Powering Daintree

A study of supply options for the
Australian Renewable Energy Agency

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Executive Summary

Sunverge has been engaged by ARENA to:

- Define the challenges faced in supplying energy in the Daintree community;
- Identify options to supply power to residents of the Daintree community, including analysis of current state technologies (traditional and renewable) and analysis of system and energy load data;
- Analyse tariff and financial structure options to enable a community based scheme which rewards efficient behaviours and delivers improved infrastructure; and
- Develop options and recommendations for pilot and broader rollout of energy supply technologies to the Daintree community

This report presents Sunverge's findings from its investigation and engagement with members of the Daintree community and key stakeholders including representatives from Queensland's Department of Energy and Water Supply, Douglas Shire Council, Wet Tropics Association and the Jabalbina Aboriginal Corporation.

As part of the process, Sunverge reviewed a number of existing studies and reports relevant to power supply issues in the Daintree community, including the 2017 Ener-G report and Ergon Energy's engineering 2013 Daintree Supply Report. Many of these studies relied on information contained in previous reports with little reliance on gathering primary data to establish load profiles for energy and load requirements.

Sunverge sought to improve the accuracy of the energy requirements analysis and thus the accuracy of supply option definition by undertaking real metered data analysis, spatial survey analysis, and analysis of Sunverge's own load data set for Far North Queensland combined with standard power system planning and forecasting practices.

Sunverge undertook spatial analysis, gathered energy consumption data from a number of sites and developed load profiles to establish the community power requirements. In the process Sunverge discovered significant differences between the different regions within the Daintree.

Sunverge also conducted meetings with a number of OEMs through a market sounding process to develop indicative costing at concept level for a range of solutions applicable to the Daintree area for comparison purposes. The network design process adopted was similar to that used by Ergon Energy. The expected Load and Generation spatial arrangements determined the number and expected type of transformers, synchronous machines and cables, thus providing a more quantitative cost estimate.

This information formed the basis for the analysis of the following five scenario options for complete power supply (i.e. network plus generation or standalone generation) to the Daintree community.

1. Single Daintree electrical microgrid with synchronous machines and a staged pathway for high renewable uptake
2. Multiple Daintree electrical microgrids (three segments)
3. Daintree gas microgrid with high renewable uptake using power to gas and biomethane

4. Microgrid supply to Cape Tribulation (leverage of existing generation to extend in small LV networks)
5. Upgrade of individual Remote Area Power Supply options

Through discussions with key stakeholders, four main criteria of equal weighting for a successful power supply were agreed, being:

- Equity
- Reliability
- Environment and sustainability (including renewable potential)
- Economic

The five scenario options were each assessed against these criteria.

Each option was assigned a score from 1-5 for each of these criteria and summed for simple ranking of preferred supply options as set out in more detail in the *Our Approach* section of this document.

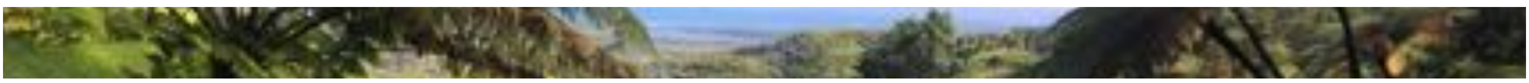
Power supply options assessed

As part of this process, Sunverge was able to investigate many different technologies and options at a high level for suitability. These included:

- Ultra lean burning spark engines
- Liquid vs gas engines
- Heat to electrical recover (organic rankine cycle and inverter)
- Distributed micro combined heat and power generation
- Gas reticulation, in particular using polyethylene pipe (P.E)
- Hydrogen injection into P.E pipeline for storage (Fuel Cells)
- Traditional and modular battery energy storage systems and inverters
- Power to gas to power fuel cells (including high pressure)
- Methanation of hydrogen (fuel cells)
- HEMS (Primary hot water control over an IP network and local frequency sensing).
- Near synthetic inertia storage devices (ultra fast battery and fuel cell systems).
- Traditional synchronous machines for inertia and fault power.
- Traditional cable vs overhead line systems.
- Traditional European vs American style LV networks and transformers
- Traditional MV switchgear (Extendable) to allow flexibility for future growth without significant capital expenditure.

Biofuels

With regards to biofuel options, it is noted that Sunverge and ARENA also made enquiries through the Queensland Government's Biofutures Queensland office. Feedback received indicated that production is limited and currently in feasibility study stage with numerous projects. Whilst commercialisation of these projects remains some years away, the current indications are that the supply of biofuels is at present uneconomical but may be considered at future dates depending on renewable penetration targets and improvements in costs and technology.



Pathway to 100% renewables

The report finds *Option 1 - Single Daintree electrical microgrid with a staged pathway for high renewable uptake* to be the preferred option to supply reliable, renewable and cost-effective power to residents and businesses in the Daintree.

This option recommends the development of a full underground electric microgrid (network) to enable equitable and reliable access to power for customers and facilitate a greater diversity across loads thereby allowing a higher renewable self-consumption rate.

For the purposes or achieving equitable, reliable, economically sound and environmentally sustainable energy supply for residents, it is recommended that the network be supplied by an appropriate generation mix. This report proposes that such a mix could include synchronous gas generation, central and distributed solar, and a solar to gas facility to address seasonal solar irradiance and enable long term storage of excess renewable generation.

The report aims to provide a feasible pathway to an equitable, reliable, economically sound and environmentally sustainable energy supply for residents with the following recommendations.

1. a staged approach to building a reliable, low-impact underground microgrid which is initially serviced by a mix of traditional gas generation and solar PV and leverages regional skill sets
2. subsequent to the provision of reliable, low impact microgrid power, exploring options to increase the renewable generation of the system to approximately 80% through:
   - first understanding the detailed load characteristics of the whole system based on analysis of installed system (traditional) generation for a period of up to one year, then based on actual system load data and detailed site investigation
   - implementing a plan to reliably increase renewable penetration and deploy innovative energy technologies including potentially large scale, long term storage (eg solar to gas)
3. establishing a mechanism to allow customers to benefit from sharing their excess solar production (similar to a Feed In Tariff scheme)
4. implementing residential and business tariffs with a fixed and variable component similar to those offered to grid connected customers in regional Queensland
5. encouraging a public private partnership arrangement to the development of the microgrid
6. obtaining stakeholder support and agreement on the key principles for engineering solutions, tariff structures, subsidies and schemes, ownership, regulation and governance
7. Funding the development of a next stage detailed Microgrid pre-construction study with reputable project proponent including detailed survey data, detailed engineering cost studies, pre-approvals and detailed project plan for Option 1. It is noted that the Queensland Government is currently considering its commitment to further studies relating to the supply of power in the Daintree and recommended that this be considered as part of those activities.

Acknowledgements

Sunverge would like to thank representatives of the following stakeholders for their contributions to the development of this report from data gathering to the development of recommendations:

- Ergon Energy Corporation
- Jabalbina Aboriginal Corporation
- Wet Tropics Management Authority
- Queensland Department of Energy and Water Supply
- Russell and Teresa O’Doherty

In addition, we would like to thank the following Daintree residents and businesses whose support allowed Sunverge to gather the first real interval load data insights into energy consumption patterns in the Daintree:

- Russell and Teresa O'Doherty
- Cape Tribulation Beach House
- Heritage Lodge and Spa
- Daintree Tea
- Lync-Haven

Understanding the supply challenge in the Daintree

The Daintree World Heritage listed rainforest is an area renowned for its spectacular scenery, dense rainforest, mountain ranges and rugged topography. It is one of Australia's largest rainforest wilderness areas and, with the exception of roads and limited freehold properties, has remained largely untouched by modern development.

Challenges to date

Visitors travel from all around the world to experience the scenic and natural beauty of the rainforest as it stretches down from the mountains to the coastline and reef.

Whilst eco-tourism contributes significantly to the Queensland economy, the ecological significance of the area has meant that debate has raged for decades over how development and conservation can coexist in an ecologically sustainable manner.

These debates include the dispute over the Daintree Coast subdivisions in the late 1970s, the now famous Daintree Blockade, National Park declarations in the early 1980s, World Heritage listing in the late 1980s, buy-back schemes in recent years and countless studies, inquiries and plans into power supply to the region.

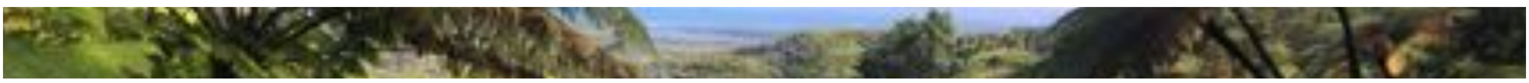
Numerous studies have been undertaken over recent decades to specify the challenges faced by providing power supply to the Daintree community, including:

- Cost Estimates for Daintree Supply Option A (Dec 2013) Ergon Energy
- Cost Estimates for Daintree Supply Option B (Dec 2013) Ergon Energy
- Proposed Daintree Powerline Environmental Impact Assessment Study (Oct 1998) GHD
- Isolated Communities Power Options Study 2017 V2.0.pdf (2017) Ener-G
- Daintree Futures Study (Nov 2000) Rainforest CRC
- Environmental Protection (Water) Policy 2009
- Daintree and Mossman Rivers Basins Environmental Values and Water Quality Objectives Basins Nos. 108 and 109 and adjacent coastal waters (2009) Queensland Government
- Ergon's Developers Handbook Develop, Design and Construct Work version 8 Ergon Energy

Daintree/Cape Tribulation Electricity Survey (March 2016) Compass Research

The area has been excluded from Ergon Energy's supply territory and successive state governments have been unable to find an equitable, reliable, economic and environmentally suitable solution to the challenge.

The following additional issues compound the complexity of the challenges associated with providing equitable, reliable, economic and environmentally sustainable power solutions to the residents and businesses in the Daintree.

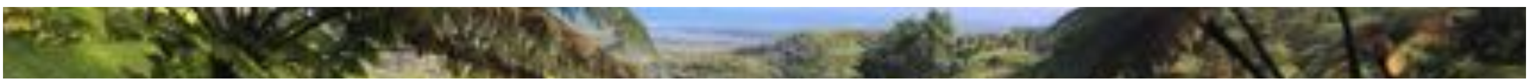


Geographical challenges

- The region sits 'between the rainforest and the reef', with mountains to the west and ocean to the east and rivers marking the northern and southern boundaries of the area. The rugged landscape and steep ranges present a number of physical challenges for electricity and communications infrastructure, although most of these can be overcome by appropriate undergrounding along existing roads or easements.
- There is a known region through the range which is rock and will need directional drilling to facilitate any underground network options. From discussions with drillers who have experience in the region for a telecommunications operator, indications are that most locations are favourable and so other quicker drilling methods or possibly even cable ploughing might be feasible. At this stage, given unknown variables, a conservative approach was taken in the option analysis. Engaging one or multiple local operators for detailed quotations and exact route planning as part of a pre-build investigation would tighten up this ambiguity.
- The constraints of remote location, and limited access via river cable ferry, have potential for significant impact on both SAIDI and OPEX costs of any grid. It is therefore recommended that the equipment installed be robust with high reliability and to introduce modularity for components which have lower reliability such that failed components can be isolated without a significant adverse impact. Additionally equipment such as energy storage systems and protection switchgear/relays should have components which have existing integrations schemes where all bugs have been discovered and remedied before being implemented in the Daintree.

Environmental challenges

- The Daintree is well known for its frontier approach to energy supply and has many dated residential Solar power installations to enable isolated supply to homeowners and reduce individual generator running costs. Many systems have been in operation since the Queensland Government's successive Daintree Remote Area Power Supply Subsidy schemes dating back to 1996 and 2000 and rely on aged and inefficient technology.
  However, a big wet season and high seasonal variances in solar output, combined with the absence of a grid mean that self-consumption potential is low in the current community power supply arrangements. This report asserts that the introduction of a microgrid will serve as a platform through which diversity will be increased and solar potential can be maximised
- As a World Heritage listed area, there have been strong concerns about the potential environmental risks associated with energy infrastructure development in the area. These risks need to be addressed through any proposed energy supply option, however it should also be noted that any decisions regarding future supply options should take into account ways in which to reduce the current environmental damage caused by the burning of over 4 Million litres of diesel per annum and in some cases the dumping of out-dated lead acid batteries into the eco-system.
- This report recommends the development of a power system which will significantly reduce the environmental impact of current supply solutions whilst at the same time demonstrating an economically sound solution with a pathway to 100% renewable energy supply in the area.
- Due to the Daintree being a heavily forested area direct shading was also estimated on a roof by roof basis as part of the survey of roof area to estimate available rooftop PV potential. While some solutions are available for roofs with intermittent shading from a branch such as micro inverters or DC optimizers such solutions are typically more



expensive than traditional string inverter systems and do not make up for lost energy not falling on a particular panel during shading. As seen below a significant proportion of roof space available has significant shading and is not viable for installing any sort of PV panels.

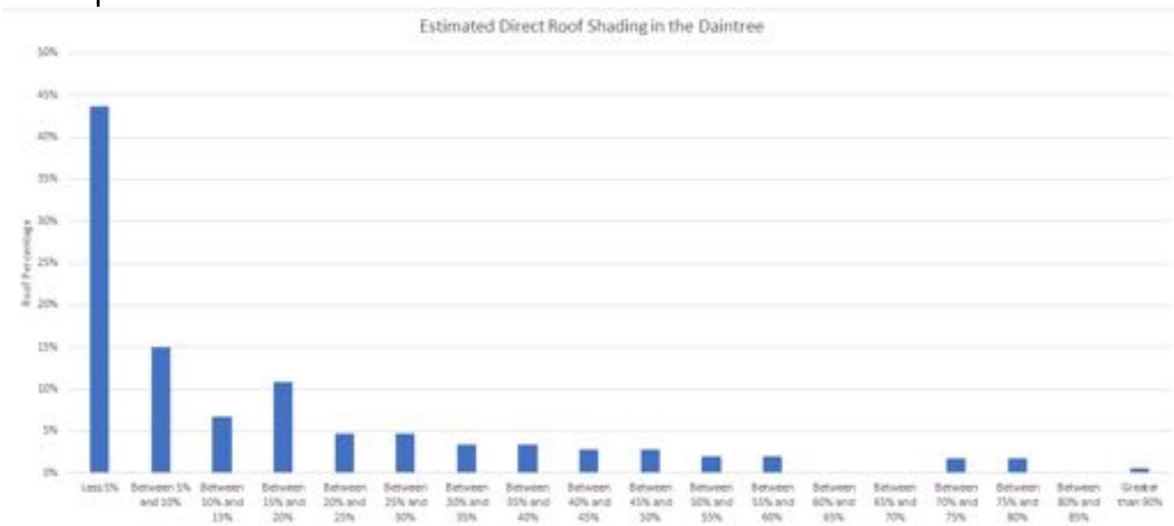


Fig 1.0 Estimated Distribution of Roof Shading (Tree/Branch Overhand via Aerial Photography)

- Roof shading isn't uniform over the whole Daintree region or load class. Cape Tribulation, for example, has significant roof-top shading issues and is one of the largest regions needing energy to be transported to this location or generated locally via traditional liquid or gas hydrocarbons.

The image below represents typical conditions for accommodation cabins which are one of the most significant load contributors within the Daintree Rainforest area. As shown, many premises are in scenic but poor photovoltaic locations.

Fig 1.1 Accommodation Cabins, Typical for the Daintree and a Large Load Sub Group

Diverse stakeholders

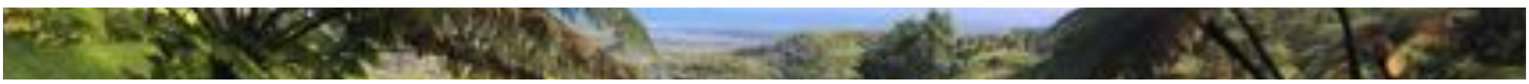
- The ongoing debate between development and conservation in the Daintree region shows the extent of diversity of views amongst stakeholders.
- Common feedback amongst the majority of reports to date indicates that there would be support for a scheme which provides a more equitable, reliable, environmental and economic solution to the supply challenges of the Daintree. Sunverge believes that its preferred option will provide a solution which best meets these objectives and adheres to the wishes of the vast majority of Daintree residents.

Economic challenges

- Power systems have traditionally been built using public resources on the premise that electrification enhances community welfare and the public good.
- In the case of the Daintree, there is a strong economic motivation to substitute diesel generation costs at the premises. However, the economic challenges associated with low customer numbers per installed kW or km of network, environmental restrictions and challenging physical environment mean that a suitable solution will require some level of government incentive or subsidy in order to build a scheme which meets all the requirements of the community. The costs associated with the preferred solution are listed later in this report and will require detailed investigation as part of the next stage of pre-construction works.
- In addition to diesel fuels being used for electrical generation, significant LPG is also being consumed within the Daintree for almost all heating and cooking usage. This additional infrastructure is also restricting the local businesses and reducing funds for upgrades and overall improvement such as more efficient AC systems. Below is a typical LPG installation for a larger commercial site.

Fig 1.2 Large LPG Tanks, LPG used for Cooking and Heating (Primary Hot water), Typical Supplier Elgas

- Inter-tie into the Ergon Energy Network has been proposed by many different studies and was included as part of an option that Ergon Energy did in 2013. This option would required significant reliability and loadflow/protection studies along with likely network upgrades. Ergon Energy's report from 2013 noted that for only supplying



Forest Creek and Cape Tribulation a new feeder to supply this additional load would cost in excess of $16M to construct .

Technological challenges

- A number or technological challenges exist in a densely rainforested community that is humid, close to the sea and prone to cyclones and monsoons.
- From a network perspective, overhang from foliage would cause a number of significant issues to any overhead configuration.
- From a system stability perspective, numerous microgrid challenges are specified in detail below, however these include typical issues experienced with loads in microgrids, lack of diversity, and establishing the right mix of generation to support a transition to renewables. The system will also need fast response mechanisms to cope with sudden load changes the intermittency of renewables as well as long term storage to cope with seasonality.
- In addition, the system would need communications and metering infrastructure, although it is expected that this would be a minor incremental cost to the overall microgrid development.
- The strong wet season and location 'within a bowl' from the mountain ranges to the immediate west and between Cow Bay and Cape Kimberley presents seasonality challenges for significant renewables as long term or baseload storage is needed to cater for periods of high rainfall and low solar production.

Equity

- In addition to being excluded from traditional power supply solutions, there are various other barriers to equity for residents in the Daintree, for example:
    - access to state and federal government schemes, including credits and rebates for electricity supply or the installation of energy efficient appliances or renewable generation. This report recommends the state and federal government investigate ways in which regulatory barriers can be amended to enable such schemes to be equitably accessed by members of the Daintree community. These schemes include access to renewables certificates (eg STCs), low income energy rebates associated schemes.
    - Access to affordable products and services. Whilst the Daintree community is not geographically distant from the city of Cairns, the study found that residents and businesses are charged a premium significantly higher than residents in Cairns and the surrounding region for electrical products and services. For example, quotes for solar installations were at least double those offered in Cairns, well above any extra charge for travel time. If a microgrid were in place, one potential role for the state government would be to assist in the creation of a market opportunity for the installation of solar PV similar to the recent initiative in remote communities.

Daintree Characteristics

The following is a summary of key information in relation to the Daintree community.

Site, customer and demand information	
Geographical description (e.g. size and description of key features/constraints)	• No existing electric network (excluded from Ergon regulated supply territory) • 120km reticulated MV and LV line required to supply entire community • Approximate direct distance of Daintree excluded territory 40km from Daintree River to Bloomfield River, northern and southern communities separated by the Alexander Range • Dense, world heritage protected rainforest • Solar farm potential in excess of 100MW based on spatial analysis of large cleared areas • Rooftop solar DG marginal due to foliage and seasonality • Large end of line load centre at Cape Tribulation • Significant seasonality due to wet season, both long and short term storage needed for significant PV uptake.
Population • permanent vs. non-permanent vs. tourists etc • Number of customers (resi, C&I)	Census data 2011 • 640 residents • Additional 550 overnight visitors • Approx 42 businesses • Approx 273 residential dwellings
Demand	• Max demand 3.2MW based on current population • See Load duration curve below
Current cost of electricity ($/kWh) for different customers	As noted in the Compass Research "Daintree/Cape Tribulation Electricity Survey" undertaken in March 2016, only 6 out of 100 customers could give an estimate of how much power was costing them per kWh and the analysis could not determine whether the costs included allowance for capital expenditure or not. The average cost per kWh of these reported respondents was 48c/kWh, and this is likely to be higher if capital costs are included.

The below table is a summary of the Load Duration Curve for the various communities within the Daintree and the entire Daintree system.

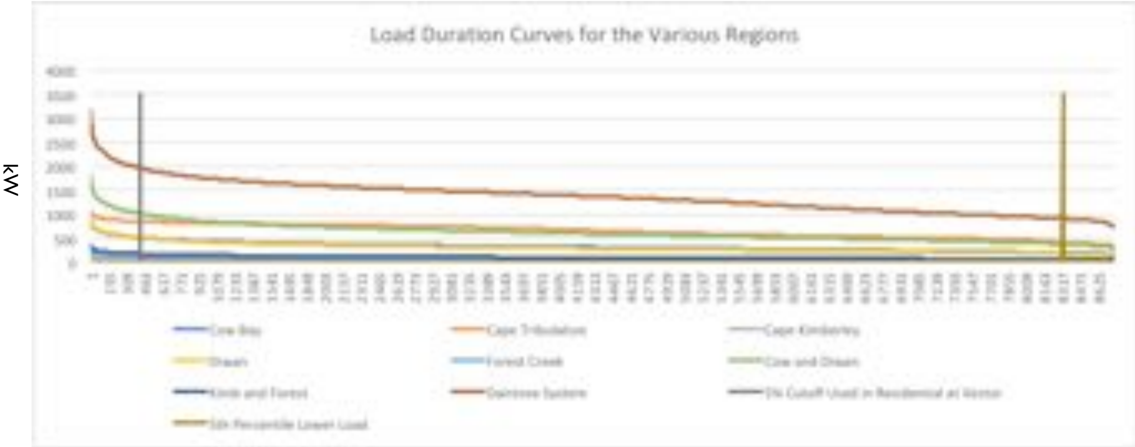


Fig 1.3 Estimated Load Duration Curves for the Daintree Networks from Model Described in this report.

The following table adapted from the *Isolated Communities Power Options Study 2017 V2.0.pdf (2017) Ener-G* highlights the variability in estimates regarding population.

Table 1: Table of Property and Customer numbers per community

Area	Dept of energy 2005	Missing Link 2009 (lots)	Daintree power grp 2016	ERGON Report EOI's (2013) (customers)	Ener-G 2017	Assumed no of Properties for energy calculations in this report
Cape Tribulation	97	69		42	95 lots/65 residences	Pessimistic: 65 Optimistic: 95
Thornton Beach/ Noah Ck		23			25 lots/17 residences	Pessimistic: 17 Optimistic: 25
Diwan	178			45	188 lots /111 residences	Pessimistic: 111 Optimistic: 188
Cow Bay	139	317		89	375 lots /184 residences	Pessimistic: 184 Optimistic: 375
Cape Kimberley				18	82 lots /31 residences	NA
Forest Ck	206	178		43	166 lots /94 residences	NA
TOTAL	**620**	**587**	**800**	**237**	**930 lots / 502 residences**	

Ergon Energy's electricity network just crosses the Daintree river and connects to a few properties at the back end of Forest Creek.

