of becoming a tourism destination.

Support for the research, development and trialling of a zero emission ferry between Cairns and Yarrabah could also be used to spur the creation of a local zero emission marine vessel industry, and assist the existing reef tour fleet to plan and transition towards low, and eventually zero emission boats.

While this project presents an ambitious agenda, combined it has the potential to deliver a genuine difference for the community, support local job creation, improve access to transport and other essential services, and has the potential to spur additional development.

The intention would be for this project to also support broader efforts in the Far North Queensland and Yarrabah communities to decarbonise the energy sector, improve climate resilience, and seek opportunities to achieve synergies between the transport and energy sectors e.g. using electric vehicles as “batteries-on-wheels”.

6. Summary of Findings

The development of the Project will generate a variety of positive economic benefits for the Yarrabah community. The construction of the Project will provide a one-off GRP stimulus of $2.6 million to the Yarrabah economy directly and indirectly.

Once completed; the project will continue to deliver strong economic impacts for Yarrabah. The Project will contribute an estimated $2.1 million per annum to local GRP and support approximately 18 direct and indirect FTE jobs on an ongoing basis. This will be achieved through increased household incomes and expenditure within the community due to lower household energy costs, and the ongoing operations of the Project initiatives.

Estimated economic impacts during construction and once operational are even larger across the broader Far North Queensland region.

Through the YEKC, the Project will increase visitation to the region by an estimated 4,000-8,000 visitors per year, generating notable expenditure within the precinct and across the community more broadly. The YEKC will combine with established tourism offers across broader Far North Queensland to significantly increase the tourism potential of the Yarrabah Shire. This will substantially increase the depth and resilience of the local tourism industry and make the development of future short stay accommodation more economically feasible.

As a new tourism experience, the Project will support the recovery in visitation post the COVID-19 pandemic.

The Project will also deliver significant financial, health, and civic benefits to residents and support broader economic development outcomes, including:

- Greatly increased reliability of electricity supply and community resilience following weather events such as cyclones.
- A net reduction in GHG emissions, by replacing grid electricity with solar and battery storage.
- Significant community educational and recreational opportunities through the YEKC.
- Annual household energy savings of approximately $1.7 million per annum across the community.

A cost-benefit analysis (CBA) evaluated the Project and found that it will generate a net positive socio-economic impact of $0.5 million NPV over 20 years for the Yarrabah community. The findings of this analysis support the merit of the Project and the long-term economic and community benefits it will provide to the Yarrabah community.

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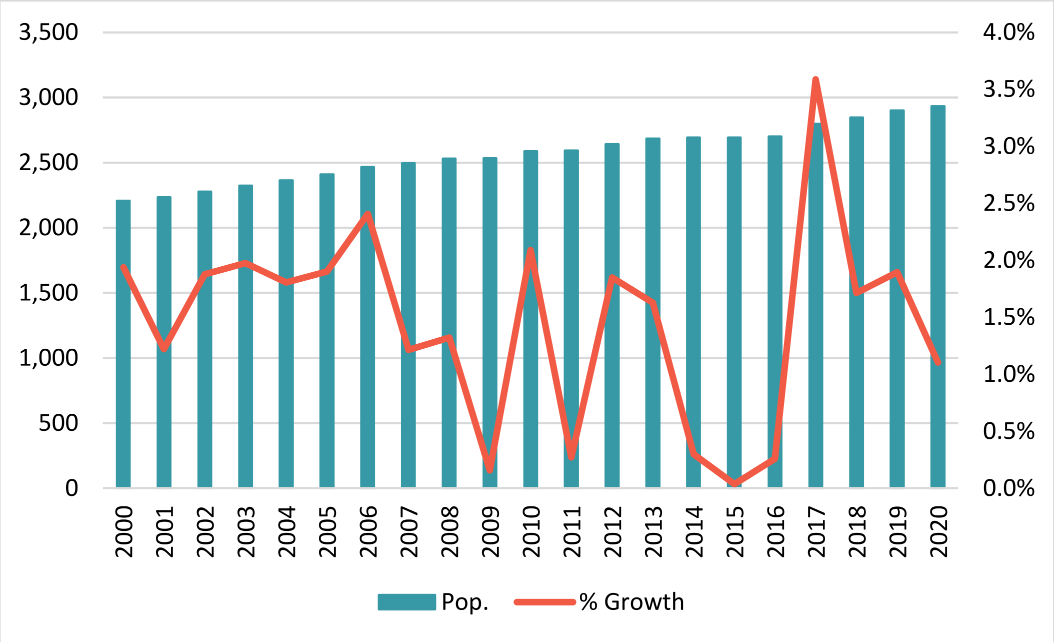
Appendix A: Socio-Economic Indicators

Population Growth

Yarrabah currently hosts an official resident population of 2,993 with growth of 1.1% during 2019-20. However recent surveys undertaken by Council indicate an actual population closer to 4,000 residents.