The Ergon network from Wonga Beach is approximately 13 km away from the river and is on a spur. The existing assets are light hardwood pole structures with air break switches along the backbone. As the line length would need to be significantly increased to even cater for just Forest Creek and Cape Kimberley, security and reliability for both the existing and new section would need automated switches such as sectionlizers and/or auto-reclosers, neither of which would probably be able to be installed on existing pole structures while staying within the planning limits of Ergon (detailed engineering per pole analysis would be required to confirm). Auto-reclosers would not improve reliability for Daintree residents but would protect the Ergon network upstream of the Daintree. Below is a typical pole in the lower Daintree along the Mossman Daintree Rd (courtesy of Google Maps street view)

Fig 1.4 Typical Three Phase Ergon Hardwood Pole Structure Supplying Lower Daintree (with small conductor)

There is likely to be a requirement for significant reinforcement of assets, including overhead conductor, thus triggering new cross-arms and new pole structures for the expected load from just Forest Hill and Cape Kimberley.

Due to the line length it is expected that volt drop would be a problem, thus needing voltage regulators (probably open Delta systems most likely located at Forest Creek). A proper loadflow and fault analysis with Ergon would be needed. Ergon has previously stated reinforcement works could cost multiple million dollars if a new feeder is required due to additional load.

Further, the high impedance line would mean that residents of Forest Creek who connected to an Ergon main grid would likely be significantly restricted as to how much solar pv they can install.

Sunverge specifically agreed during the process that it would not investigate an option to connect to the Ergon main grid for this specific report. This would require detailed work with Ergon reinforcement and reliability planners than was not considered or included in the scope.

Our approach

As part of our study, Sunverge proposed to undertake the following actions:

- investigate how the physical energy will be supplied to the various communities within the Daintree area (including possible MV/LV reticulation);
- analyse and develop tariff structure options to support deployment and funding of improved infrastructure and achieve efficient and reliable community power supply;
- analyse and compare finance structure options to enable a community based scheme which rewards efficient behaviours and improved infrastructure;
- conduct engineering analysis of current state microgrid technologies for improved efficiency, local generation and self-consumption and reliability within the microgrids;
- provide analytical review and modelling of required programming to optimise losses and self consumption across the microgrid, including reporting on how distributed assets will act as one group to minimise total energy usage/losses of diesel/gas, while providing incentives for efficient behaviours;
- model the interaction between multiple units within the microgrid/s; and
- develop indicative costing (through market sounding) at concept level for a range of solutions applicable to the Daintree area for cost benefit comparison purposes
- conduct preliminary engagement meeting with each of the key stakeholders;
- conduct research to reveal more information, including information such as type of existing water heating and other electrical and thermal loads; and
- conduct a high level assessment of energy efficiency options, including survey of existing stock and cost/benefit of replacement for stock like hot water, lighting, etc.

In addition to these items, and given the data challenges surrounding the Daintree area, we decided to reconcile with existing reports especially engineering reports such as those done by Ergon Energy and the general planning methodology such as ADMD with any significant differences needing to be explained.

As part of the process, Sunverge met with key stakeholders from Queensland Department of Energy and Water Supply (DEWS), the Daintree Power Committee (DPC), members of the community, Jabalbina Aboriginal Corporation, Wet Tropics Management Authority and Douglas Shire Council.

Review of studies undertaken to date

The following studies were reviewed as part of this process.

- Cost Estimates for Daintree Supply Option A (Dec 2013) Ergon Energy
- Cost Estimates for Daintree Supply Option B (Dec 2013) Ergon Energy
- Proposed Daintree Powerline Environmental Impact Assessment Study (Oct 1998) GHD
- Isolated Communities Power Options Study 2017 V2.0.pdf (2017) Ener-G
- Daintree Futures Study (Nov 2000) Rainforest CRC

- Environmental Protection (Water) Policy 2009
- Daintree and Mossman Rivers Basins Environmental Values and Water Quality Objectives Basins Nos. 108 and 109 and adjacent coastal waters (2009) Queensland Government
- Ergon's Developers Handbook Develop, Design and Construct Work version 8 Ergon Energy
- Daintree/Cape Tribulation Electricity Survey (March 2016) Compass Research

It is noted that whilst many of these studies provide valuable insight into the supply challenges for the Daintree community, none has to date performed a system energy forecast based on actual metered data and load profiles to support the development of credible supply options for the Daintree community. For example, Ergon Energy's 2013 report explicitly stated that it was using the information it had at hand such as 4kVA and 20kVA for ADMD and its 'pricebook', to give the most detailed physical engineering study to date in the Daintree.

As such, Sunverge proposed to undertake sample metering data and build system load profiles and potential distributed PV profiles to improve the options analysis for both the spatial and temporal differences throughout the network. This dataset then allowed for a more detailed approach rather than using the standard ADMD for different classes (Residential, Commercial and Industrial) that is typically implemented and often more than adequate for standard new developments. The spatial approach, whilst more complex, was deemed more appropriate for the Daintree due to its clustering of high load accommodation lots compared to the typical Ergon network (explained in further detail later on and contrasted to what was known back in 2013).

The spatial characteristics provided more detail into size of reticulation by determining locations of load centres and potential generation locations, estimated locations of transformers. This analysis informed the type of network which was to be designed (ie more typical European with large LV feeders off large transformers or a more American/OHL network with many smaller transformers and smaller transformers) when both thermal (load) and voltage considerations are taken into account.

Temporal characteristics provided both the ADMD for the different classes (useful for reconciliation purposes), total energy throughput, system stability issues, low load durations and determining the requirements for long and short energy storage (dependent on the amount of PV generated).

Establish existing load data

Sunverge undertook a process of data gathering and calculations to establish the load profiles and energy usage intervals of the various customer segments that make up the power consumption in the Daintree.

The methodology and calculations are listed below in Attachment C, however the next section of the report details the approach including the installation of metering equipment on a sample of sites to improve the accuracy of energy load planning.

Metering on friendly sites

The following five sites had metrology equipment installed for a period to assist in the study. These sites were a mixture of load types but included important high load sites with a significant known diesel burn, thus including sites which have material impact on this investigation with respect to required reticulation and generation size.

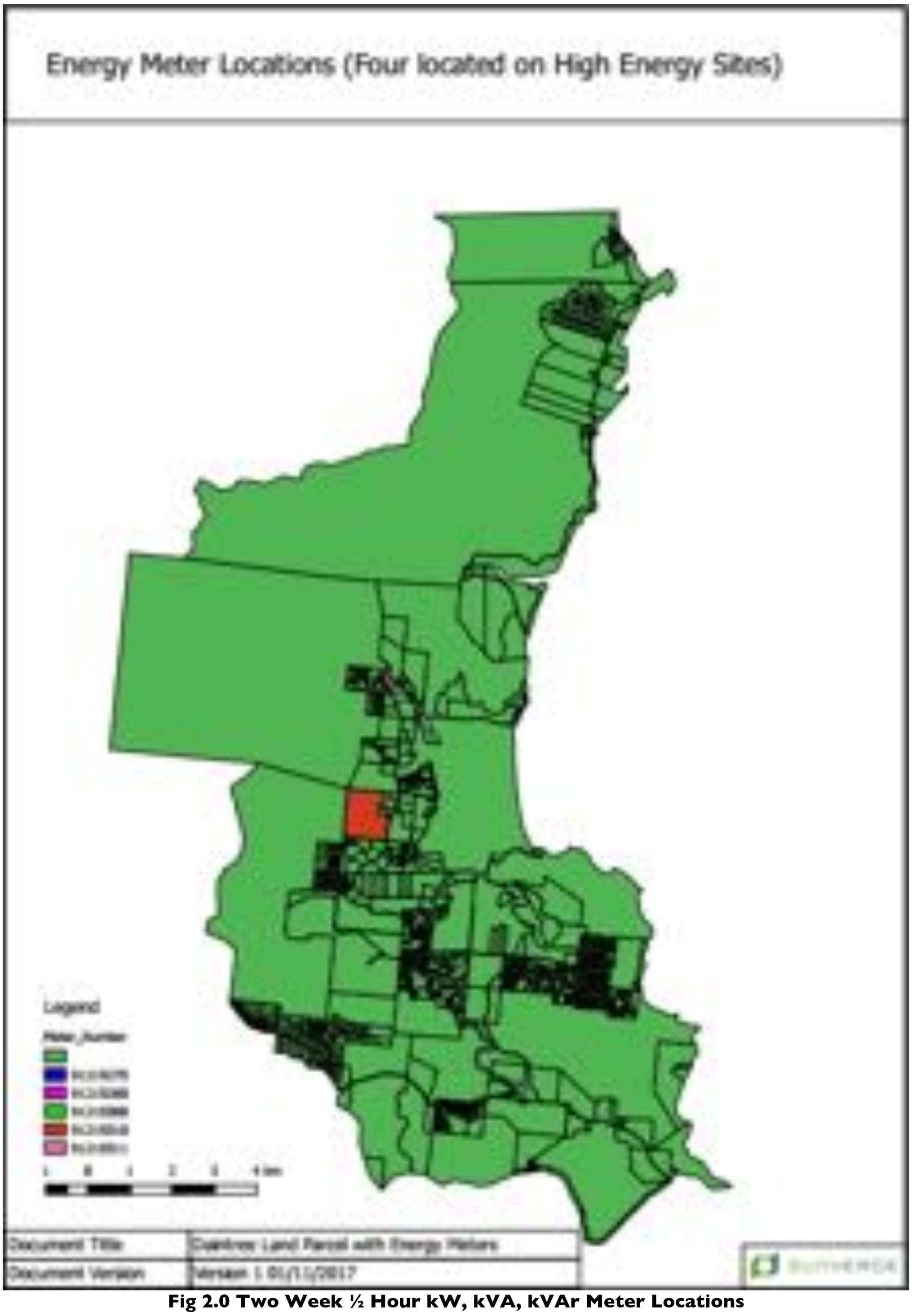


Fig 2.0 Two Week ½ Hour kW, kVA, kVAr Meter Locations

Develop load profiles

Establishing accurate load profiles in the Daintree is critically important as the load assumptions underpin the fundamental design of any supply solution. Such considerations include volt raise/drop, thermal capacity, number of transformers, generators and switchgear, size of cables, storage and spinning reserve/very fast demand response (load or generation) etc. The potential for variance is high. It is noted that a previous study found the total system peak to be 1.38MW, which was significantly less than the 3.4MW peak based on actual data calculated through Sunverge's system modelling. Whilst the 1.38MW figure was based off the best available information they had at the time. it should be noted the same study stated potentially $16M more would be needed over and above the estimated cost of $40M to build this network.
Given the high potential cost variability, Sunverge considered it important to derive an accurate picture of these characteristics with the information available to head off unforeseen expenses such as what may have occurred using the previous dataset.

Sunverge created a spatial roof top area model which was used against known consumption (yearly diesel consumed litres) and LPG/heating (some of which was qualitative data from interviews). This then allowed an apportioning by roof area and load class. This was especially useful for the residential customers as previous yearly consumption data was lacking and needed to be created. For residential customers which had the least amount of data but the greatest number of potential connections the ADMD was very similar to what Ergon Energy use for their planning developments providing confidence in the methodology used.

Load profile creation not only determines how much energy is being consumed in the Daintree but it also determines network utilization in the area. It defines the diverse power and energy requirements across different regions and thus the required network topography needed to leverage that diversity.

Load profiles are especially important for power calculations, After Diversity Maximum Demand (ADMD) calculations, network sizing (thermal and voltage) and PV self consumption and storage required when adding PV for example to offset thermal generation.

In addition such profiles are needed in maximizing the efficiency of the thermal plant and thus how many and what type of generation is needed (number of machines, size and fuel type for example) for reliable power supply.

Until recently there was very little available accurate energy data with respect to detailed consumption let alone actual load profile as there is no energy metering in the area. Many studies conducted to date have relied at best on surveys and at worst on speculative and subjective data sources.

Ergon does not typically provide 8760 (hourly annual) data profile, so Sunverge relied on its own internal metered data set as well as the profiles gathered in the metering exercise.

For new developments Ergon provides ADMD calculations for different classes Residential and Commercial below and above Mackay. This is standard system planning practice around the world. Utilities seldom provide non diversified full year profile data as most don't have a significant dataset.

Sunverge collected as much data as it could with the assistance of the Daintree Power Committee, DEWS, publicly available information, site visits and discussions with locals.

The data that was collected was then combined with geospatial analysis and subsequent metrology data to allow a consumption chart per land parcel to be created.

The land parcel consumption was then joined by type (Residential, Commercial or Industrial) and size to over twenty different profiles drawn from Sunverge's existing database of actual multi-year loads in Far North Queensland and reconciled to those that were measured at certain sites.

These profiles were then scaled to ensure the energy component remained the same and thus provided a profile for each land parcel with a permanent building on it. This process then allowed a spatial join to be performed to allow for analysis of the load and power distribution and thus the benefits of leveraging the diversity between the various regions (Forrest Creek, Cape Kimberly, Diwan, Cow Bay and Cape Tribulation).

Verification and metrology

Owing to time constraints due to access to Ergon metering equipment, Sunverge was able to gather approximately 2 weeks of shoulder season half-hour interval data including watts and vars.

Physical site data-loggers were placed at five different locations, including the atypical load site (being Daintree Tea Farm - Industrial load with significant motor loads). Three typical commercial accommodation sites were included in the metering exercise with one site being a very large user in Cape Tribulation a top 5 load consuming over 110k litres of diesel annually. Finally, a typical residential dwelling for the Daintree with two people residing at the premise was also included as verification for the data set Sunverge already had for Far North Queensland and the spatial modelling apportioning used (load apportioning via Residential roof area).

As a percentage of total load, we expect these sites to be around 5% of total consumption. However given similarities especially around accommodation type and appliance stock it is believed to be reflective of pre-existing profiles seen in other regions which are hot and humid.

In addition to the metering exercise, some sites also logged their Diesel consumption during this period. This data was useful as a validation to the assumptions used which were based on verbal statement during site visits and typical machine efficiencies for their type. The diesel efficiencies chosen for modelling were 0.32 (Commercial) and 0.28 (Residential) which collated well with the consumption and metered results seen onsite during the two week period.

As expected the operators of the diesel generators in the Daintree are currently performing optimization by manually ensuring the machines are running only when needed and sufficiently loaded.

Residential operators would turn their systems off during low use periods and ran on batteries (i.e. at night), while commercial operates had multiple machines which they turned on and off depending on the load onsite.

Profile verification was also performed. In the case of the Daintree tea site the profile was fully generated off the metered data as this was a very unique load usage both in the Daintree and elsewhere (large rotating plant being turned on and off).

The residential load profile was compared to what would have been chosen for that site via the Daintree spatial load apportioning model. The hot water in particular can be seen with morning and smaller evening spikes. This aligns to typical bathing behaviours and supports the proposal to switch the LPG hot water systems onto electricity to improve network stability and utilization and allow for some controllable load to occur.

Additionally the residential Daintree metered load actually had a slightly better solar PV utilisation factor compared to the Sunverge model for the same location and time due to its slightly higher midday load, therefore improving the expected system performance compared to that which was originally modelled (seen below).

The chart below represents the metered Daintree residential load averaged into a day compared to the Sunverge existing residential data set using multi-year Far North Queensland data within Sunverge's load profile data base and adjusting for roof size (square meters for a residential home).

For the metered Daintree residential load, the profile has been averaged out across a day from the available data. The modelled data set used real customer data from Far North Queensland and the same month as the metered data for the Daintree Residential load.

For this chart, the data represents data gathered during early November.

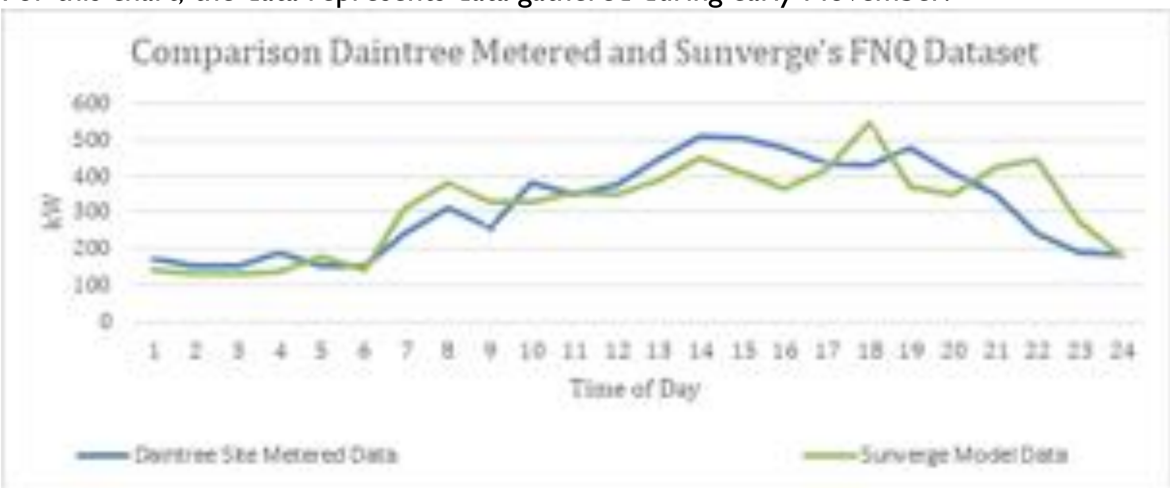
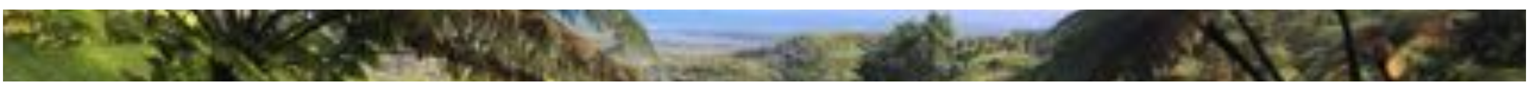


Fig 2.1 Comparison between Actual Measured Load and Daintree Load Model for Early November (Res)



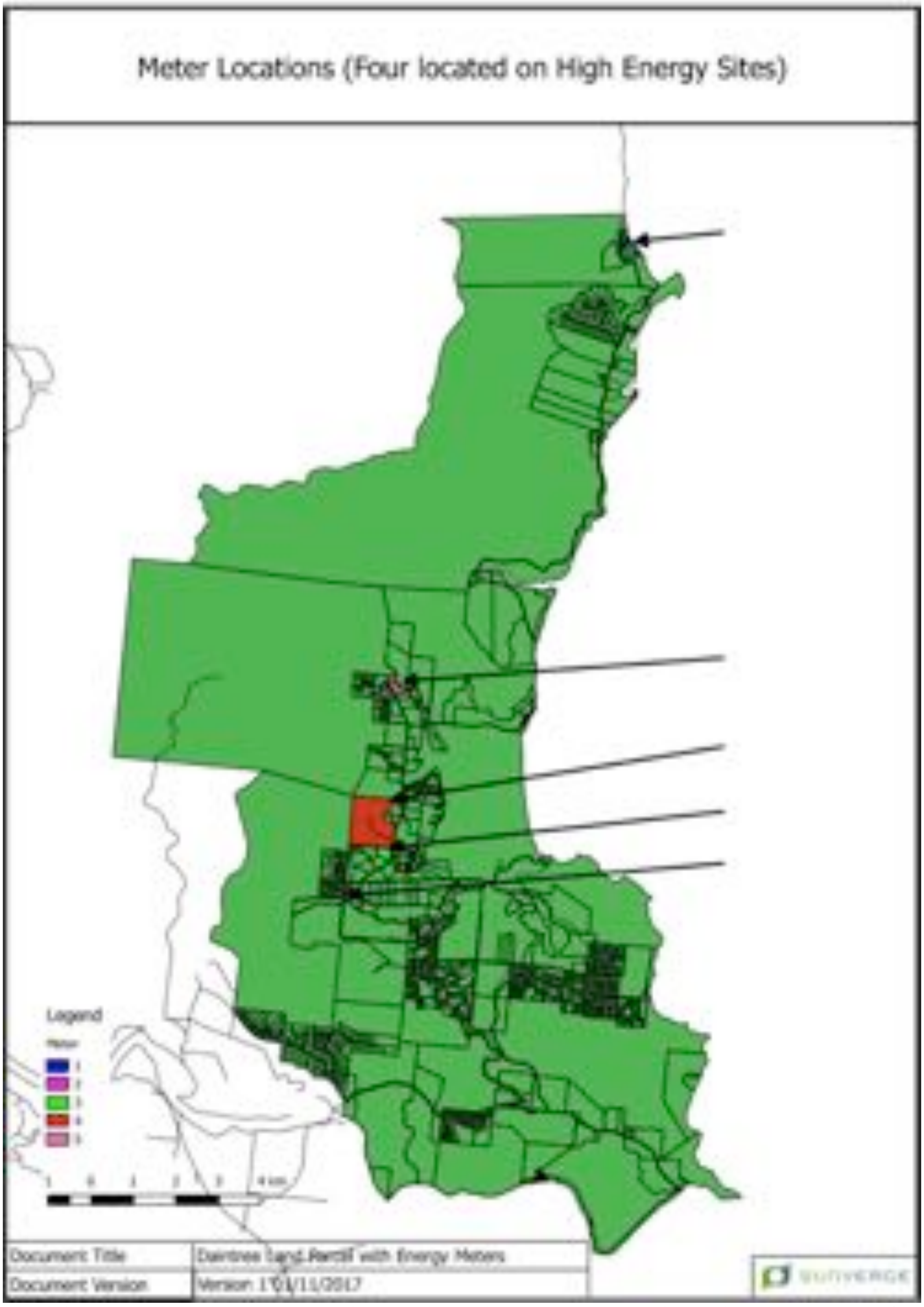


Fig 2.2 Properties with Meters 1. Cape Tribulation Beach House 2. Heritage Lodge and Spa 3. Lync-Haven 4. Daintree Tea Farm and 5. Residential Property

Profile Generation

All land parcels with a consumption figure were assigned an 8,760 scaled profile (hourly profile over one whole year). This profile was generated by firstly defining if the land parcel has been grouped into a business (commercial or industrial) or Residential.

In line with how the consumption data was generated many businesses actually ran over multiple individual land parcels, thus all the individual land parcels belonging to an individual business needed to be collected. Additionally, any known consumption for a business needed to be assigned directly to this group, for example one of the larger business with a known diesel consumption below at Cape Tribulation where multiple land parcels belong to the same business

Fig 2.3 Above highlights the roof centroids for this particular business over multiple Land Parcels

Once every land parcel had been assigned its specific profile, these were spatially joined to the network in question. In addition Monte Carlo analysis was performed in determining the expected ADMD per distribution node.

This analysis is useful for both a reconciliation check with Ergon Energy and in determining the structure of the microgrid, i.e. a larger more centralized MV/LV transformer and LV network (European style) or a more distributed smaller MV/LV and LV network system (North American network style).

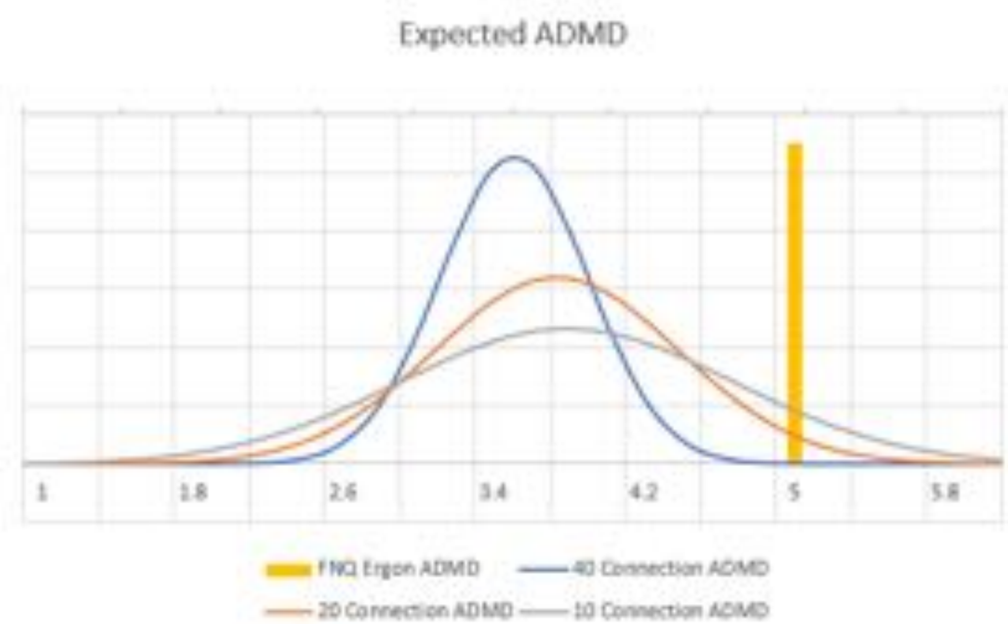


Fig 2.4 After Diversity Maximum Demand Distributions for Different LV Connection Counts (MV/LV Dst Planning)

Expected ADMD in Daintree

As can be seen the ADMD calculations fall within the Ergon Energy report expectation for the areas below Mackay (4kVA). In part this is because the Daintree has an older, smaller occupancy than FNQ and so a slightly lower expected consumption level even when connected to the microgrid compared to FNQ.

For FNQ, Ergon Energy state 5kVA for the ADMD in their developers handbook (https://www.ergon.com.au/__data/assets/pdf_file/0004/6736/PW000101R104-Developers-Handbook.pdf) for sites north of Mackay.

It is suggested for the Daintree microgrid to increase both diversity and thus lower the ADMD and therefore amount of installed equipment (kVA based).

Sunverge is proposing to follow a more European style of network configuration. Additional benefits with such a model in the Daintree are higher fault current levels (typically transformers are around 80% of system impedance ignoring generators) and lower maintenance as cables have both a longer life and less proactive maintenance requirements compared to above ground structures (ie increased transformers).

It was also observed that the Daintree is very diverse with respect to energy consumption even among Residential loads. Direct discussions and previous studies support this conclusion. Whilst this energy diversity on the surface is a challenge for operators, larger LV networks to some degree mitigate against this as they incorporate more connections as seen in the ADMD distribution curve below.

The below graph is a histogram of the Residential Customers (with the Y axis representing the number of potential customers in each consumption group and the X axis representing the annual consumption group)

This data like all the load profile data was generated by Sunverge as there was no existing data for the Daintree. The data was reconciled with the typical non load profile ADMD and consumption data published by Ergon for reticulation planning development.

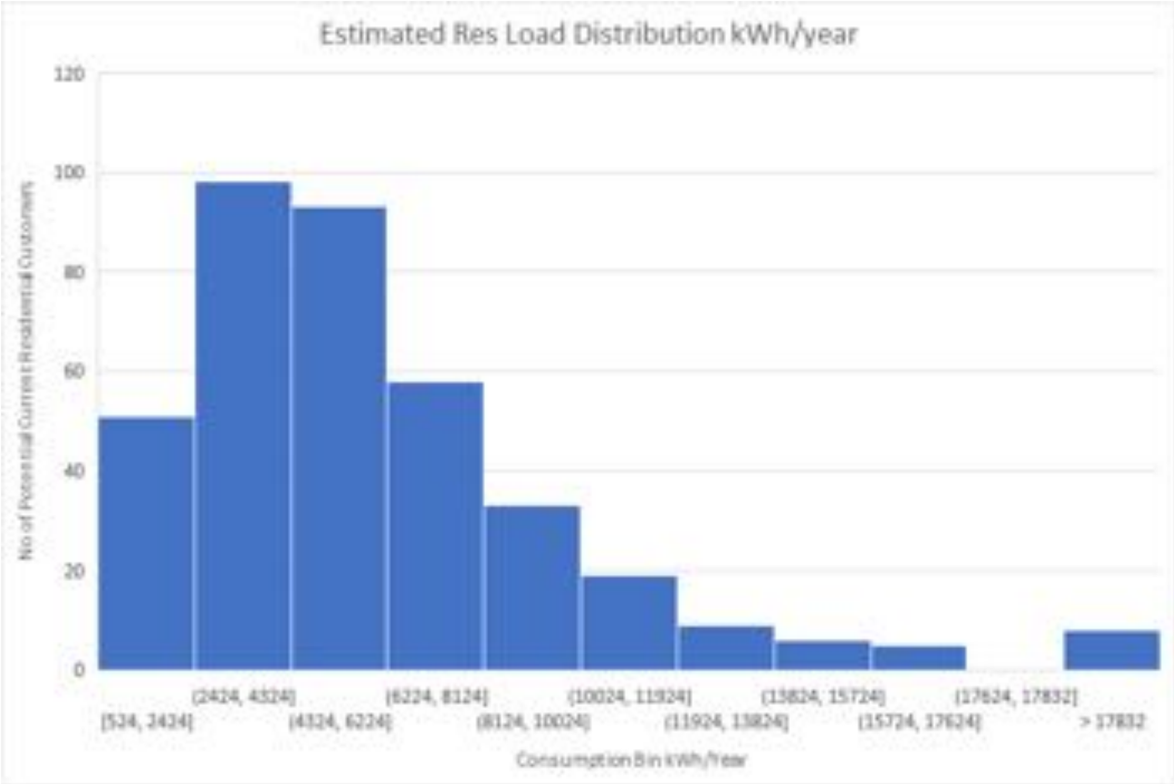


Fig 2.5 Expected Residential Load Consumption Distribution in the Daintree using Daintree Load Model

The analysis reveals that total system load peaks around late February, which is driven by FNQ profile habits of air conditioning. There is however some mitigation in that as this is also the tail end of the wet season in the Daintree, and as such the motels in the region are not at full occupancy.

Some artificial additional weighting could be added however this peak is conservative for system modelling as additional weighting is qualitative and will make it easier for self consumption of PV for the suggested PV farms.

It was thus determined to leave the dataset as it is as it comes from Sunverge's quantitative dataset for Far North Queensland and provides more of a worst case scenario with respect to Synchronous machine size requirements and fuel demands (ie less solar self-consumption or higher losses with storage systems).

This data principle comes from Sunverge's multi-year multi-second load dataset for the Northern Australasian region.

Ergon does not typically provide 8760 (hourly annual) data profile, so Sunverge relied on its own internal metered data set as well as the profiles gathered in the metering exercise.

For new developments Ergon provides ADMD calculations for different classes Residential and Commercial below and above Mackay. This is standard system planning practice around the world. Utilities seldom provide non diversified full year profile data as most don't have a significant dataset.

This chart is of the entire Daintree Commercial, Industrial and Residential demand as derived by Sunverge.

All loads are added together on an hourly basis. Known consumptions were assigned directly. If a commercial load wasn't known then via a curve fit using the roof area to assign an estimated consumption. Closest match profiles (via consumptions and class) where then assigned and scaled appropriately

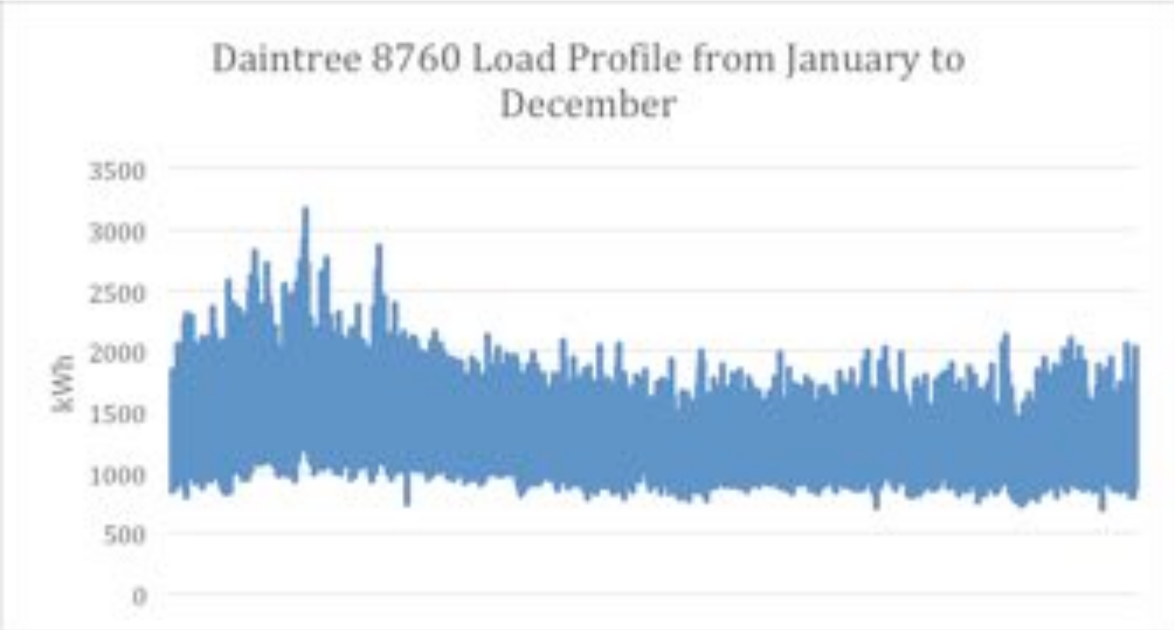


Fig 2.6 Estimated Yearly Load Profile for the Daintree using Daintree Load Model

Common system planning practice for new developments (what the Daintree will become if a grid system is constructed) is to model systems based on demand and energy assumptions made from best available data sources. This is because metered data isn't available for new developments at the time of planning a new power system. In the absence of metered data it is important to test that modelled data reconciles with observations.

In this case a level of comfort is derived from the fact that the modelled data reconciled well with existing Ergon data points and with actual periods of metering performed

It is interesting to observe from the data that there is around 800kW of base load throughout the year and as expected the load has a strong commercial element in it thus allowing for a highly desirable diverse MV system.

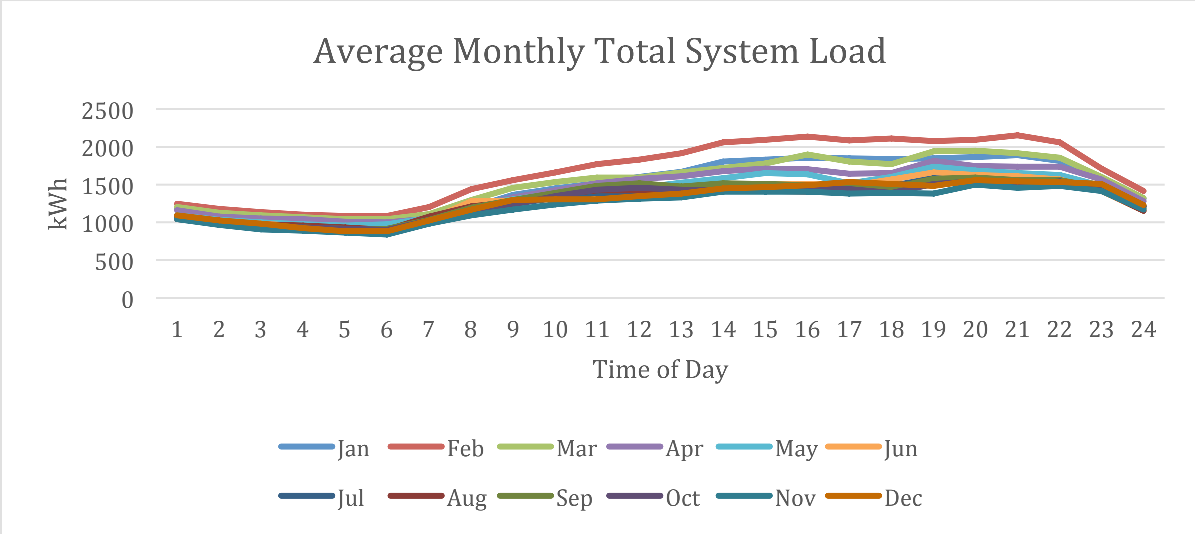


Fig 2.7 Estimated Average Daily Profile for Each Hour for Each Month in the Daintree

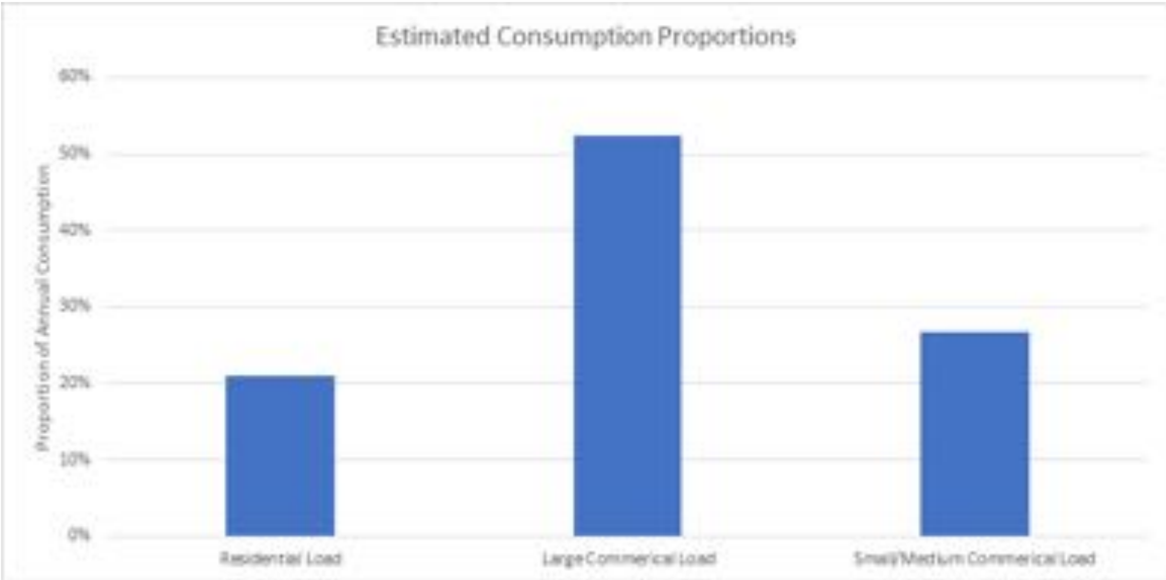
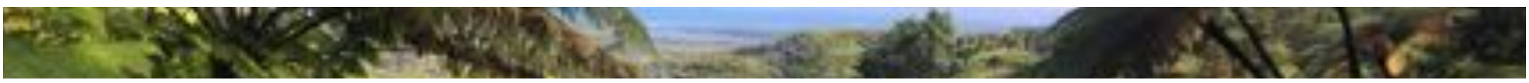


Fig 2.8 Approximate Consumption Breakdown in the Daintree

The approximated breakdown considers large commercial loads which are greater than 100,000kWh/year these are predominately the larger resorts and a few shops such as PK's at Cape Tribulation. The smaller commercial loads are mostly B&B's with a few others. It is expected that the proportion of Residential and SME will increase in the coming years if a microgrid is created due to freehold title blocks, however it is still expected that Large Commercial (Resorts) will continue to make up over 40% of all consumption within the Daintree Rainforest.



Spatially the Peak power demands are as expected located where there is a large commercial load centre as seen below.

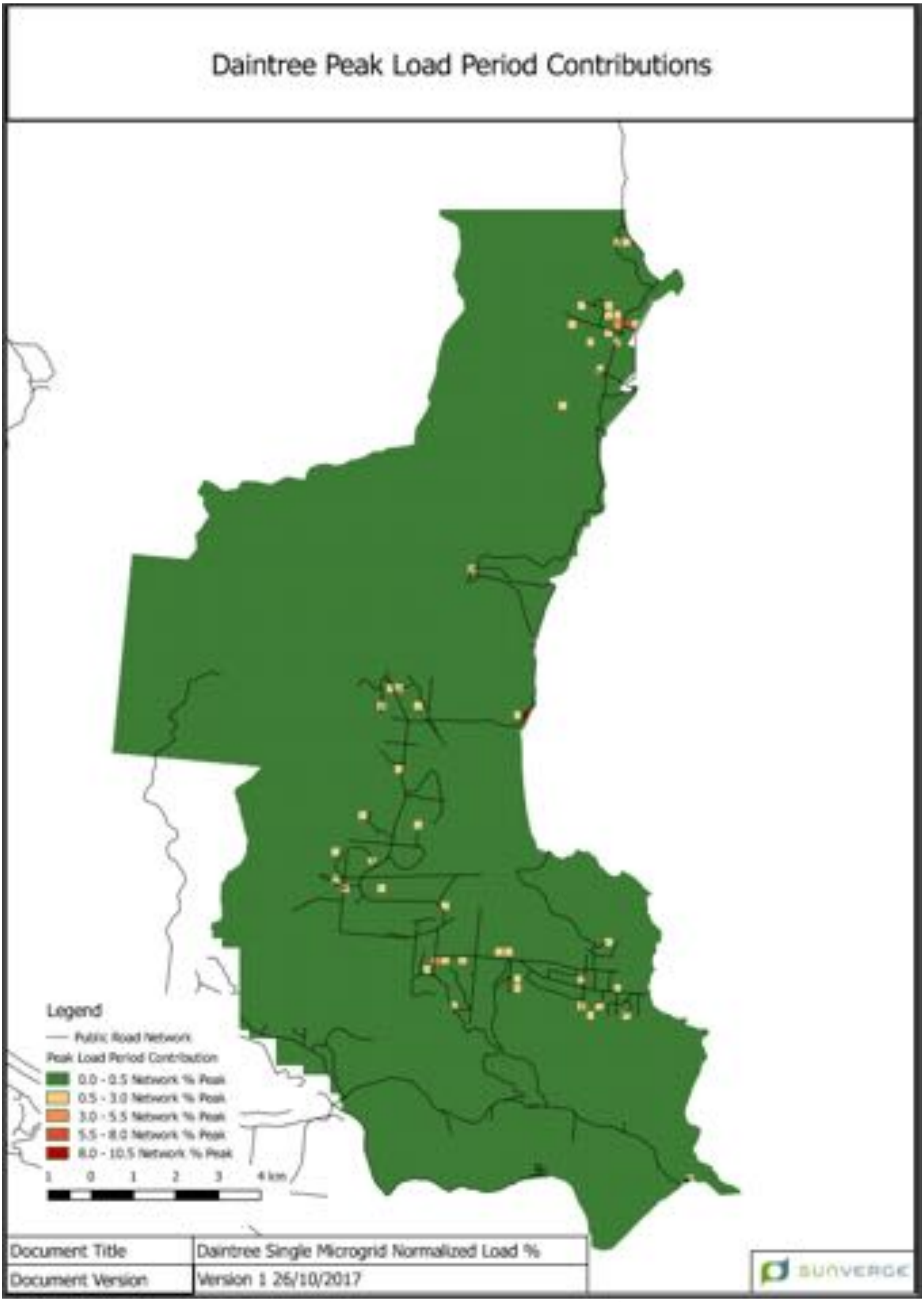


Fig 2.9 Peak Power Demands in the Daintree Especially Cape Tribulation (Microgrids need to consider Edge of Grid Demands such as above)

Develop scenarios

From the above analysis, Sunverge was able to develop a range of scenarios for options to meet energy supply requirements within an isolated community.

Given the timeframe constraints on the study, five scenarios were developed through consultation with the core stakeholder group during the regular stakeholder meetings, including a mix of generation and network options from connected microgrids to distributed standalone systems. It was expected that these scenarios would be used to provide directional guidance on where next efforts should be spent in the development of any future power solutions.

The five scenarios determined for the purpose of this study were:

1. Single microgrid
2. 3 separate microgrids
3. Numerous small microgrids linked by gas pipelines
4. Extend [3] separate microgrids from existing generation assets at Cape Tribulation
5. Individual Remote Area Power Systems

The scenarios are detailed below with reference to their respective planning schemas, physical features, renewable potential and costs and benefits.

It should be noted that the estimates of grid connection were excluded from the scope of this study. Previous studies have suggested that the Ergon grid, which serves a very small number of properties at Forest Creek, may be able to be extended to serve the remainder of the Forest Creek Community of approximately 126 properties.

Sunverge has not undertaken analysis of this option, however based on visual inspections of the existing network assets which extend from the nearest township, Sunverge considers that extensive work would need to be undertaken to upgrade the capacity of the existing network including power lines, poles, cross arms, transformers, switchgear and reclosers.

To consider this potential option it should be noted that significant analysis work including the Ergon network planning team needs to be undertaken.

Assess available market technology and market sounding

To assess current state technologies, Sunverge approached a number of relevant businesses for information about technical product solutions and their potential applicability to isolated tropical environments.

These included generation manufacturers, microgrid developers, equipment suppliers, fuel (gas and diesel) suppliers, directional drilling operators and renewable energy technology providers. We also approached a number of battery suppliers and new technology providers for control systems, communications and demand management devices.

In accordance with non disclosure agreements, much of the information provided can only be disseminated in a way which does not disclose the identity of the vendor and as such will only be revealed at a high level for the purposes of this study unless specifically requested and approved by the vendor.

Prepare indicative costings

Sunverge prepared indicative costings for the 5 supply options listed.

As per our recommendation it should be noted that an in-depth pre-construction assessment would be needed in order to proceed to the development of any of the supply options. These indicative costings were developed on the basis of available information and discussions with vendors and should not be relied upon for project commencement until an in-depth study of costs and required approvals for the preferred supply option is undertaken.

The indicative costing for each Supply Option is listed below in terms of capital and operating expense assumptions for each option.

Assessment methodology for Supply Options

Once the Supply Options were defined and costed based on feedback from the market sounding, Sunverge assessed their relative merits using a simple scoring approach where each Supply Option was assigned a score between 1 and 5 for each Success Criteria based on its relative performance against the other Supply Options. Scores were then tallied up and the ranking of Supply Options determined with the highest value being the preferred option.

The assessment methodology is outlined in the table below:

Success Criteria	Highest Score (5)	Lowest Score (1)
Equity	• Ability to provide equitable access to affordable energy for all community members	• Low percentage of equitable access to affordable energy
Reliability	• Higher SAIDI and SAIFI reliability due to diversification and modular generators	• Lower reliability due to single point failure or no N-1 on generation
Environment and sustainability	• Likely to have low disturbance to fauna through existing easements and roads • Likely to have high renewable penetration	• High initial and ongoing transport and diesel fuel dependency, leakage risk, soil contamination, etc
Economics	• Lower combined cost of capex, replacements and operating and maintenance over system life across the entire customer base	• Higher combined cost of capex and ongoing operations (e.g. fuel) across the entire customer base

Modularity and Future Proofing

Given the inherent risk and uncertainty associated with choosing options to build a power supply system, Sunverge has recommended the design of a network which will be able to cater for a range of Generation supply options should these vary from the recommended generation solution proposed.

For the purposes of future proofing the system, and enabling different generation types a specific network configuration is proposed below.

As with most new power system networks everywhere civil works are the single most expensive and restrictive component within the electrical power system network.

It is proposed that the Daintree systems use standard sized European (Urban/Suburban Australian/New Zealand) construction technique typical for 7-9MVA feeders. This uprating of the MV network allows for flexibility in land procurement for hosting the primary generator sites and any future solar farm sites without issues of both voltage drop and thermal rating problems. This flexibility also provides significant load and distributed generation headroom on the expensive, fixed MV network with only a very small additional cost of a slightly larger cable.