Despite population statistics being highly volatile from year to year, Yarrabah has averaged significant annual growth of 1.7% over the past five years. Over the next 20 years, Yarrabah is projected to grow on average 0.9% per annum.

Figure A.1: Population Growth



Source: QGSO (2021)

Age Profile

Yarrabah has a young demographic, with a greater share of the population representing children and a notably lower share of retirees and elderly people compared to Queensland as a whole.

Table A.1: Share of Population by Age (2020)

Age Band	Yarrabah	Queensland
0-14	31.9%	19.3%
15-24	20.6%	12.7%
25-39	21.3%	21.0%
40-65	21.6%	30.9%
65-80	4.1%	12.3%
80+	0.5%	3.8%

Source: QGSO (2021)

Education Outcomes

Yarrabah educational outcomes significantly lag the state of Queensland as a whole, with less than 30% of the population having completed year 12 or equivalent schooling compared to over half of Queensland.

Table A.2: Highest Year of Schooling (2016)

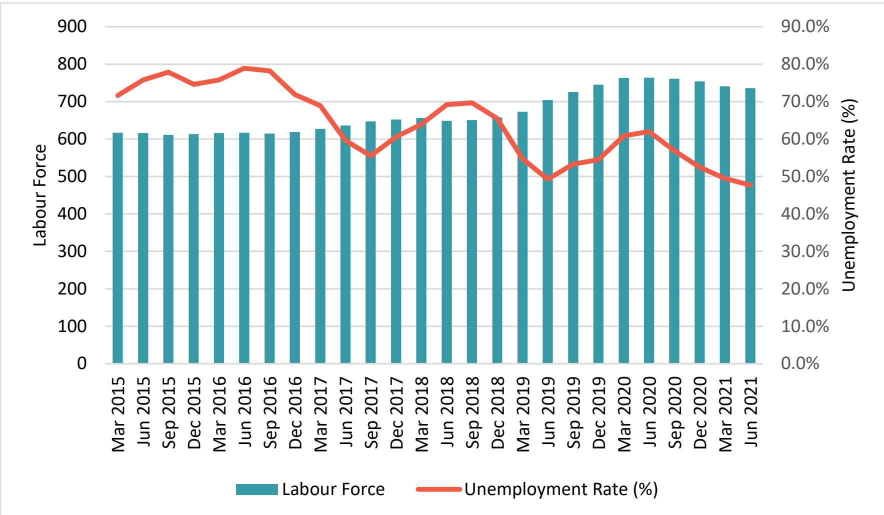
School Year	Yarrabah	Queensland
Year 12 or equivalent	27.1%	52.4%
Year 11 or equivalent	16.7%	6.8%
Year 10 or equivalent	34.1%	22.4%
Year 9 or equivalent	11.4%	4.2%
Year 8 or below	7.4%	4.9%
Highest year of school not stated	3.4%	9.3%
Total	**100.0%**	**100.0%**

Source: QGSO (2021)

Labour Market

The Yarrabah labour market has sat above or around 50% unemployment over the past five years (State-wide unemployment currently sits at 6.8%). However notable progress has been made, with a declining trend in unemployment from over 70% in early 2015. The local labour force has also grown significantly (nearly 20%) since 2015 to 736 people as of June 2021.

Figure A.2: Labour Force and Unemployment (Yarrabah)



Source: QGSO (2021)

The main employment sectors in the Yarrabah are currently government led:

- Health care and social assistance (28.2% of employment) health outcomes in Yarrabah and many remote Indigenous communities remain well behind Queensland and national averages (Productivity Commission, 2021).
- Public administration and safety (25.7% of employment), with Council a major provider of essential services to the community.
- Education and Training (23.9% of employment): Public schooling is currently provided in Yarrabah up to grade 10.