With this is mind a small incremental cost of using both ducts to protect cable assets is recommended and follows best practise within Australia. While the duct will slightly derate the thermal capacity of the cable, the water soaked soil compensates and the duct with draw wire both protects the cable extending life while the draw wire allows for quick replacement if cable can't be repaired thus saving costs and disruption issues for a future replacement job. XLPE cables are recommended due to their overload capability (elevated temperature) and for their relatively simplistic MV joints and terminations compared to other cable technologies.

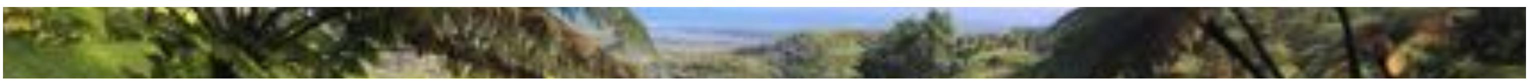
185AL is a standard size allowing for standard boots to be used on distribution TX and switchgear bushings, thus providing cost savings and familiarity for fault crews in Queensland.

Switchgear recommended for size and cost is secondary equipment that is extendable in the future. This allows the addition of more switch bays should the need arise. Equipment such as the ABB SafePlus and Schneider RM6 fulfil this and have sufficient thermal and fault making, breaking and withstand capabilities. This extendibility from either side allows for future generator bays should the need arise.

Since the physical network will be designed for either modularity (Switchgear design) or significant hosting overhead (MV Cables) standard network augmentation can be implemented without significant additional CAPEX costs.

Generation will be arranged in bays with spare room to allow for additional bays should sometime in the distant future additional generators are needed.

Energy storage is also proposed to be modular in that they are also stored in bays, which also allow to future extending depending on the amount of PV connected to the microgrid.



Sunverge has extensive experience with distributed generation systems especially Battery Energy Storage Systems. This experience has shown us that in remote locations in particular systems need to be fault tolerant and robust to ensure operational costs do not spiral. Sunverge considers that appropriate system design should ensure that if a fault does occur (both the battery module or Inverter) this fault only disconnects that piece of equipment or in the worst case a small sub group. This approach allows for the system to ride through a fault which may or may not clear itself with only minimum loss in performance.   In addition for faults which need repair modular systems which are within 1 or 2 man lifts and that are virtually plug and play are desirable as callout costs and strategic spare are prohibitive for large and complicated equipment.

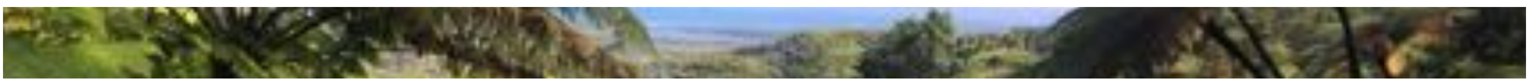
Both the Power to Gas (ITM) and the Battery/PCS (Poweroad and Sinexcel) come in modular blocks allowing for future extension. In the case of the Battery/PCS these are also both in standard 19inch 3U rack size where the modules allow for easy extension but also improved low power efficiency by temporary turning off modules not needed. This modular approach allows for significantly easier future proofing as the units themselves are almost plug and play coupled with the proposal to use extendable MV switchgear and a oversized MV cable backbone significant growth can be accommodated and it would be proposed that a similar approach be implemented where the developer pays a contribution cost as is typical for NEM connected grids in Australia.

Supply Options

The following table provides a summary of the key considerations, issues, costs and benefits of the assessed options.

Each schema is set out individually in more detail below.

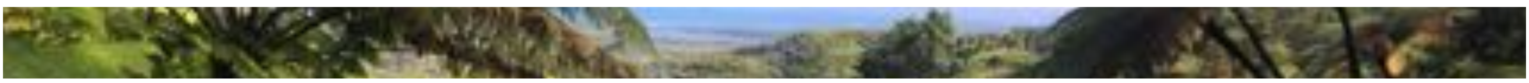
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Name	Single microgrid	3 separate microgrids	Numerous small microgrids linked by gas pipelines	Extend microgrids from existing generation assets	Remote AREA Power Supply (RAPS)
Description	Single electrical microgrid with powered by gas and centralized solar	Three electrical microgrids built around load centres	Three or more electrical microgrids linked by gas pipeline	Existing diesel generators leveraged to power adjacent existing large customers	Subsidised upgrade to individual RAPS scheme
Key components	• 120km reticulated underground cable (LV and MV) • Connecting all homes to an isolated microgrid • HW Load control • 3.4MW Synchronous Generator • Stage 2 0.5MW 0.5MWh Battery (Peaker Storage) 2MW Solar Farm • Stage Expansion of solar farm • 4.7MW S2G2E Facility (Ultra high efficient Power to Gas to Power fuel cell)	• 95km reticulated UG cable (LV/MV) • Smaller gen sets supplying each node (may require larger gensets to deal with LDC lack of diversity) - estimate 5MW gen • Three different generation centres • Supplies most customers	• 80 k UG gas pipeline (PE) • 30km reticulated UG cable (LV) • Smaller gen sets supplying each node (may require larger gensets to deal with LDC lack of diversity) - approx. 5MW gen • Supplies MOST customers	• Utilise existing site infrastructu re • Build small LV network to supply limited customers with existing customer gensets	• Individual sites receive a subsidized more efficient, refreshed hybrid system (solar, diesel/gas generation, battery storage)



Pros	• Network allows greater solar self-consumption • Higher reliability • Lower O&M and risk • Pathway to 80-100% renewables, lowering fuel costs • Future revenue upside for growth of vacant freehold lots	• Lower cost capex network • Able to be handled in small staged blocks	• Allows for fast connection solution • Could provide a 100% renewable solution (through use of biogas/hydrogen)	• Requires no subsidy • Low capex solution - using existing generation	• No central infrastructure required • Lower scheme regulation costs
Cons	• Land acquisition may be challenging • Requires comms	• Lower renewable uptake potential due to diversity • Poorer load utilisation due to load centre mismatch • Higher cost capex Gensets • Higher cost O&M for distributed gen • Governance challenges and networks	• High O&M and replacement on Gensets • Large generation losses due to inability to capture heat • Manufacturers unable to supply the right product for the territory	• Inequitable - supplies 20% of customers by numbers • Requires large site generation access at unknown cost • Not large enough for investor interest • High admin cost potential (metering, etc.)	• Similar solution to existing • High removal costs not currently included • Inequitable due to locational solar irradiance potential diversity • Low renewable potential

Cost	• $65M Capex
	  • Network 32.3M
	  • Generation 25.1M
	  • Comms 3.6M
	  • Other 3.6M
	• $1.3M Ongoing Opex
		• $60M Capex
		  • Network 27.3M
		  • Generation 23.2M
		  • Comms 3.6M
		  • Other 6.0M
		• $2.8M Ongoing opex
			• $70M Capex
			  • Network 10.5M
			  • Pipeline 11.1M
			  • Generation 39.1M
			  • Comms 3.6M
			  • Other 6.0M
			• $2.5M Ongoing opex
				• $15M Capex
				• $2M Ongoing opex (mostly fuel)
				• NB - serves small % of population
					• $42M capex (frequent refresh)
					• Ongoing opex $2.7-$3.6M

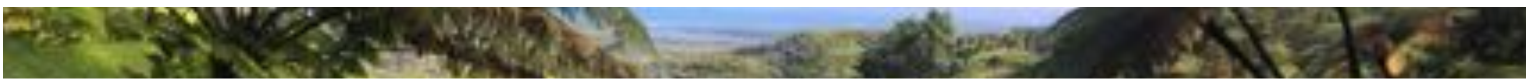
Benefit (avoided fuel costs)	• $4.5 - $6M per annum savings	• $4.5 - $6M per annum savings	• $4.5 - $6M per annum savings	• $1.6M per annum savings	• $1.2M per annum savings
Renewable % potential	• Pathway to 80-100%	• Max likely 40-60%	• >80%, likely 50-60%	• < 10%	• Max likely 30%-40%



Cost Assumptions

As a result of the market sounding exercise the following key cost assumptions were made for each of the asset types used to build up the various supply options:

	Asset class	Metric	Cost range per unit ($,000)
Network assets	Underground cable	Km	150 - 220
	Underground gas pipeline	Km	25 – 150
	Transformer	units	30 - 50
	Switchgear	units	100-140
	Pillar	units	2
	Meter	units	0.5
Generation	Gas gen (large)	MW	1,200
	Gas gen (small)	MW	4,500
	Solar farm	MW	1,000
	S2G2E	MW	1,400
	RAPS	kW	4 – 7
Connection equipment	Step up transformers	units	200
	Ring Main Units	units	300
Other not specified	Land		
	Facilities		
	Gas storage tanks and equip		
	PM and contingency		
	Comms/fibre	km	30



Assessment of Supply Options

Based on the assessment methodology listed above, the following scores and rankings were determined for the Supply Options.

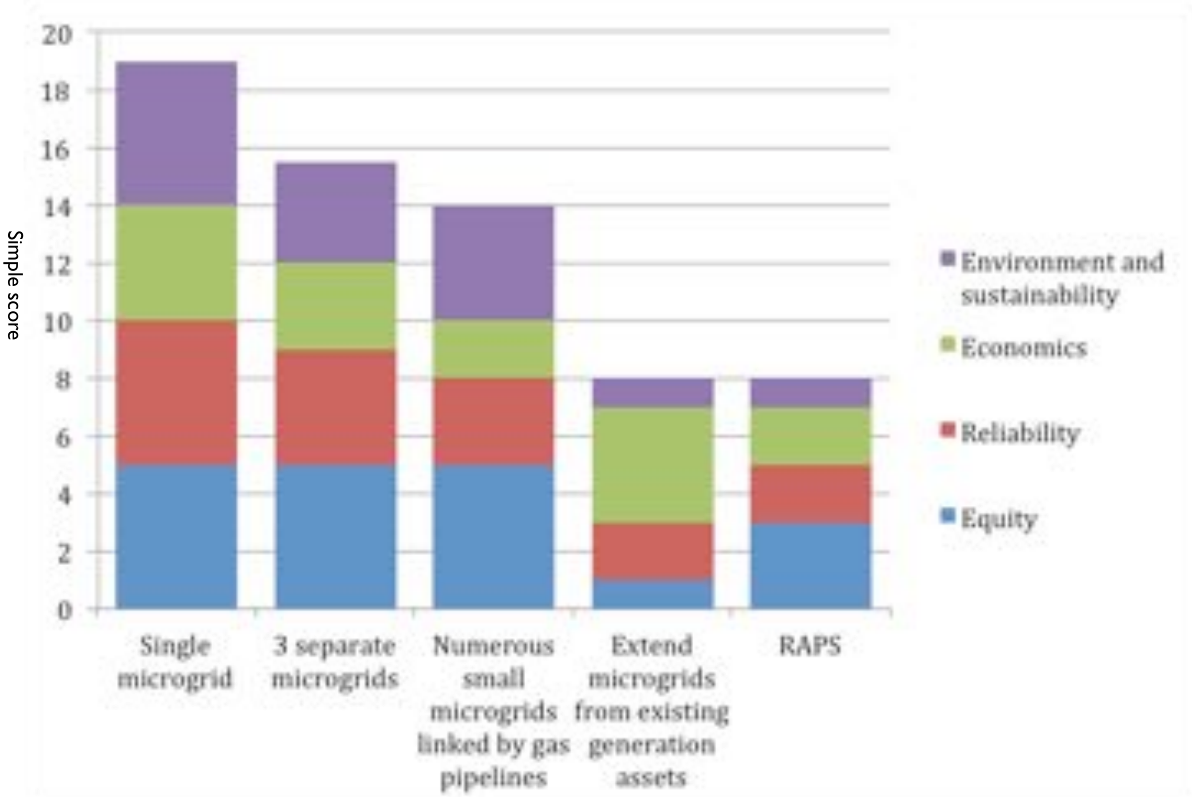


Fig 2.10 Options Assessment Chart

Supply Option/ Success Criteria	Single microgrid	3 separate microgrids	Numerous small microgrids linked by gas pipelines	Extend microgrids from existing generation assets	RAPS
Equity	5	5	5	1	3
Reliability	5	4	3	2	2
Economics	4	3	2	4	2
Environment and sustainability	5	3.5	4	1	1
Total Score	19	15.5	14	8	8

Option 1

Single Daintree Electrical Microgrid with a Staged Pathway for High Renewable uptake (Synchronous Machines co-located at Solar Farms)

This option provides the most system stability to accept both rapid load and distributed generation changes with little to no impact on both the local voltage and system frequency. This is achieved due to the higher fault power and inertia this option provides compared to other options investigated. Inertia in particular is a function of rotating mass, this combined with both a diverse protection schema for PV, synchronous machine governors and fast acting load such as batteries, solar to gas and controllable loads i.e. hot water help mitigate against system collapse due to sudden load/generation events). The presence of a cable network and larger synchronous machines also provide a microgrid with relatively high fault power, which mitigates against voltage fluctuations thus providing a more resilient grid which still remains within typical grid operating requirements for power quality.

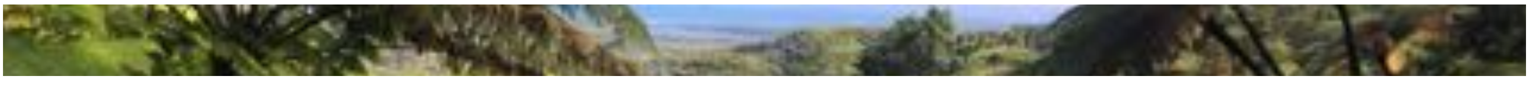
While not costed as a scenario a larger microgrid with larger resources including storage could possibly be helpful in deferring any future upgrades to the existing Mosman to Forest Creek feeder. In 2013 Ergon Energy stated if a new feeder is needed due to load growth this would cost more than $16M.

An investigation with Ergon would be useful in determining if such a microgrid could be beneficial to them and what they may contribute. It is proposed that the MV voltage be 11kV and as such a step-up transformer would be needed (probably an autotransfer for cost and size) as well as MV metering and switchgear.

The Daintree has a significant load centre at the end of the network being Cape Tribulation. This location is problematic to supply as there is little PV potential and the road to Cape Tribulation itself is difficult for heavy trucks. The road contains both step elevation with many switchbacks between Cape Kimberley and Diwan over the range and a narrow road from upper Diwan to Cape Tribulation with very aggressive speed bumps to slow traffic. Because of both tourism and local wildlife like endangered species such as the southern cassowary trucking either gas (LPG, LNG) or liquids (Diesel) isn't optimal in the long term and so transporting energy in the form of electricity is appealing from both a logistics and environmental aspect.

An integrated network also opens up the possibility to access the cleared land in the southern sections of the Daintree especially around Cape Kimberly region which is also outside much of the orographic lift which significantly effects much of the rest of the Daintree thus providing for improved solar potential. These areas are currently being used either for cattle or in the case of the old banana farm small left vegetables and so require zero land clearing including of regrowth forest.

This option also allows for either a staged approach to increase renewables or for that to be scrapped without additional network augmentation should in future years it be decided that the area should have high renewable penetration.



As stated elsewhere the Daintree Rainforest creates some interesting issues especially when large PV penetration is desired, the location having a strong seasonality with the wet and dry creates a situation similar to Northern Europe where during one season PV production is in significant excess and during the other it is in deficit.

This problem creates the need for both peak but also the more problematic baseload storage. Whilst battery systems are very good and efficient for storing excesses which are usually within a single day with excess being stored at midday and then used to support the evening peak load, such systems are not ideal for long term storage. Battery systems become very expensive to store baseload energy over a few days let alone energy surpluses over a few months as expected if large scale PV penetration is built in the Daintree.

Both cost of batteries (MWh) and internal battery cell losses for system which are storing large amounts of energy are problematic. As such, this study has investigated the potential use of a system such as solar to gas plant which, many of which are currently being implemented in Europe. (Note: unlike batteries the main cost in power to gas to power are the fuel cells and compression equipment. Many commercial high pressure systems are based on K-Type cylinders with manufactures often creating self-contained packs of multiple cylinders. As such the physical tanks cost a very small proportion where such packs may store a MWh or more thus providing opportunity to store very large amounts of energy for relatively low costs when compared to batteries storing the equivalent energy. This feature allows for long term inexpensive storage of renewably generated gas to deal with seasonal solar discrepancies).

It is therefore recommended that for this option a staged approach is implemented with the final configuration being a solar to gas fuel cell, the addition of PV will also future proof against large loads such as new tourism centres without the need to augment existing Synchronous machine generation.

Additional benefits is that less generation installation capacity is needed especially for an N-1 system, this is due to the overall generation peak being less for the entire system than added up the peaks of the individual components due to diversity and the fact that each individual system would need N-1 generation (this is a standard practise throughout the industry in Australia when operating microgrids). As such there will be many more machines and thus maintenance required and the initial up front CAPEX also increased due to more machines and larger install kVA install for Synchronous generation assets (also included more protection relays, MV switchgear and step up transformers with such a scenario).

This supply option would involve the development of an isolated microgrid consisting of:

- 120km reticulated underground cable (LV and MV) network
- Connecting all homes within the isolated microgrid, with provision for adequate network supply for future new connections
- Maximising existing hot water load control and encouraging additional new and replacement hot water load control potential
- 3.4MW LNG gas generation (comprised of a number of smaller units and two LNG evaporators, LNG upfront CAPEX costs for systems of this size are more than offset by the fuel costs, additionally the major component in LNG is methane which is already in the Daintree and in the case of leak will float into the air not pool damaging

waterways without bunded systems like liquid fuels) to provide initial efficient, reliable generation whilst renewable penetration is being increased. Compatability with biofuels would be considered advantageous.

- Stage 2 (To be implemented while Cape Tribulation is being reticulated)
- 2MW solar farm
- 0.5MWh/0.5MW (Steady state) Modular Peaker Battery (Battery and PWS)
- Stage 3 (Anytime)
- 8MW solar farm
- 4.7MW solar to gas fuel cell facility
- Optional bio-fuel station to increase the ultimate energy supply for the area to 100% renewable

This is the preferred option as it most closely achieves the objectives of providing equitable, reliable, renewable and sustainable supply to the area.

Potential supply would be provided to all free-hold properties. It would be undergrounded along existing roadways and easements and without interrupting any additional vegetation.

The introduction of a full microgrid with Solar to Gas storage facility would allow for greater energy diversity and thus increased solar uptake to provide the lowest cost LCOE over the project life when compared to other supply options.

Note the main issues with this system from a stability analysis is the sudden loss of the PV Farm when it is at or near full output as this is the period in time which has the greatest rate of change of power. To mitigate against this it is proposed that very fast acting energy storage system be implemented. For example, the Sinexcel/Poweroad BESS has capability of full power output within 50mS while the ITM can respond within 1 second, at such speed coupled with potentially HEMS systems on hot water the rotational inertia or inertia constant for two machines operating and typical governor response rate a drop of 90% within a few seconds is acceptable (an extreme case of a very fast cloud front crossing a PV farm).

Control of sudden power increases is controlled by using standard frequency watt controls within the many inverters, it is proposed that three different settings with different dead bands and slow ramp rates be used (10% per minute), this will allow for the system to be damped without the need of too much external help from energy storage systems, this will then allow much of the work for the energy storage system to mitigate against excess energy production rather than frequency stability caused by the imbalance of load to generation, thus systems can be optimized more fully for energy storage.

It should be noted that while this option is the most feasible for waste heat recovery from the Synchronous machines (exhaust and water jacket, compared to distributed options, economies of scale), even with newer technologies using the Organic Rankine Cycle and inverter based electrical extraction from the turbine at the sub 5MW levels only around 10% of capacity can be expected. At this location after discussions it was determined that a 300kW module could be fitted however equipment costs only made up 40% of the total turn key costs with a full installation being quoted at over 3 million AUD. Additionally with the expectation of more solar being installed on this network the use of the

Synchronous machines is lessened and thus the utilization drops and the subsequent payback for such a unit.

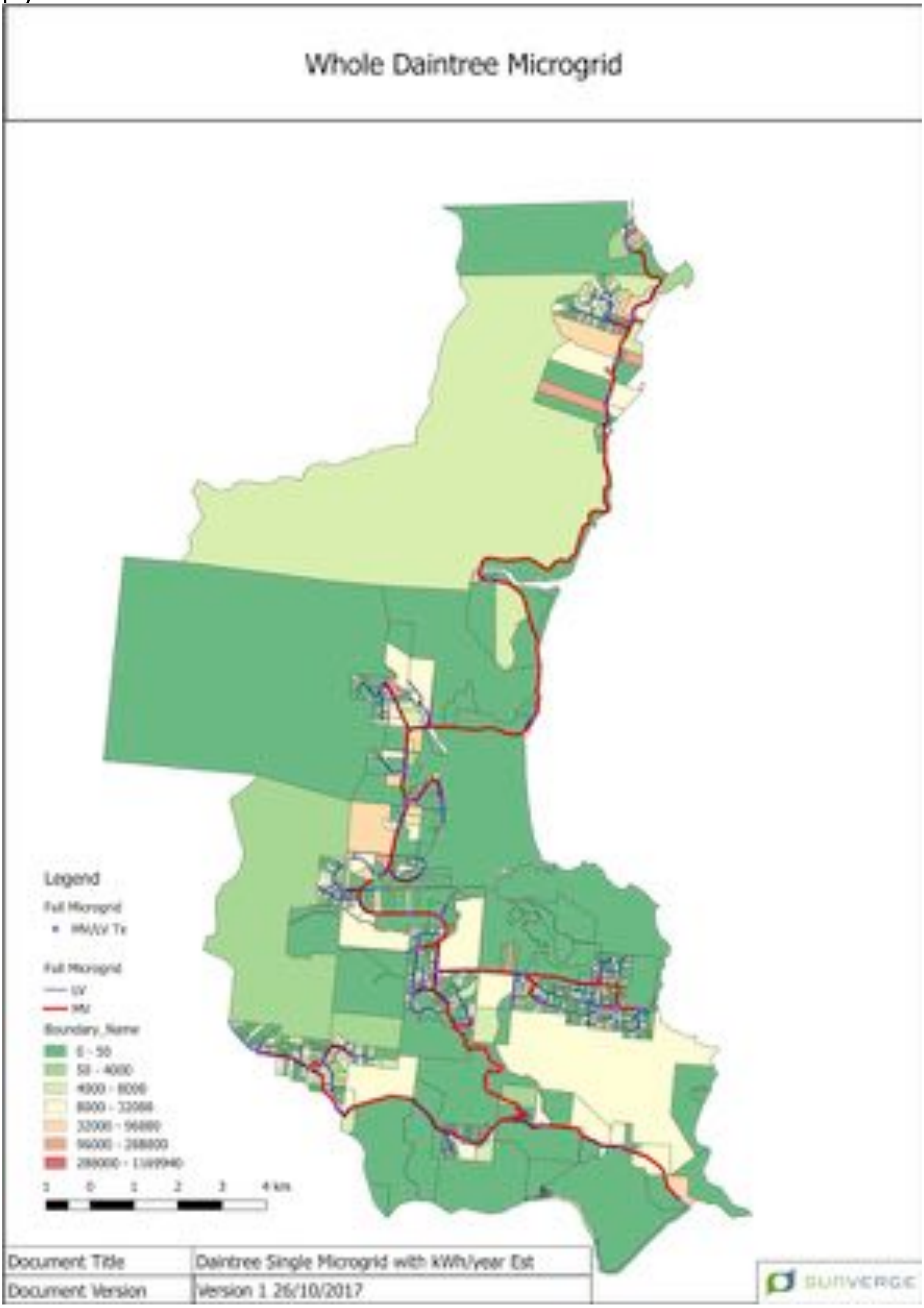
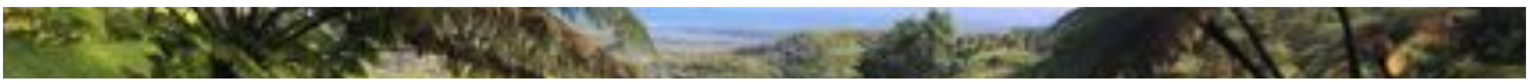


Fig 3.0 Option 1 Whole Daintree Microgrid GIS Overview with MV/LV and Estimated Yearly Consumption per Parcel



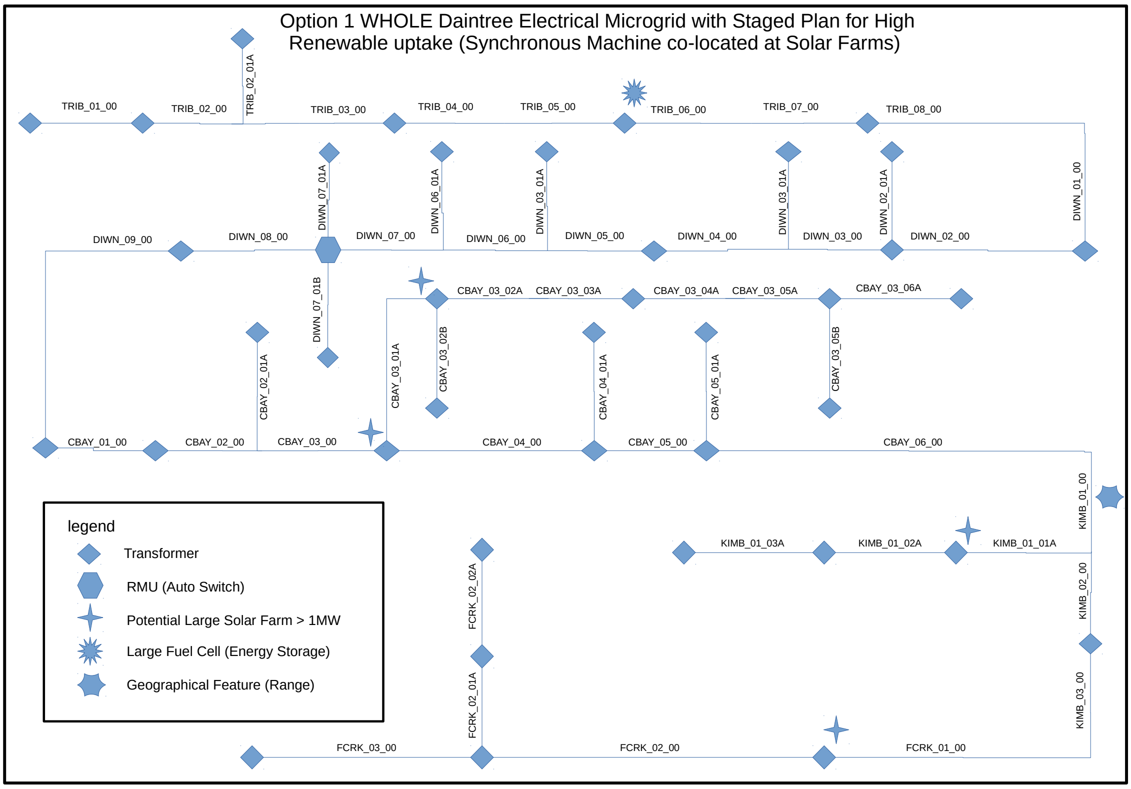
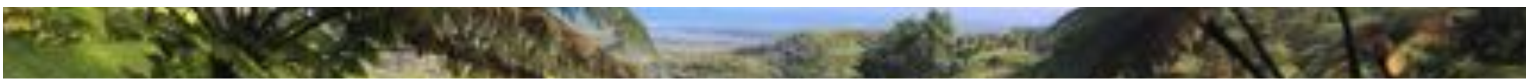


Fig 3.1 Schematic View of Possible Proposed Single Microgrid Option



Option 2

Daintree Electrical Microgrid (Broken up into Three Segments, less PV Potential and Lower Diversity)

This option provides benefits due to the requirement to install less physical cable and duct. Some cost reductions are achieved through the rocky section joining Diwan/Cow Bay to Forest Creek and Cape Kimberley where only directional drilling with many expensive setup pits due to the many switchbacks or a very large directional drill bypassing much of the road is saved using this option.

This option would provide:

- 95km reticulated UG cable (LV/MV) networks, broken into three main segments
- Smaller generation sets supplying each node (may require larger gensets to deal with LDC lack of diversity) - estimate 5MW gen
- Three different generation centres, being one for each segment
- Electricity supply to most, but not all customers

This option is seen as less beneficial to Option 1 because it reduces the energy diversity across the microgrid and thus the solar and renewable generation potential. Costs are also increased due to the separation of the microgrid and the need for three different generation centres and control centres, estimated around 25% more initial generation capacity needed for N-1 compared to option 1 (some dependency on Synchronous machine size but using common sizes). Finally, a segmented microgrid loses the benefits of load matching and optimisation between the northern Cape Tribulation community loads and the southern Daintree community (Diwan, Cow Bay, Cape Kimberley) loads. Cape Tribulation entire load centre including the expected two resorts which are awaiting “grid power” will be almost 50% of the entire energy consumed within the Daintree, this load will also have significant overlap with solar generation production due to the running of air-conditioning units by their guests.

Ergon Energy costed out a very similar network design for their option B back in 2013. The network Ergon designed was a little smaller (more due to lack of accurate road/road side following) and was vastly smaller with respect to the electrical capacity. Ergon used their standard planning methodology of 4kVA ADMD (RES) and 20kVA ADMD (Commercial), and as stated by Ergon this was the best data they had at the time. As we now know there are many commercial users consuming well over 100,000 litres of Diesel and many thousand of cubic meters of LPG due to most being accommodation lots and or resorts.

Ergon planned for three networks like option B, total installed generation capacity 1.425MW costing in 2013 44.4 million, option A which cut out Forest Creek and Cape Kimberley (total peak of 280kW) was $40M with a possible additional $16M to upgrade due to new load on the existing Ergon line network.

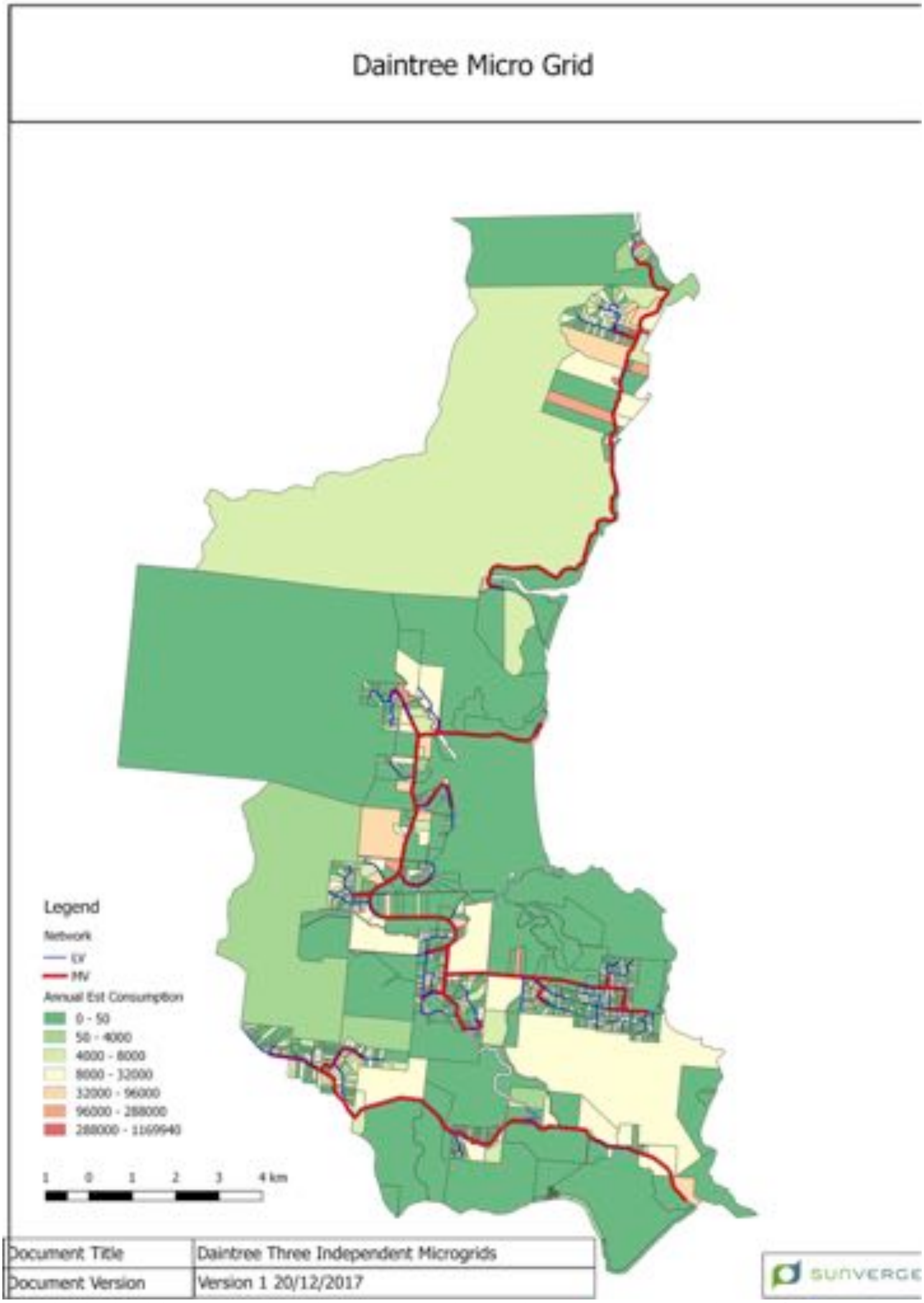
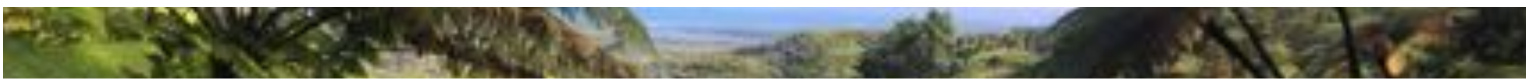


Fig 3.2 Option 2 Separated Microgrids due to Terrain and Distance between load sites MV/LV and Parcel Annual kWh Consumption



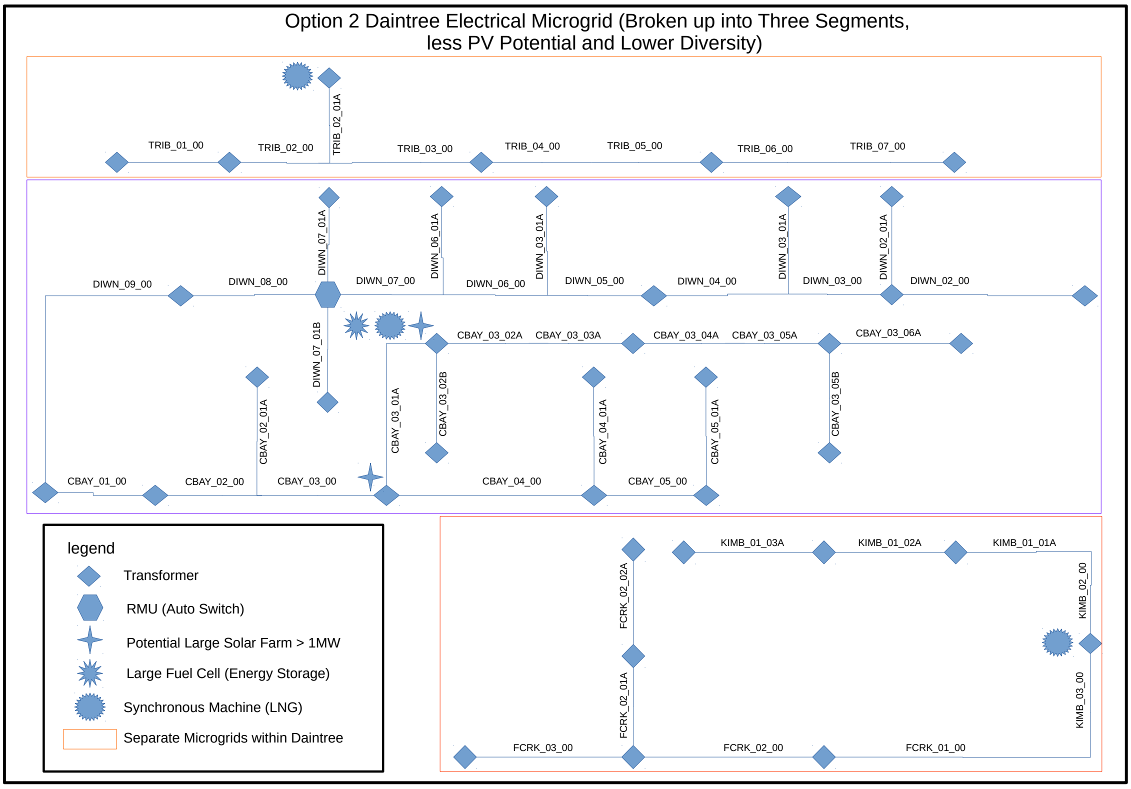
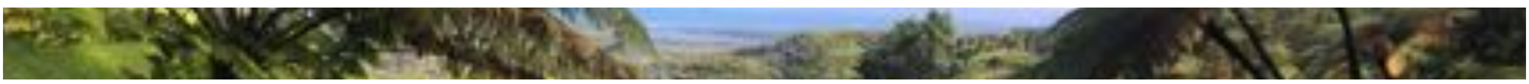


Fig 3.4 Schematic Overview of Option 2



Option 3

Daintree Gas Microgrid High Renewable Uptake Using Power to Gas and Biomethane (Spur Gas pipeline not shown, all PE Pipeline)

This option would involve:

- 80km UG gas pipeline (PE)
- 30km reticulated UG cable (LV)
- Smaller generation unit sets supplying each node (may require larger gen sets to deal with LDC lack of diversity) - approx. 5MW generation
- Supply to most, but not all, customers
- Option for large Solar to Gas facility or bio-fuel plant

This option was initially appealing due to the low cost, high reliability and simplicity of installing underground PE (Polyethylene) gas networks.

PE pipelines are very easy and quick to install with minimum labour costs compared to other forms for reticulation, modern PE pipeline joints come in built with cutters and heaters allowing for very fast joint (T or Inline) to be performed in addition these pipelines can accept high concentrations of H2 gas without the issues of hydrogen embrittlement as seen with other pipeline technologies. PE is limited to relatively low pressures but with the backbone being an expected 100mm ID a medium to low pressure network for the relatively low energy throughput wasn't expected to need expensive compressor or regulating stations along the network (specialised trainset pipeline simulators such as Synergi Gas or Simone would be required to confirm this due to the range and thus elevations involved as pipelines are sensitive to elevation changes). Additional benefits with the pipeline solution was that the large diameter pipeline itself had considerable line packing ability (pipeline acted as an energy storage device), this moderation along with a few low pressure tanks was appealing as it not just lessoned the impact of short duration loads but also allowed for the line to be sectionalized in case of an emergency, such events would then use the gas stored within the pipeline awaiting temporary connection to a regulator off a high pressure tanker truck (common practise within the gas industry).

However, lower diversity would increase the generation capacity required, while cogeneration units remove some of the load required that would be expected to be taken up by the electrical grid as hot water elements, the Daintree's need for heat is very limited compared to other regions where cogeneration could be used.

Sunverge discussed this with multiple suppliers. Yanmar in particular were very interested however even with their solutions equity was a problem with supplying every residential customer to same opportunities as waste heat was needed, additionally simple OEM systems like Yanmar's generation scheduler became quickly convoluted and not suitable for anything other than extensive R&D/pilots as seen below.

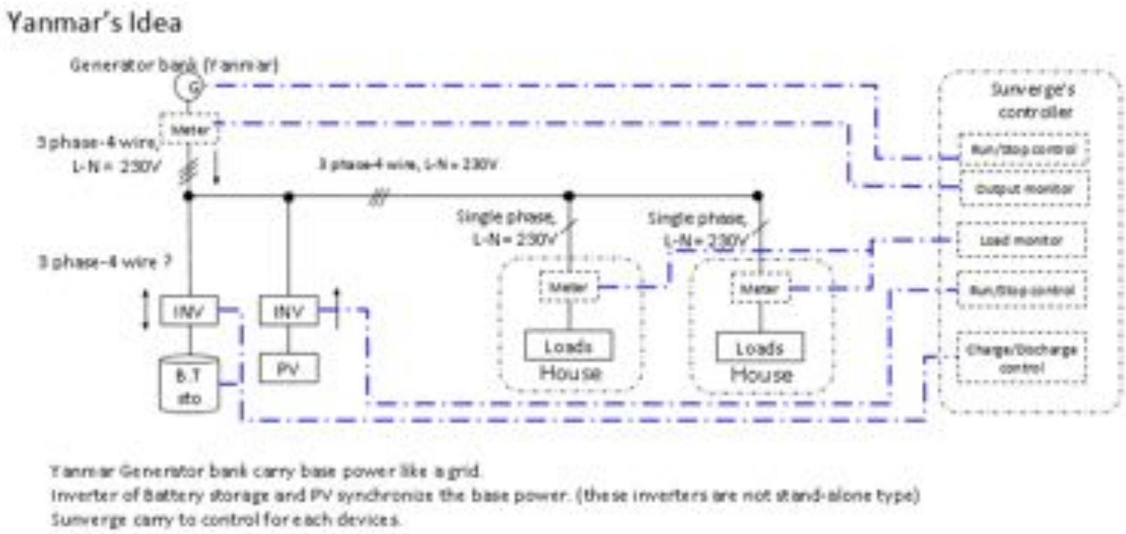


Fig 3.5 Proposal from Yanmar for CHP supplying multiple sites in conjunction with a third party aggregator.

This option is seen as less beneficial to Option 1 because it relies heavily on micro gas generation units which have high heat losses that are unable to be captured in the Daintree area given the low need for heating loads.

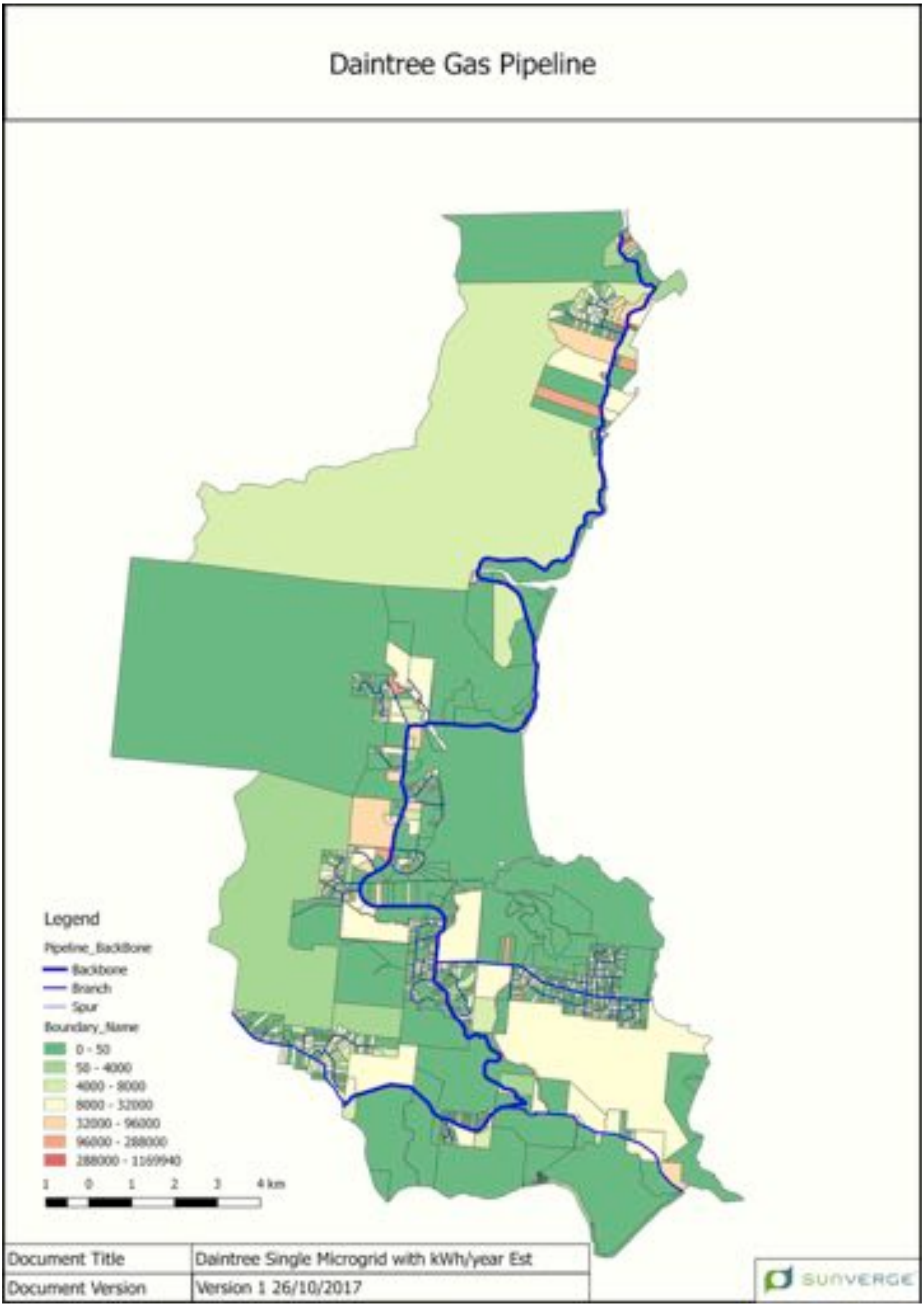


Fig 3.6 Option 3 Energy Transport via PE Gas Pipeline and Land Parcel Annual kWh Consumption

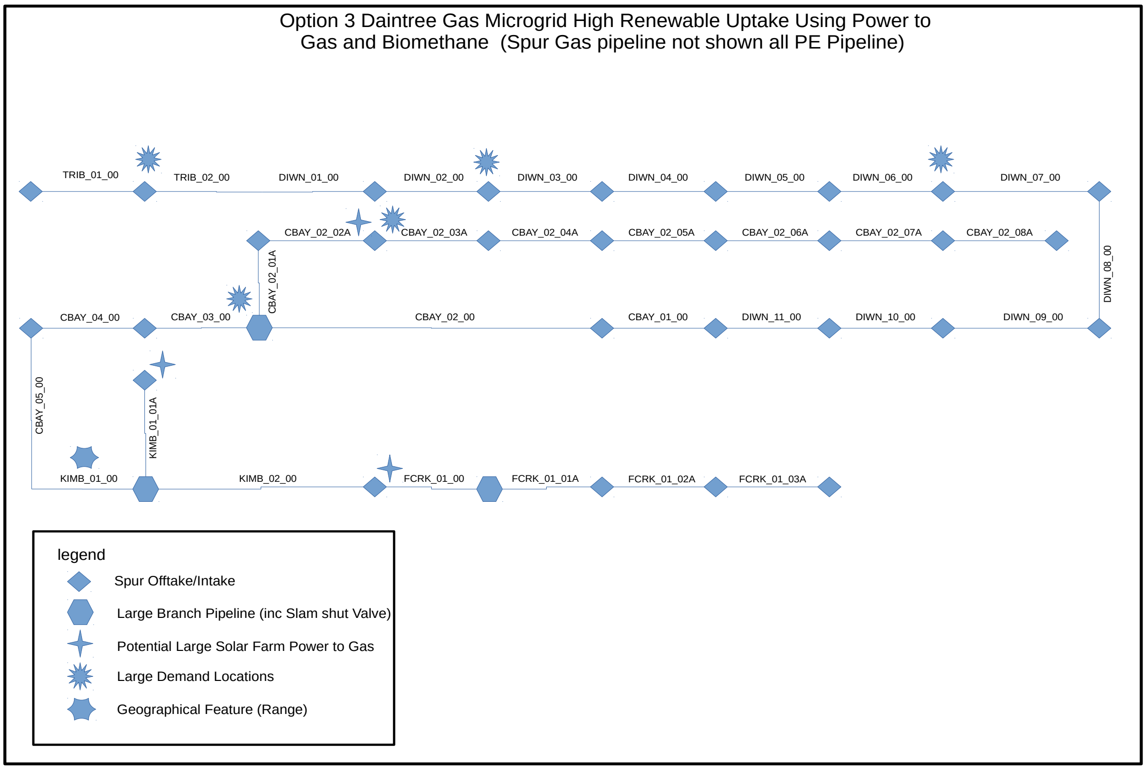


Fig 3.7 Option 3 Schematic

Option 4

Cape Tribulation - Leverage off Existing Generation and load density per km to extend in small LV networks (LPG substitution and some local PV)

This option only addresses Cape Tribulation (nearly 50% of the load by annual consumption but only around 15% of total customers).