Building Approvals

Local residential building activity is highly limited due to significant space constraints, with most houses owned by Council. A total of 24 new dwellings have been built over the past five years at a total value of $9.6 million.

Tale A.3: Residential Building Approvals

Period	Dwelling Units	Residential Building Value ($000)
2015/16	0	0
2016/17	14	5,120
2017/18	10	4,483
2018/19	0	0
2019/20	0	0
2020/21	0	0

Source: QGSO (2021)

Appendix B: Input Output Modelling Methodology

Input-Output models are a method to describe and analyse forward and backward economic linkages between industries based on a matrix of monetary transactions. The model estimates how products sold (outputs) from one industry are purchased (inputs) in the production process by other industries.

The analysis of these industry linkages enables estimation of the overall economic impact within a catchment area due to a change in demand levels within a specific sector or sectors.

Impacts are traced through the economy via:

- **Direct impacts,** which are the first round of effects from direct operational expenditure on goods and services.
- **Flow-on impacts,** which comprise the second and subsequent round effects of increased purchases by suppliers in response to increased sales. Flow-on impacts can be disaggregated to:
    - **Industry Support Effects (Type I)** derived from open Input-Output models. Type I impacts represent the production induced support activity as a result of additional expenditure by the industry experiencing the stimulus on goods and services, and subsequent round effects of increased purchases by suppliers in response to increased sales.
    - **Household Consumption Effects (Type II)** derived from closed Input-Output Models. Type II impacts represent the consumption induced activity from additional household expenditure on goods and services resulting from additional wages and salaries being paid within the catchment economy.

Economic impact analysis considers the following four types of impacts.

Table B.1: Economic Activity Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Product	The value of output after deducting the cost of goods and services inputs in the production process. Gross product (e.g. Gross Regional Product (GRP)) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project either directly or indirectly.
Employment	Employment positions generated by the Project (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: REA

Regional Model Development

Multipliers used in this assessment have been created using a regionalised Input-Output model derived from the 2018-19 Australian transaction table (ABS, 2021a). Where required, values were converted to current dollars using CPI (ABS 2021b).

Estimates of gross industry production in the catchment area were developed based on the share of employment (by place of work) of the Catchment Area within the Australian economy (ABS, 2017) using the Flegg Location Quotient and Cross Hauling Adjusted Regionalisation Method (CHARM). See Norbert (2015) and Kronenberg (2009) for further details.

Modelling Limitations and Assumptions

Input-Output modelling is subject to a number of key assumptions and limitations (ABS, 2021a):

- **Lack of supply–side constraints:** The most significant limitation of economic impact analysis using multipliers is the implicit assumption that the economy has no supply–side constraints. That is, it is assumed that extra output can be produced in one area without taking resources away from other activities, thus overstating economic impacts. The actual impact is likely to be dependent on the extent to which the economy is operating at or near capacity.

- **Fixed prices:** Constraints on the availability of inputs, such as skilled labour, require prices to act as a rationing device. In assessments using multipliers, where factors of production are assumed to be limitless, this rationing response is assumed not to occur. Prices are assumed to be unaffected by policy and any crowding out effects are not captured.
- **Fixed ratios for intermediate inputs and production:** Economic impact analysis using multipliers implicitly assumes that there is a fixed input structure in each industry and fixed ratios for production. As such, impact analysis using multipliers can be seen to describe average effects, not marginal effects. For example, increased demand for a product is assumed to imply an equal increase in production for that product. In reality, however, it may be more efficient to increase imports or divert some exports to local consumption rather than increasing local production by the full amount.
- **No allowance for purchasers' marginal responses to change:** Economic impact analysis using multipliers assumes that households consume goods and services in exact proportions to their initial budget shares. For example, the household budget share of some goods might increase as household income increases. This equally applies to industrial consumption of intermediate inputs and factors of production.
- **Absence of budget constraints:** Assessments of economic impacts using multipliers that consider consumption induced effects (type two multipliers) implicitly assume that household and government consumption is not subject to budget constraints.

Despite these notable limitations, Input-Output techniques provide a solid approach for assessing the direct and flow on economic impacts of a project or policy that does not result in a significant change in the overall economic structure.

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