This option involves:

- Utilising existing site infrastructure (large customer generation) in Cape Tribulation
- Building small LV network to supply limited customers with existing customer generation sets

Whilst this option has a low capex cost it does not supply power to more than 20% of the population and raises many issues around equity, generation contracts and operation and maintenance obligations. It also has very low renewable potential and provides no significant improvement on existing supply options.

Options like this are being looked at by various existing fuel suppliers to the region. Sunverge is aware of one such operator who has a modified approach where LPG substitution of some of the diesel is being proposed. This is a commonly used method to allow the existing diesel generators to burn both diesel and LPG simultaneous thus getting some of the cost advantages of LPG (dollars per energy content).

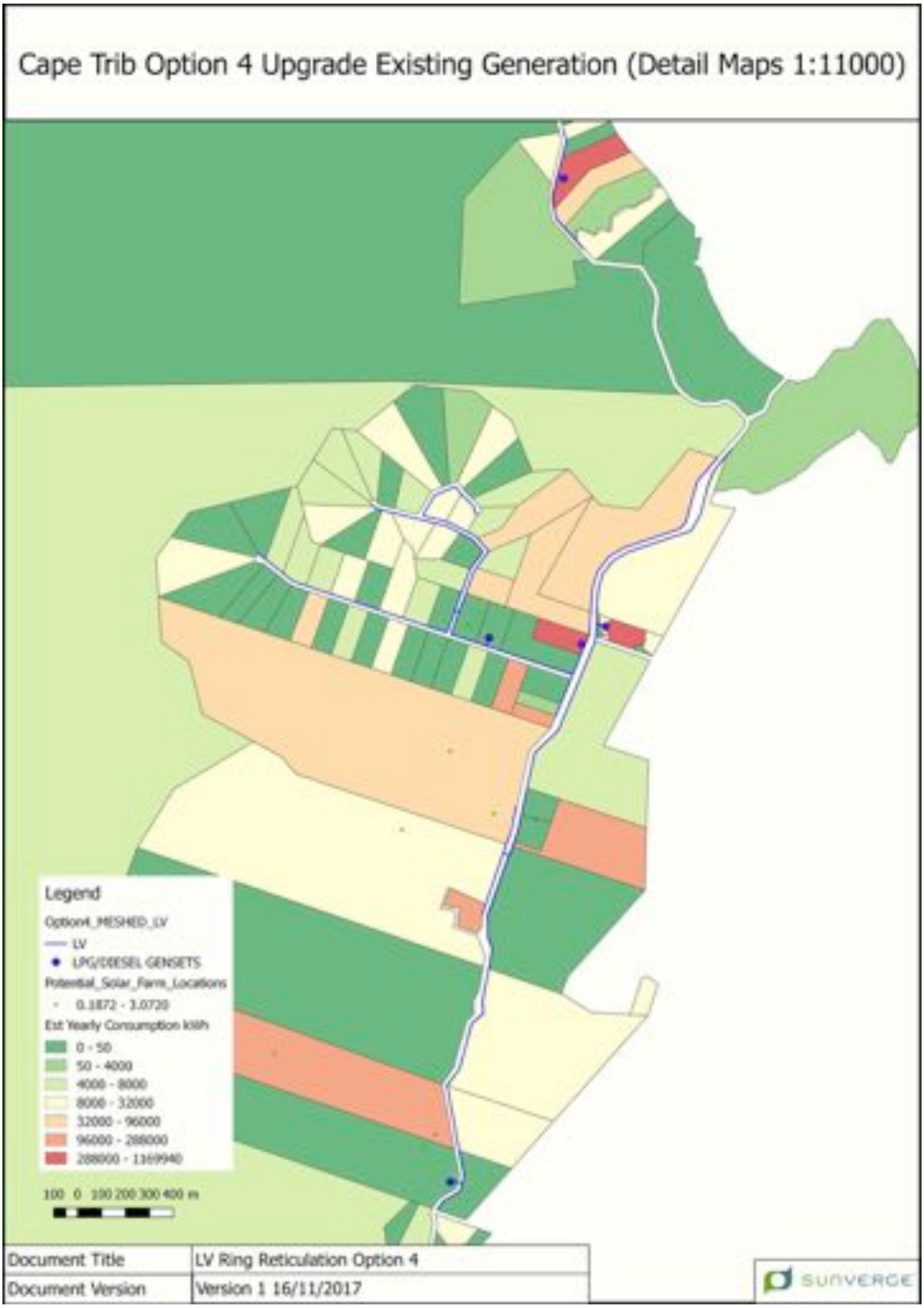
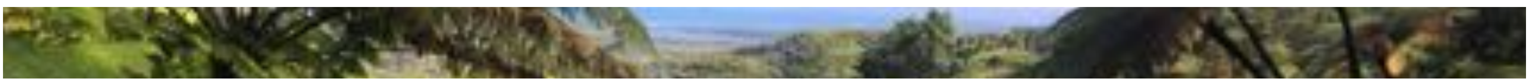


Fig 3.8 Option 4 Closed Ring LV Network using existing augmented LPG/Diesel Generation at Cape Tribulation



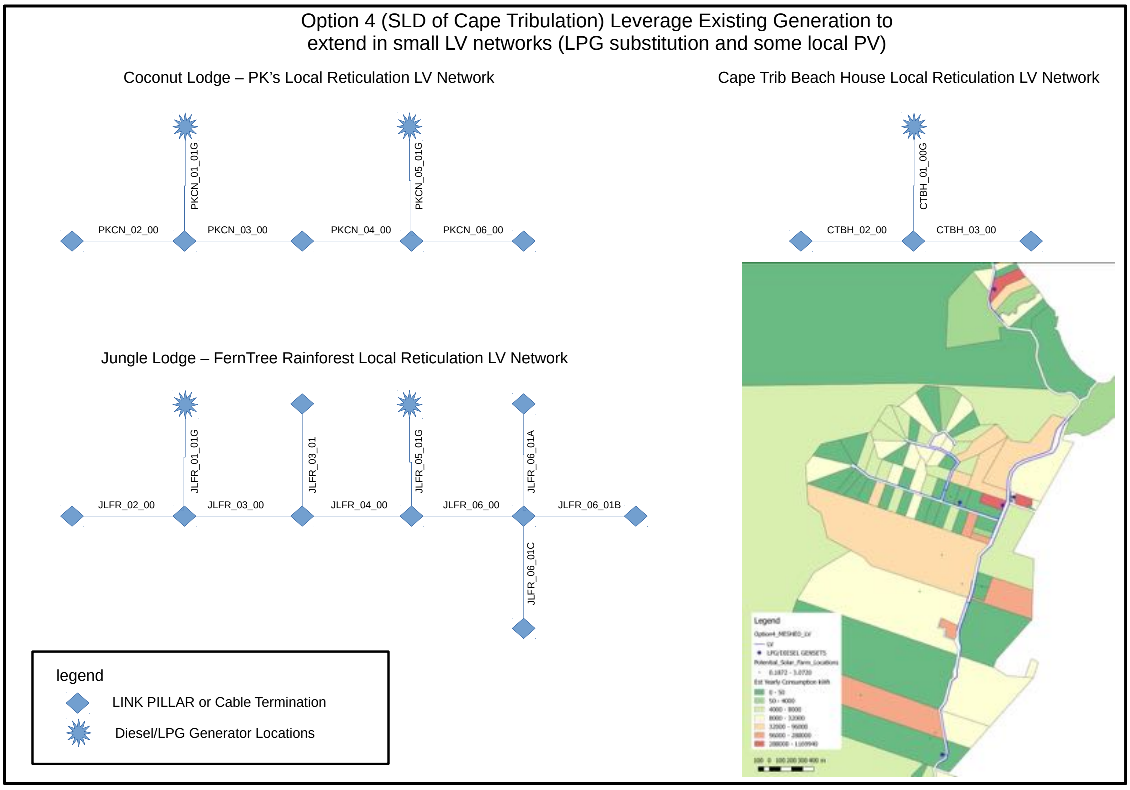


Fig 3.9 Schematic of Option 4 LV Networks

Option 5

Upgrade of individual hybrid supply options

This option needs a lot more installation generation compared to the other solutions which are leveraging the diversity of load between different units, of interest the 2016 Compass Research Daintree Cape Tribulation Electricity Survey indicated that the average generation is around 13kW while the ADMD expected for both Ergon Energy and this study for collective MV/LV Distribution groups is around 4kVA.

Because of this factor both the Diesel backup and solar/battery solution needs to be scaled up more than what would be needed for near self sufficient grid connected systems to accommodate for the few days where load and or PV generation is much lower than expected.

In addition in the Daintree the strong seasonal wet also significantly reduces PV potential while forcing customers to use diesel generation during these period.

Only around 60% of the Daintree residential roofs are suitable for the very cost effective traditional string array systems, many roofs have some sort of shading which at one time or another will knock out an entire array.

It is recommended that for the majority of the roofs that DC-DC converters be used to mitigate against this problem. Also, due to the high rainfall and dust from the local dirt roads, panel fowling will occur, therefore this option would mitigate against adversely impacting a whole string. This upgrade of the panels is reasonable as many systems now are a mismatch of different panel ages, sizes and manufactures making such systems suboptimal and prone to failure and long downtimes trying to sort out which system failed, in addition a clean cut is needed with respect to warranties as interfering without replacement of breakers and wiring will as Sunverge has seen in other projects cause contractual demarcation problems, especially around system performance.

The Recommended solution for Residential properties (small B&B excluded)

- 15kVA Diesel Generator
- 6kW PV Array (Either multiple MPPT for roofs with less than 10% shading OR DC-DC optimizers)
- DC coupled Battery System 12 – 14kWh (DC coupling due to efficiencies for most systems, or some newer AC coupled systems like the Tesla Powerwall 2, noting some concerns around liquid cooling and long term maintenance with such systems).

This option would be an extension to the existing supply model in Daintree and would involve:

- Individual sites receiving a subsidized more efficient, refreshed hybrid system (solar, diesel/gas generation, battery storage)
- No central infrastructure
- Lower scheme regulation costs

- Similar solution to existing approach where each customer looks after their own supply, albeit with refreshed equipment similar to the scheme offered by the Queensland Government 20 years earlier

It should be noted that high removal costs for existing equipment is not currently included in the analysis.

This seen is not seen as favourable as it is:

- inequitable due to locational solar irradiance potential diversity,
- costly to maintain on an ongoing basis
- unable to achieve significant renewable potential due to lack of diversity.

Tariff Structures and Development Options

Developing fair tariff structures that are equitable and promote efficient use of service whilst at the same time providing a fair return for the asset owner is a complex challenge.

Many potential structures are available ranging from fixed charges to variable usage charges, to charges for peak demand or capacity or a mix of these options. Some of these options were covered in the Ener-G (2017) report and have been considered below in the context of responses from the stakeholder group.

Many studies have shown that customers generally don't want to pay excessive charges and prefer simplicity to complexity.

In a system such as the Daintree there will be a high cost to serve based on customers per km of installed system. The ability to charge a tariff similar to what NEM connected customers currently pay will depend on a range of factors, namely:

- Capital cost to build the preferred option;
- Ongoing operating cost to maintain the system;
- Replacement allowance or sinking fund required to refresh the system;
- Energy produced and consumed in the system;
- Required rates of return for the Asset Owner; and
- Incentives or subsidies available to reduce the capital or operating costs of the system.

All of these variables have the potential to distort the cost per unit of energy or Levelised Cost of Energy for the solution.

Assumptions

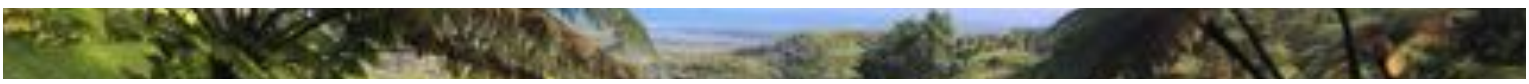
Feedback from numerous discussions and reports of the community's appetite to pay for power indicates overwhelming support for charges to be similar to those charged to other electricity ratepayers in the National Energy Market.

As such for the purposes of this analysis, we recommend assuming a standard tariff structure that includes a fixed component of $100 per quarter for residential customers and around 30c/kWh consumed. We also recommend assuming a Feed In Tariff scheme that allows community members to share their excess rooftop solar PV at around 10c/kWh.

Depending on the variability of the factors listed above, significant variation can arise that can affect the overall calculation of the reflected costs of supplying power or any subsidy required to supply it.

The detailed calculation of reflected costs, tariffs and subsidies requires a strong definition of a preferred scenario or set of scenarios and a well defined set of values around the factors listed above.

To define these factors for investment decision making, Sunverge recommends future analysis be used to refine these variables.



However, for indicative purposes it can be noted that based on a required investment return of 10% and a low case scenario for future energy consumption and load growth with tariffs as specified above, a required subsidy of approximately 50% of the expected capital cost would be required to ensure the project success within a 10 year timeframe.

It is noted that this analysis does not include significant load growth or additional environmental, employment, social or economic benefits that would accrue to the Daintree after the provision of improved energy infrastructure.

Community Service Obligation (CSO) and role of the State Government

Various reports into the Daintree have listed the CSO contribution as an issue, noting the State Government's concerns regarding any potential increase to this scheme.

Whilst a mechanism and detailed costing is yet to be developed, it should be noted that any CSO obligation – if required – could be minimised by striking the appropriate balance between the factors listed above.

If the appropriate capex solution can be provided by a Public Private Partnership arrangement and sufficient initial financial support is available from state or federal governments, there is potential for ongoing CSO commitments to be minimal and focused on supporting governance or oversight arrangements for the system.

Depending on the state's appetite to achieve renewable targets, there may be a role for the state in providing a Contract for Difference or similar scheme to encourage a mix of solar PV, storage and Biofuel investment as included in the Renewables 400 program.

Funding and development options

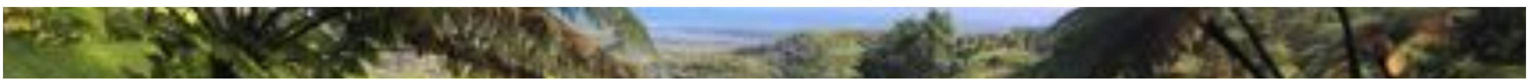
A large range of funding and development options is available to deliver an infrastructure project of this nature.

These options include:

- Public – using government businesses or agencies to fund or develop the infrastructure
- Private – where a private entity takes on the funding risk and development responsibilities to build and operate the system
- Public Private Partnerships – where government and businesses partner and share resources to assist in the development of infrastructure projects.
- Community groups – where the community forms a group and seeks or provides its own financial support for the development of its solution.

For the Daintree community, we recommend exploring a Public Private Partnership (PPP) model, where reputable proponents are able to deliver the required project, contracts and governance under an agreed model that receives government support.

We recommend community involvement through a governance structure to oversee the regulatory or licencing framework, similar to other microgrid arrangements around the world.



Regulatory and governance options

In a community such as the Daintree, a scheme that is developed by a PPP arrangement will require ongoing regulation or governance to ensure that the objectives of the project are being met.

Sunverge is prepared to work with stakeholders to provide its expertise to develop a scheme and approach to licencing that meets the needs of the community and the financing and operating entities. It is expected that this control scheme would be adapted based on our experience from other remote microgrid operations around the world.

Conclusion and Recommendations

The report aims to provide a feasible pathway to an equitable, reliable, economically sound and environmentally sustainable energy supply for residents with the following recommendations.

Recommendation 1
Key stakeholders to support a staged approach to building a reliable, low-impact underground microgrid which is initially serviced by a mix of traditional gas generation and solar PV and leverages regional skills for real world operation

Recommendation 2
Key stakeholders to support, subsequent to the provision of reliable, low impact microgrid power, exploring options to increase the renewable generation of the system to approximately 80% through:

- first understanding the detailed load characteristics of the whole system based on analysis of installed system (traditional) generation for a period of up to one year, then (based on actual system load data and detailed site investigation);
- implementing a plan to reliably increase renewable penetration and deploy innovative energy technologies including large scale, long term storage (e.g. solar to gas)

Recommendation 3
Key stakeholders to support establishing a mechanism to allow customers to benefit from sharing their excess solar production (similar to a Feed In Tariff scheme)

Recommendation 4
Key stakeholders to support implementing residential and business tariffs with a fixed and variable component similar to those offered to grid connected customers in regional Queensland

Recommendation 5
Key stakeholders explore options to encourage a public private partnership arrangement to the development of the microgrid solution

Recommendation 6
Key stakeholders to support and agree on the key principles for engineering solutions, tariff structures, subsidies and schemes, ownership, regulation and governance

Recommendation 7
Agree on funding for the development of a next stage detailed Microgrid pre-construction study with capable project proponent including detailed survey data, detailed engineering cost studies, pre-approvals and detailed project plan for Option 1. It is noted that the Queensland Government has made a commitment to provide $1M of funding for a study for renewable solutions for the Daintree and it is recommended that these funds be considered for the support of the pre-construction study for Option 1.

Attachment A - Engineering considerations of current state microgrid technologies

Existing Microgrids

There are many remote unconnected microgrids throughout both Australia and the world.

Most of these grids are primarily powered by diesel fuel, although because of the cost of shipping diesel to these remote locations (even with the drop in crude prices worldwide for the last few years) there has been a strong push to supplement the energy stream with something cheaper and often renewable solutions are a desired end goal.

The Hawaiian islands are very interesting as they form separate microgrids, in addition the Hawaiian islands have some of the highest PV penetration anywhere in the world. Islands such as Molokai have small populations (7,000 approx.) very high existing PV penetration and are targeting to be fully renewable by 2020 (https://www.pv-magazine.com/2017/07/19/hawaii-regulators-approve-hecos-100-renewable-energy-plan/) and the state as a whole by 2045/2040.

Diesel Microgrids

Like inverter based systems reciprocating machines have bands which they are most efficient when converting the energy in the fuel stream into electrical energy to be used on the microgrid.

Typically, there are multiple machines operating in an N-1 configuration, machines are turned on and off depending on the loading conditions. Optimization is performed for system efficiency and ensuring minimum load for each machine isn't exceeded for a pre-defined time limit (generally continuously rated diesel generators are set to 70 – 100% of their nameplate rating).

Older diesel machines were more susceptible to low load problems, where typically operating a diesel machine below 30% for an extended period will start to cause issues such as wet stacking. Wet stacking is when oily liquids leak from the exhaust manifold into the engine proper. This partially burnt oil liquid occurs due to the cylinder not being hot enough typically due to underload conditions (idling for example), long periods of operating like this allows the deposits to build up inside the cylinders and in severe cases cylinder liner polishing can occur. This can and often does lead to higher maintenance, faster wear rates of parts and a loss of performance. It is because of this that many operators of diesel microgrids are concerned about the loading patterns that occur when PV is introduced and thus are looking at battery solutions to help ensure a minimum system load is maintained.

Cylinder liner polishing (or glazing) once present requires a full rebuild to fix. This is a hard carbon deposits on the wall of the cylinder. If this has progressed often the cylinder bores will need re boring.

Gas Microgrids
As with diesel reciprocating machines, gas machines also have an optimal band which they are recommended to run in. Typically for a gas machine this is from 50 – 100% (however some manufactures don't recommend their plant be below 70%). This design constraint needs to be factored into any power system planning considerations and was accounted for in the modelling for this study, particularly in relation to minimum loads.

While Gas engines don't suffer from wet stacking they do face other problems of running at low loads in that gas engine cylinder pressure isn't enough to maintain proper control of the oil in the cylinder. Oil can work its way past the O rings and into the combustion chamber where it can carbonize in the cylinder under such conditions. These carbon deposits can cause pre-detonation to occur, commonly called knocking or pinking, modern ECU's have knock sensors (either measure the cylinder peak pressure to detect knocking OR using piezo knock sensors which can reduce the compression ratio significantly mitigating against this issue however like diesel machines extended low load operation can cause in severe cases cylinder liner glazing/polishing like diesel machines and thus needing a rebuild.

Microgrid Operations
Irrespective of whether the prime movers are Diesel or Gas, operators will have multiple machines that have been optimized for both limiting the number of start-ups (highest ware periods) and operational efficiency of the machines taking into consideration both the magnitude and duration of minimum load periods to ensure the machines have sufficient load to burn off any unwanted oil build ups before it becomes an issue.

Sunverge has been involved with a few different operators specifically looking at meshing battery energy storage systems, over sized pv systems and traditional diesel generations (both inside and outside of Australia).

All these studies formulated around minimizing solar spillage while minimizing the duration the machines were operating a low load and power fluctuations (turning on and off machines specifically but also system stability). Typically with existing microgrids there is one or two small machines, to ensure the stated N-1, this often means that systems with little to no DG headroom (additional PV accepting capacity) often ride those two machines for significantly longer periods than the rest of the units.

In cases like this the larger machines almost become redundant and thus are poorly optimized for capex. Additionally, maintenance issues occur as there is no down time for scheduled maintenance without incurring significant solar spill.

BESS systems are also being looked at to improve power factor. Typically most of these microgrids are inductive. What has been known but often forgotten about is that the PV solar farms are often at or near unity, this large removal of real power however has left the existing reactive power. Traditionally this has been supported by under exciting the rotor (supply reactive power). Depending on the load and PV generation this potentially creates another limiting factor (IE not enough reactive power can be supplied without spinning up another machine, undesirable).

Modern ESS's are coming out with true reactive power support with some modular suppliers also making standard Rack 3U systems that have both power factor correction (inductive and capacitive) and active harmonic filters, PCS's Batteries modules as separate scalable modules for the BESS.

Hawaiian Microgrids

Hawaii, especially the smaller islands are on low inertia grids, because of the significant cost of energy in the Hawaiian chain, power prices are correspondingly very high.

This high price, incentives and the performance of photovoltaic systems made installing distributed solar systems very appealing, as can be seen with some island like Molokai being 41.9cents/kWh (USD) back in 2014.

As like other regions the fossil fuel base load generation being relatively inflexible are causing operational issues for the utilities. As part of their push to ensure the grids remain stable with high PV penetration HECO/MECO have tackled directly some of the existing problematic settings on photovoltaic systems as documented in the link attached (Other states with the U.S.A are starting to adopt similar requirements):
https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/producing_clean_energy/attachment1_trovandfvrt_public_nov2015update2.pdf

- Transient Overvoltage TrOV-2, this is a setting implemented in late 2015 in Hawaii, this mitigates against sudden voltage raises caused by a significant imbalance in generation to load OR protection event on a circuit.
- Expanded Frequency and Voltage Ride through. Often low inertia grids especially with large changing loads and or generation (PV) can momentary enter protection zones for disconnection. For systems with a large relative PV connected such disconnects can be very unwanted and can cause the grid to fail as suddenly there is a significant loss of generation as such because of their experience and their ability to upload new settings (Enphase, 60% market with microinverters that can accept new settings, proven in February 2015) they have been able to fine tune their settings in a real world system.

Full Frequency Ride-Through Settings for Moloka'i and Lāna'i

Operating Region	System Frequency Default Settings (Hz)	Minimum Range of Adjustability	Ride-Through Until	Operating Mode	Maximum Trip Time
Over-Frequency 2 (OFR2)	f > 65.0	60.1 - 65	No Ride Through	Permissive Operation (Freq-Watt)	0.16 seconds
Over-Frequency 1 (OFR1)	65.0 ≥ f > 63.0	60.1 - 65	20 seconds	Mandatory Operation (Freq-Watt)	21 seconds
Normal Operation High (NORH)	63.0 ≥ f > 60.0	Not Applicable	Indefinite	Continuous Operation (Freq-Watt)	Not Applicable
Normal Operation Low (NORL)	60.0 ≥ f ≥ 57.0	Not Applicable	Indefinite	Continuous Operation	Not Applicable
Under-Frequency 1 (UFR1)	57.0 > f ≥ 50.0	57 - 59.9	20 seconds	Mandatory Operation	21 seconds
Under-Frequency 2 (UFR2)	50.0 > f	50 - 57	No Ride Through	Permissive Operation	0.16 seconds

* May be adjusted within these ranges at manufacturer's discretion.

Full Voltage Ride-through Settings for O'ahu, Hawai'i Island, Maui, Moloka'i, and Lāna'i

Operating Region	Voltage at Point of Interconnection (% Nominal Voltage)	Ride-Through Until	Operating Mode	Maximum Trip Time	Return To Service - Trip Criteria (V)	Time Delay (s)
Over-Voltage 2 (OVR2)	V > 120	No Ride Through	Cease to Energize	0.16** seconds	110 ≥ V ≥ 88	300 - 600*
Over-Voltage 1 (OVR1)	120 ≥ V > 110	0.92 seconds	Mandatory Operation	1 second	110 ≥ V ≥ 88	300 - 600*
Normal Operation High (NORH)	110 ≥ V > 100	Indefinite	Continuous Operation (Volt-Watt)	Indefinite	Not Applicable	Not Applicable
Normal Operation Low (NORL)	100 > V ≥ 88	Indefinite	Continuous Operation	Indefinite	Not Applicable	Not Applicable
Under-Voltage 1 (UVR1)	88 > V ≥ 70	20 seconds	Mandatory Operation	21 seconds	110 ≥ V ≥ 88	300 - 600*
Under-Voltage 2 (UVR2)	70 > V ≥ 50	10-20* seconds	Mandatory Operation	11-21* seconds	110 ≥ V ≥ 88	300 - 600*
Under-Voltage 3 (UVR3)	50 > V	No Ride Through	Permissive Operation	0.5 seonds	110 ≥ V ≥ 88	300 - 600*

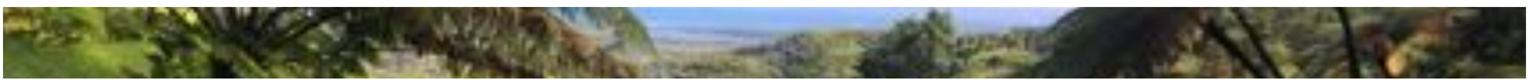
* May be adjusted within these ranges at manufacturer's discretion.
** Must trip time under steady state condition. Inverters will also be required to meet the Companies transient overvoltage criterion (TrOV-2).

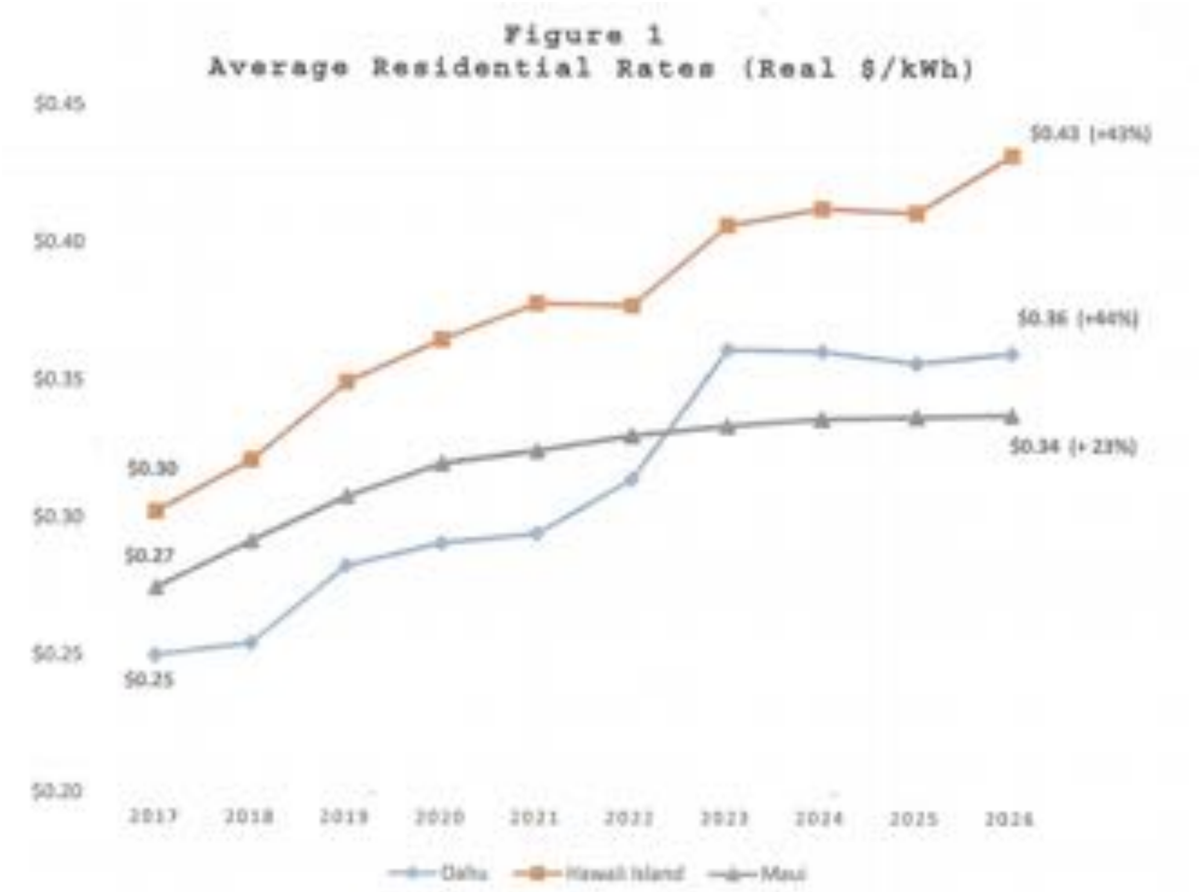
https://s3.amazonaws.com/dive_static/paychek/Docket_No._2014-0183_DO_No._34696.pdf

However, while Hawaii is being looked to throughout the world as an example there are issues.

For example the pricing structure of the Hawaiian Island chain is causing some issues and the regulator "Public Utilities Commission" has pushed back on some large grid scale energy storage projects such as those using batteries due to rapid forecasted price increases.

Below is a pricing projection in cents/kWh in USD, these projections do highlight the concern of the regulator/commission about the Hawaiian utilities in their words "haven't fully considered the affordability of their plans" and provide some caution for the Daintree microgrid not to slavishly follow what are in essence real world low inertia remote microgrids with very high renewable uptake (targeted to be 100% in the coming years on some islands).





Much of the Hawaiian utilities future plans relies on increase of the uptake of BESS and synchronous condenser resources (can convert old generators into synchronous condenser and is a common practice for Australian utilities).

The Battery Energy Storage Systems BESS are to have multiple functions begin:

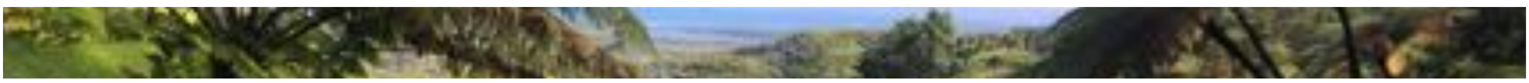
- Fast Frequency Contingency Response.
- Load Shift
- Regulate DG Ramping response.
- MECO Islands also DR Load Resource control.

In summary the Hawaiian Islands are very interesting with respect to this project due to their limited population size (smaller islands), isolated low inertia grids, goals of 100% renewable (including some of the older geological islands having zero geothermal) and currently some of the highest PV penetration in the world and very active regulator/industry, Hawaii acts as a good case study for things to emulate and things not to for the Daintree which has similar attributes and goals.

Conclusions for the Daintree

Traditional synchronous machine whether gas or diesel fuelled all have issues with supporting very long duration low loads. This is immediately remedied by having more smaller machines rather than fewer larger units, however disadvantages include

- Higher initial CAPEX cost.
- More units therefore potentially more maintenance to begin with, when all machines are running before significant PV farms built



- Complicated control systems

Advantages:
- Higher unit flexibility and therefore better efficiency from fuel to electrical energy
- Lower minimum load requirements
- Simpler maintenance routines
- More even unit utilization (all machines operated rather than sitting)

All microgrid operators with significant PV have specific ramp up rates on their PV systems, operators such as those in Hawaii are using or intending to use BESS's for both ramp up and ramp down rates, this significantly reduces changing power generation within the grid and thus is less demanding on the synchronous machine controller.

BESS's or fast energy storage units are becoming a critical component to ensure the frequency remains stable not just for ramp rates but frequency watt controls including RoCoF.

In addition synchronous condensers are being considered. These units not just act as a flywheel but also provide fault and reactive power support (voltage). Such units are also advantageous as they can be converted from traditional generator systems.

If/when the Daintree goes 100% renewable it would be recommended that a similar approach is used, in this case possibly with a disconnecting clutch mechanism to allow the prime mover to remain for emergency use.

Protection settings.

Around the world the HECO settings are probably the most advanced and are the most well tested, while there are some differences with respect to voltage and frequency, the Daintree grid would benefit from adopting something similar.

As such it would be recommended that similar settings be adopted to mitigate against the well documented issues of distributed PV on a weak grid such as in the Hawaiian Islands, which from most accounts the new settings have shown to have worked as intended.

Attachment B - Daintree Microgrid Stability Issues for High Renewable Uptake

Electrical grids big or small are always a balance between load and generation. When this balance is disturbed with either too little or too much generation then the system frequency will either decrease or increase by how much energy it takes to physically accelerate the rotation of generator and prime mover/s of that grid.

Additional complexities can occur with respect to voltage stability and protection. These issues are typically caused by issues with low fault power and the type of loads connected to that system (classic system with no series capacitors).

One of the biggest issues with respect to small non NEM-connected microgrids is that they are typically more sensitive to load, generation, voltage stability and fault conditions compared to national grids.

This is because microgrids often have less reserve and security capacity coupled with the intrinsic problems of being low inertia systems. Such systems have high angular acceleration for a given change in power compared to the wider grid with low fault power/system high impedance susceptible to voltage fluctuations caused by rapid power flows.

In the case of the Daintree, during high PV generation periods, the PV to Load ratio will be high and without energy storage PV/generation would exceed load. This situation is worsened when the Daintree microgrid is segmented up as economic reasons will mean smaller generators will be used for each sub grid.

Thus as a proportion of total generation a single load or PV source is significant bigger than that of the system as a whole and so more strain is placed on the primary synchronous machine governors lowering the ability to operate machines in efficient burning operation bands.

This breaks down into three primary issues within isolated microgrids, these being:

- Frequency stability issues due to fluctuating load/generation
- Voltage stability issues due to rapid changing power flows especially reactive power on high impedance networks.
- Low fault power, which creates difficulties in protection discrimination coupled by the fact there is low inertia so typical MV feeder faults have significant impact on frequency stability and increase possibility of pole slip and system collapse.

Voltage Stability

Voltage and Fault power are interconnected. It is proposed that a single Daintree microgrid be formed allowing for at least two 850kW lean burning machines to be in operation.

This will allow for a simple radial network making protection coordination easier.

In addition, standard but large 3C 185AL XLPE MV cables will be used, the LV network will be more European/Urban Australian with larger 300-500 5-7% P.U transformers reticulating on 4C 120AL PVC.

The main reason for this proposed schema is to keep a system which is relatively low in impedance (transformer size is around 80% of system impedance per voltage step ignoring generation), so larger transformers will provide large LV fault currents. A cable network is also advantageous as the reactance/inductance is very small due to the very close physical spacing of conductors (conductors are also in trefoil configuration), thus limiting voltage fluctuations to as low as possible.

Problematic loads such as those with large motors, like that connected to the main grid may have to connect to either soft starters or capacitor banks for example. The intent is to follow the AS/NZS Power Quality standards which themselves are taken from the IEC 61000 series.

Frequency Stability

Systems which are labelled low inertia systems, mean power systems which have low ability to resist the change in the balance between generation and load.

In traditional systems this inertia is physical rotational inertia of both the generator and prime movers to the connected synchronous machines. In a system such as proposed PV DG power will be significantly higher than that of the synchronous machines, this difference is taken up by system load and energy storage devices absorbing the excess, however because this is imperfect at a sub second (multi cycle) the difference is absorbed or generated via the rotating plant, additionally fault current is mostly generated by the synchronous machine/s.

Typically, there are multiple measures put in place to ensure grid stability while providing some backup contingency in the process these being:

- Spinning Reserve (Existing connected Synchronous Machines)
- Non-Spinning Reserve (Fast Startup Generation)
- AUFLS (Automatic Under Frequency Load Shedding)
- AOFGS (Automatic Over Frequency Generation Shedding)

In addition to the above it is proposed that in this grid hot water control can be used to provide both load shedding BUT also load support during an overfrequency event, using hot water the cost is near zero as the efficiency is near 100% (electrical into thermal energy). We note that current hot water in the Daintree is predominately gas-fuelled, however propose introducing tanked hot water as a cost effective and efficient storage vessel for excess solar generation.

Such schemes are achieved is by having multiple set points/blocks on both under and over frequency and in national grids rate of change of frequency dF/dt (RoCoF) controllers. Each block is separated by frequency and because this is an inertia system in time as well, by widening the frequency separation this has a damping effect slowing everything down and thus lessoning the changes of the system going into a wide oscillation and collapsing.

For the Daintree it is not proposed to use RoCoF relays unless a much higher change rate is used that that normally used. The reason for this is that the proposed operational frequency band is larger due to the expected swings (in line with other such networks) and even expensive primary plant RoCoF relays when tested are not consistent in both their measurement of the df/dt and timing to trip, as such with such a weak system unwanted tripping could be problematic with these devices and controllable load and fast generation are a significant proportion of this grid making up for this shortfall.

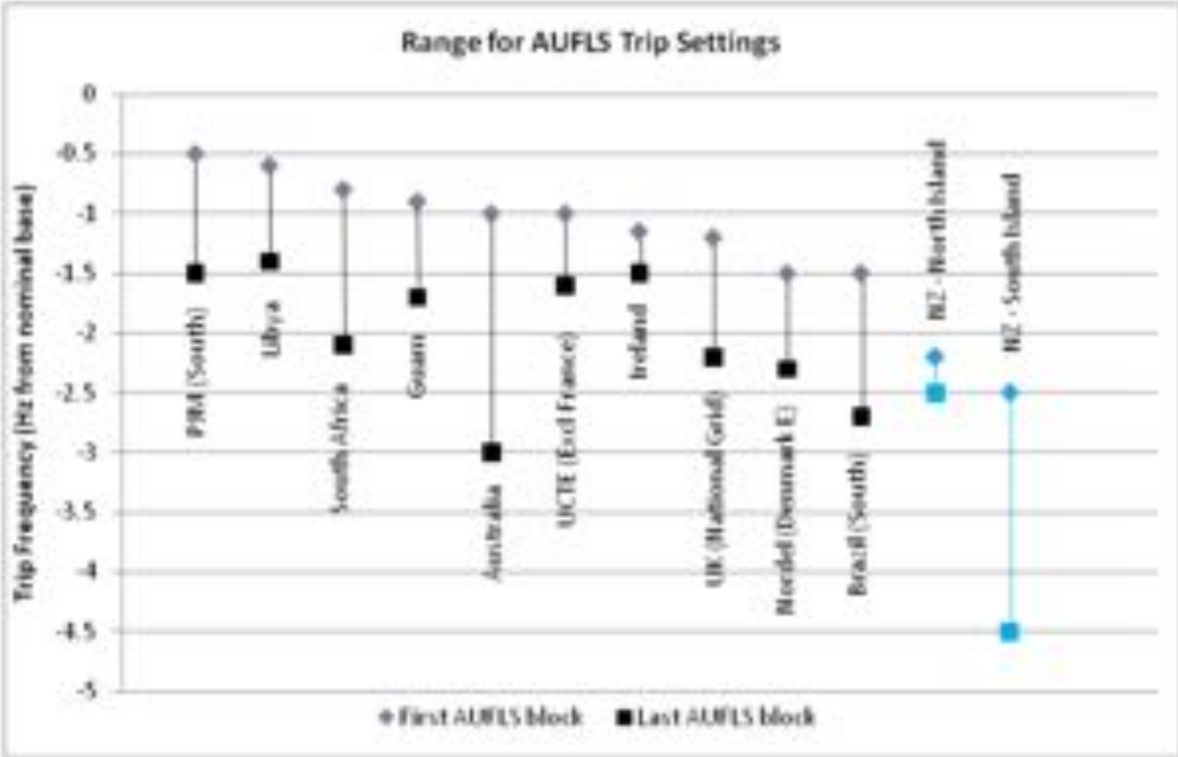
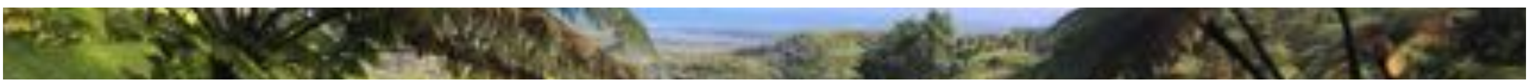


Chart courtesy of Transpower New Zealand AUFLS Technical Report August 2010, highlighting typical block separation.

To ensure the systems remain stable, sufficient separation is needed as demonstrated by the near failure of the system by the findings of the system operator in the North Island NZ. This is similar to the wide separation used in the Hawaiian grids which are unique in that they are often classic weak microgrids (especially on the smaller islands) with very large PV penetration and hence their new standards they are implementing.

Similar to the two islands of New Zealand (until significant amount of large Combined Cycle Gas Turbine (CCGT) where they faced plant damage below 47Hz) it is proposed that the Daintree Microgrid have a wide operating band to allow for sufficient load and generation block separation (including variation in PV generation to ensure not all inverters behave in the same way, ie having a dangerous simultaneous disconnect in the network). This ensures the system never becomes underdamped and thus collapses. The proposed upper and lower primary generation disconnect limits are 55 – 45Hz, which also roughly follows the Hawaiian grids (note they are 60Hz base).

In Germany, significant grid destabilization problems arose when high penetration levels of solar PV were reached because most of these DER were required to trip off within fairly small frequency tolerances.



The Daintree Microgrid Controllable Load and Generation are as follows:

- Synchronous Machine up to 4 X 850kW Lean Burning Reciprocating Engines (Fault Instant-ons Rotational Inertia and Spinning Reserve via motor controller)
- High Power Storage Generation (ITM or similar up to 5MW from 0-100% Load and Generation response within 1 second, external and frequency controllable. Additional security and modularity can be obtained using new rack battery and PCS such as the Poweroad and Sinexcel which are both fully modular (including turning off modules for efficiency) but can go from 0 – 100% charge or discharge within 50ms acting similar to the SA Tesla system in December 2017 ramping up to 100MW within 140ms due to coal power plant tripped out.
- AOFGS Solar Farms, these inverters will have ramp up generation rates (no ramp down due to no battery systems). Solar Farm inverters will have 6 different simple frequency watt power reduction ramps and deadbands to lessen system frequency oscillations (sudden reduction in generation then load then generation etc)
- AOFGS and Frequency Watt Control of Distributed PV Inverters, simple wide low frequency operation band for support, tight upper frequency disconnect PF 0.99 (Explicitly don't want AS 4777:2015 PF 0.9 due to voltage stability issues and excessive reactive power currents)
- AUFLS, assuming entire Daintree on controllable HWC load, approx. 1.5MW of potential load to remove (two blocks, block 2 central network block 1 outer network). Frequency control performed via local controller.
- AOFLS, as above but deterministic as there is about 128kL Hot Water tank capacity, at this capacity even at 1.5MW approximately 6mins to raise 1 degree, minimum tank temp 60C as per Australian Standard.

Synchronous Machines

Synchronous machines will be the prime source of grid forming, inertia and fault current production.

For system stability a minimum of two machines will be running (spinning). Because of the expected operating environment these machines will need to be able to operate over a large performance band with the following features needed:

- Low or No Load/Idling for at least short durations (Some Diesel plants suffer incomplete burn issues)
- Transient Pickup (Issue with older spark engines)
- Short cold startup time (Spark engine issue)
- Sufficient total Rotational Inertia
- Sufficient Fault Power to allow simple overcurrent and earth fault schemes.
- Wide Operational band (Power Factor)

The synchronous machines instantaneous inertia will allow for the other fast startup generation and load shedding devices to work as explained below.

Fast High-Power Storage

The storage devices have two components. One component is long term (multi hours to multiple days during dry season storage), the other component is energy absorption and storage at rapid high power rates to accommodate PV generation following. Such systems need to use both external commands (slower) and response to changes in system network frequency.

There are various different technologies currently available from fast response battery systems to fuel cells (power to gas/H2 and back to power).

For system stability, sub-second response is needed and is similar to that of AUFLS/AOFGS with respect to the expected delay.

In the situation of the Daintree, baseload needs to be supported. Baseload support via batteries is extremely expensive and so the fuel cell options have been explored. Additionally long-term energy storage is also problematic for batteries due to self/internal discharge, while this is very small large long-term storage losses due to this phenomenon is problematic. The impact of seasonality on utilisation factors for battery storage makes the investment in long term storage options too expensive when compared to other solutions.

In Northern Europe due to the high uptake of seasonally-sensitive renewables (especially solar) grid supporting systems are being developed.

During the market sounding exercise Sunverge approached a company called ITM who currently have a number of published, established Power to Gas (Fuel Cell) demonstration projects with major European power companies. Their system and ones similar have a 0-100% power response rate within one second (load and generation by monitoring the frequency directly).

Due to the low cost to physically store H2 per kWh this allows for a simplistic protection approach in that the highest priority after safety is grid stability and so any deviation outside the allowable bands include rates of change in frequency will trigger the fuel cell to support the network (next level net load following PV excess).

Below is an example of a unit operating in a load support characteristic, including rapid power change generation following.

This fast high power response characteristic of the primary storage device is the main reason why the PV arrays can be oversized as these units are the primary source of load balancing when PV generation is occurring.

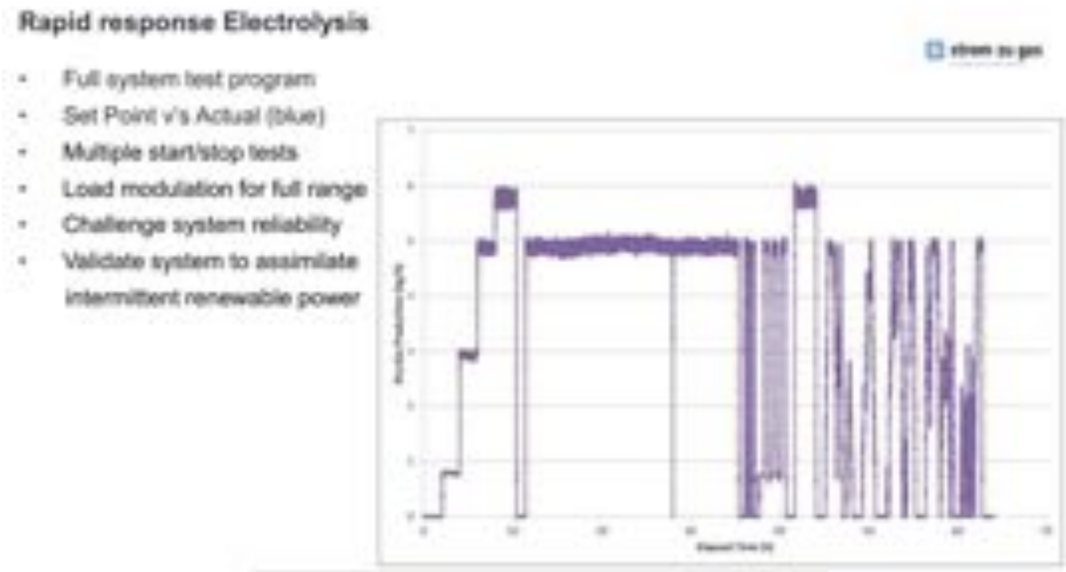
At night and during low PV generation periods these devices are primary fast acting load following generators working with the Synchronous machines to reduce the number of startup and shutdowns and total operating time but again since there total system power is far more than the entire network they are acting as both peaker and baseload power plants.

Like with national grid stability analysis, contingency analysis must be performed. The ITM unit, for example, is made up of many modular blocks lessoning the likelihood of a full system failure as failure in one is not critical.

In addition to reduce the losses and load on the MV network, it would be suggested that two locations for the main high power storage units be implemented, one being up in Cape Tribulation and the other next to the main solar farm.

The Cape Tribulation unit has two purposes, one to provide a voltage support capability as a volt/VAr function will also be implemented for both dispatch and absorption, but also as a emergency backup with a small diesel hire generation.

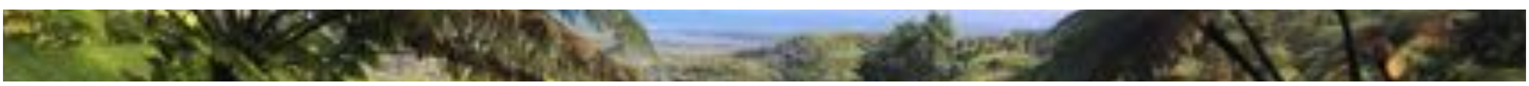
This will mitigate against the case of a large cyclone which washed out a section of road/MV cable as significant energy can be stored onsite in the H2 tanks for such an event (tank cost is rather marginal compared to equivalent in battery technology which also slowly discharges).



AOFGS Automatic Over Frequency Generation Shedding and Frequency Watt Control

This is primary used by the Solar PV systems but also any connected distributed generation.

One of the big issues with islanded systems even those of smaller nation states is the lack of diversity in such settings where either a significant proportion or all generators behave in a similar way due to their protection settings.



Such configurations can trip off to many inverter/generator systems and so an under frequency event occurs, this can then lead to load being tripped out but because these generators are no longer connected and if the load removed isn't sufficient the system may collapse (re-grid qualifying minimum using AS 4777 1min in the Daintree recommended 5min to allow for everything to settle down on Synchronous generation first).

The Solar farms will have 5 slightly different frequency watt curves. This variation allows for some damping of the system ensuring wild oscillations do not occur and eventual system collapse as they effectively act as a multi stage small block AOFGS.

AUFLS (Automatic Under Frequency Load Shedding)

Around 13% of the total energy of the Daintree is expected to be water heating with the heater elements being in total about ½ the available power of the peak load, traditional load control will be performed via the hotwater element.

This load disconnect isn't in the truest form typically called part of the AUFLS but in this microgrid we are not intending on physical MV disconnect of feeders as there aren't many (2 or 3 depending on exact site placement).

Due to energy conservation the hot water controllers will be set to absorb energy during the day, it is expected via some simple modelling that around 30% or 500kW of load should be removeable throughout the major PV generating period.

This is useful as it is expected that the periods where controllable load is important will be during the PV generation period due to things such as cloud fronts. Periods where PV generation is low will still be affected by sudden load changes but these are minimal compared to the rapid power change that is expected to be seen without battery coupled solar farms on the Daintree grid.

Similar to the previous statement around AOFGS, smaller blocks in relation to the grid size and block separation (in frequency) provide good stability. New Zealand provides a good example as they are effectively two separate islands (HVDC link) that has experienced many AUFLS events and can provide valuable learnings.

Above is the interesting 2011 event where a major generator was lost (frequency sampled at the lower and upper sections of the North Island).

One of the interesting findings from this event was that only 40 % of AUFLS tripped with the system frequency rising to 50 Hz. Had the full quantity of AUFLS tripped then the frequency would have gone very high, at 52 Hz the large gas fired plant will trip potentially returning the frequency back below 48hz, but this time without the protection of an AUFLS scheme to stop it and thus a black out on the North Island may have occurred.

This phenomenon is the same for generation disconnection and the reason for the diversity of settings being proposed for the Daintree.

Such controllable load schemes are common throughout the world including in Australasia. In Europe these controllable devices are also smart and that they also can report back how much load they can shed (refer AS 4755).

The above figure is an Australian DRED which could also be repurposed for such functionality. In this case the signal would come from the primary synchronous generator over a communication network (probably fibre laid in a duct inside main power system duct OR radio).

AOFLS Automatic Over Frequency Load Support

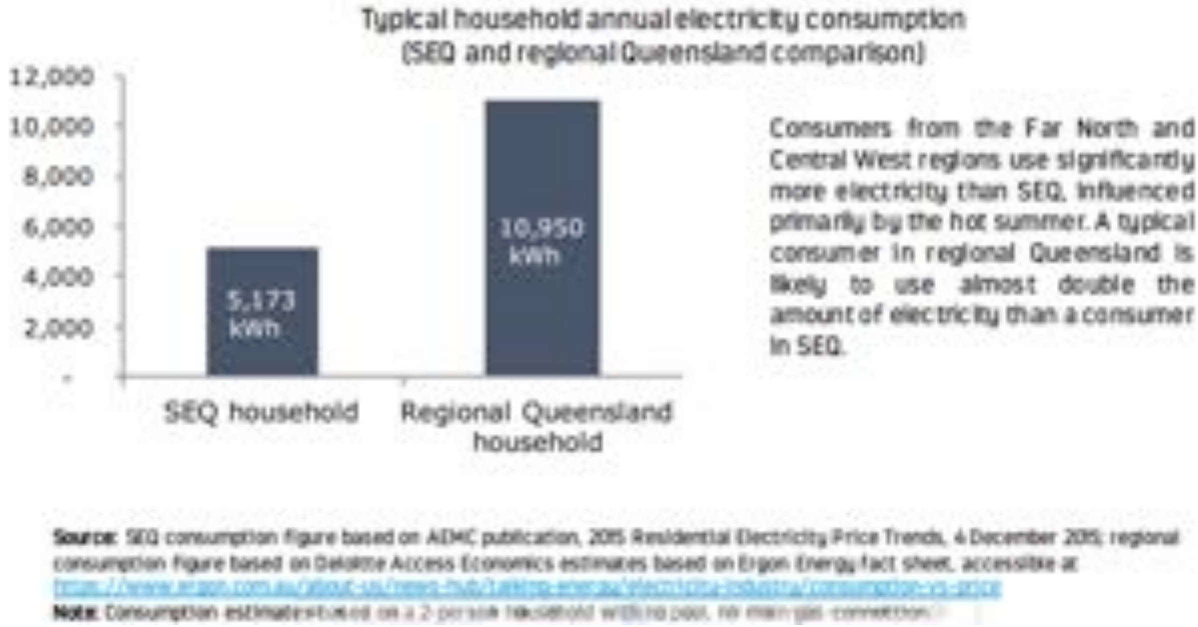
This option is less likely to be needed as the Solar farms will have ramp up rates and so will be more likely a function of the major energy storage device being slightly delayed (in the event of communication issue at the more remote location in Cape Tribulation).

Load Support is almost deterministic in this situation as the capacity of the hotwater systems to accommodate a short duration power request is near 100%. Hot water tanks are heavily stratified (water temperature) but even at a completely full tank operating just over 60C there is about 6minutes before the water in the system as a whole increases by 1 degree (ignoring small amount of thermal heat loss from tank wall to atmosphere). This again will use the same system as the AUFLS and thermal load support soaking up excess solar energy and so no more additional infrastructure is needed to provide this functionality.

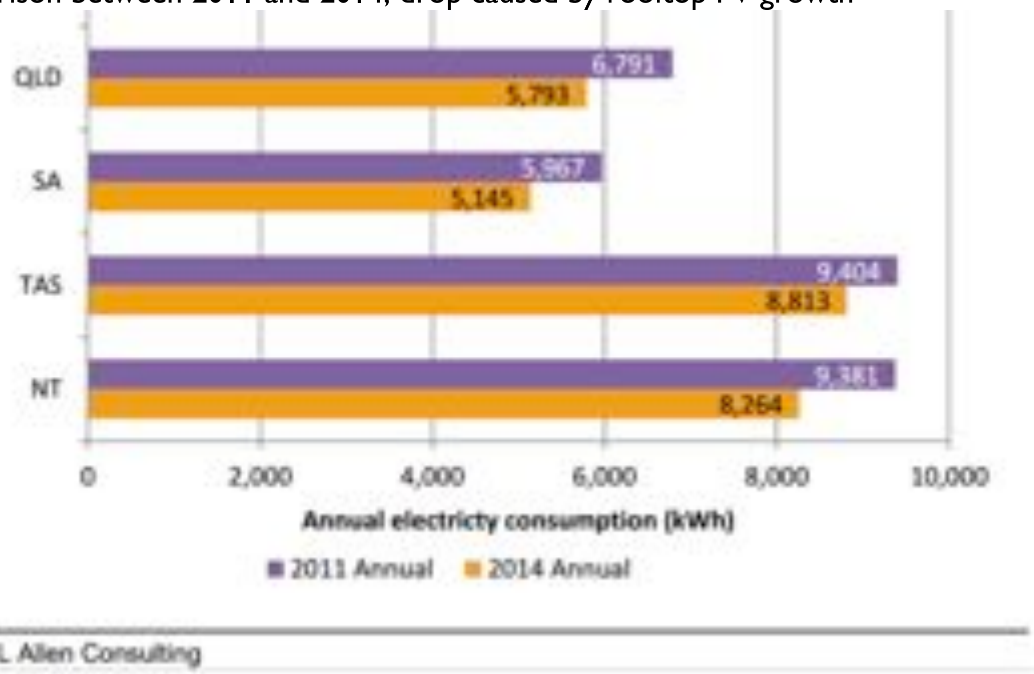
Attachment C - Methods for determining the Potential Electrical load at the Daintree (RES)

A range of available data and calculations was used to determine the potential electrical load for the community and for reconciliation with FNQ energy experts such as Ergon as specified below.

Queensland Consumption



Below comparison between 2011 and 2014, drop caused by rooftop PV growth



Cummings Daintree Survey

Capacity and Amount of Power Generated

- The survey does not allow for calculation of total power used but using FNQ Ergon averages, the 100 respondents would use about 1.6 million KWh per annum.
- Based on installed solar capacity estimated at 322 KW over the 100 respondents modified for inefficiencies and age of panels and based on Daily Global Solar Exposure equivalent of 5.3 hours per day at Cape Tribulation Store, total solar generation is estimated at about 500,000 KWh per annum.
- Total capacity of fossil fuel generators identified was 1,342 KW, about four times that of solar in the area.
- Based on hours of operation given in responses about fossil fuel generators, total generation would be 6.7 million KWh per annum. Obviously generators run at much lower levels than capacity.
- Installed generator capacity excluding solar is 6.0 KW per person compared with the national grid estimated at 2.5 KW per person, ie. 2.4 times higher than the national average.

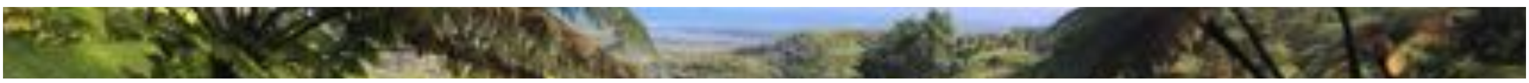
Using this FNQ per household is 16,000kWh/year, note some small businesses were included in this survey while some of the larger ones were missing in the sample (Daintree electrical consumers are very stratified with respect to significant demand usage between various properties, some properties alone account of a significant proportion of total Daintree load).

Ergon ADMD (After Diversity Maximum Demand) (MV/LV Tx point)

For Queensland and of particular interest FNQ, Ergon as published in their developer's handbook an ADMD of 5kVA (Residential) and for small Commercial a minimum of 30kVA is chosen (North of Mackay). As stated in the Developers handbook for other sites quote "the Developer to provide sufficient information on electricity requirements for the proposed commercial development to allow design works in current and future stages to ensure that the Distribution Network will have the capacity to supply these loads."

It should be noted in the past studies Ergon did in the Daintree back in 2013 they used 4kVA and 20kVA for Residential and Commercial sites respectively. While for the residential ADMD the Sunverge study aligned well the approach taken for the commercial was undersized, this however is to be expected as an in-depth investigation of the types of customers wasn't available to Ergon as it was for this study and others over the subsequent years. As explicitly stated commercial sites such as those in the Daintree especially around the Cape Tribulation region are large multi fully electrified cabins with AC thus significantly more than the 20 – 30kVA as per the generic Developers Handbook guide.

The ADMD especially for residential is useful as a reconciliation between the bottom up and Ergon's top down approach which has been successful in QLD for many decades, as was found both approaches reconciled well giving confidence of the bottom up approach and the corresponding 8760 profiles that were generated.



Ergon Daintree Scope for Microgrid

in **Attachment A**.

The expressions of interest have been grouped into six main regions (refer **Attachment B**) including:

- Cape Tribulation
- Diwan
- Cow Bay
- Kimberley
- Forest Creek
- On, or Near Network

The *On or Near Network* category refers to seven properties that appear to already have access to the grid, or do not fall within the exclusion zone. These properties have not been included in the cost estimates below.

Based on the information provided by residents, Ergon Energy has calculated the following approximate maximum load requirements for each community using the general assumption that private residences require 4 kilovolt amps (kVA) and businesses require 20 kVA:

Maximum Demand Loads

Site 1: Cape Tribulation – 350kVA

Site 2: Diwan – 350kVA

Site 3: Cow Bay – 400kVA

Site 4: Kimberley – 100kVA

Site 5: Forrest Creek – 180kVA

The following isolated generation units have been included in the estimated costs, based on the above estimated maximum demand calculations:

Developer Handbook

Rural Residential subdivisions have an average lot size greater than 2,000 m^2 each.

Ergon Energy recognises that Developers of subdivisions with average lot sizes larger than 2,000 m^2 may wish, or may be directed by the relevant local government, to install underground Electrical Reticulation.

5.1.2. Electricity supply requirements

As a minimum, Ergon Energy requires a single-phase 240 Volt supply to be provided to each residential lot.

The minimum designed ADMD allowance per lot of an Urban Residential subdivision, stage, or part thereof, is:

- 5 kVA per lot in all areas approximately to the north and to the west of the Mackay area, including the Mackay, Sarina and Moranbah areas; and
- 4 kVA per lot in all areas approximately to the south and to the west of the Mackay area,

except where otherwise detailed in the design parameters advice given to the Designer by Ergon Energy.

Where the Developer can provide evidence supporting a reduction in the designed ADMD allowance, this will be referred to Ergon Energy's Asset Manager for consideration and approval. The determination of an ADMD allowance higher than the standard allowance per lot for an area is at the discretion of Ergon Energy's Asset Manager.

5.2. COMMERCIAL AND INDUSTRIAL SUBDIVISIONS

5.2.1. General information

Commercial & Industrial subdivisions are characterised as having a minimum of two lots, and are generally required by the local government to be provided with underground Electrical Reticulation.

5.2.2. Electricity supply requirements

As a minimum, Ergon Energy requires provision for a 3 phase 30 kVA supply to each Commercial & Industrial lot, unless otherwise notified and agreed.

Compass Report using AVGS

5.2 Consumption

To provide some benchmark comparisons, the following provides estimates of likely consumption based on regional grid averages.

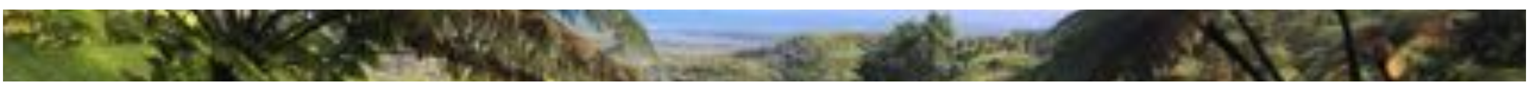
The Queensland Productivity Commission Report, March 2016, indicates that average electricity consumption per household in 2013-14 in the Cairns/Far North Queensland (FNQ) region was 6,678 KWh. Thus at FNQ area averages, the 96 households surveyed could be expected to be using 641,000 KWh.

An Ergon Data Summary Analysis gives electricity use in the Network in the FNQ region in 2012-13 as:

Residential .... 760 GWh
Businesses .... 1,153 GWh
Total .... 1,913 GWh

This ratio of 'total' use to 'household' use is 2.517.

Based on the FNQ averages, total use by the 100 respondents in the Daintree/Cape Tribulation area would come out at 1,613,000 KWh per annum.



NOTE: Cairns AVG consumption estimated at 6678kWh/year, this falls within mid ranges seen in various other publications (probably a fair assessment)

Bottom Up Diesel Consumption Residential

Averages to be used for different classes Diesel/year (Generic)

- Residential AVG over system 1560L/year
- Residential and Business AVG over system 5200L/year
- Business AVG over system 40300L/year

As part of a more comprehensive load investigation with the goal of providing hourly energy profiles (8760) needed for quantitative analysis in the various scenarios (DG availability capacity, short and long term storage, stability etc), annual diesel consumption was the most readily available data, especially for the large commercial consuming loads which due to their impact on total consumption patterns for the Daintree were of the highest criticality to get right.

From data previously obtained from the Daintree Power Committee we can see that for diesel consumption some of the larger commercial operators are using over 100,000 litres/year with the largest operator using nearly 350,000 litres (please note LPG gas is used for heating applications in this region).

From this data the number of residential, commercial and industrial loads it was estimated that there is approximately 4,000,000 litres of diesel consumed within the Daintree, this is slightly higher than some estimates of 3,000,000 litres but believed to be accurate as the Daintree Power Committee's survey acquired nearly 2,000,000 litres without many of the residential sites or all of the commercial sites, interestingly using a direct apportioning method to scale up for the missing components and the approach of using roof area for each class both reconciled well with this figure of 4,000,000 litres.

Compass comprehensive survey of a little over 1/3 properties (high residential saturation) below. Because of missing out a few large consumers in this survey overall system consumption is significantly lower than what is expected, however sample size was significant especially for the residential population and provides an in-depth view of this population.

4.2 Fuel Usage

Respondents were asked how much fuel they used and its cost.

The following table summarises by fuel types.

Table #31: Q22 – Indicated Fuel Usage

Fuel	Usage	
Diesel used	341,946	Litres
Diesel cost	$465,807.96	Year
Petrol used	53,956	Litres
Petrol cost	$77,579.90	Year
Bio used	884	Litres
Bio cost	$3,712.80	Year
Total used	**396,786**	**Litres**
Total cost	**$547,100.66**	**Year**

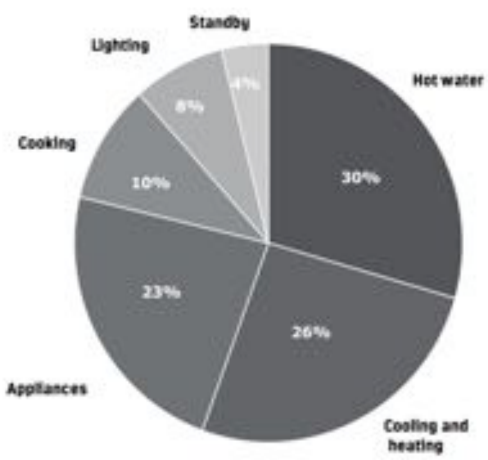
The indications are that about 400 tonnes of fossil fuel is used at a cost of $500,000 a year by the 100 residents/businesses surveyed. Average cost given was diesel $1.36/litre and petrol $1.44/litre.

Compass also uplifted and summarized Australian census data as seen below.

Census 2011 indicates that total residential population was 640 and households in the two relevant SA1s (including those connected to the grid) were as follows. In addition to residential population, overnight visitor population counted was domestic 305, international 245, total 550. On top of this, there would be substantial numbers of day visitors in the area on any given day.

	No.	%	(cf Australia)
Family households	159	*58%*	(72%)
Single and lone households	99	*36%*	(24%)
Group households	15	*5%*	(4%)
Total	**273**	***100%***	**(100%)**

Residential load breakdown using RACQ Queensland and Ergon



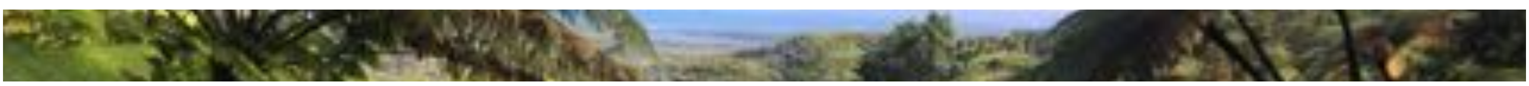
The typical electricity bill

The typical Ergon household customer uses 4,173kWh per year and spends around $385 per quarter or $128 a month on energy. See other living costs.

What contributes to your bill

The following appliances contribute the most to your energy bill:

Appliance	% of home energy use
Air conditioning and home heating	40
Water heating (hot water tank)	21
Lighting	6
Television	6
Cooking	5
Fridge and freezer (standard-size combined)	5
Dishwasher, clothes washer and clothes dryer	2
Other appliances (including computers, tablets, gaming consoles)	15



Above is the typical breakdown of the different load consumers within a typical QLD residential dwelling, this along with the Compass Report, verified electrical efficiency conversion allows for a bottom up approach for total energy consumption to be performed as seen below.

Average Total Energy per Class

Obtaining total consumption data needed the addition of gas (LPG), removal of existing PV and addition of expected loads such as AC which is very low due to energy poverty conditions in the Daintree, walkthrough below.

Residential only 14% update in AC, data indicates for FNQ between 26% - 40% Heating and cooling, taking the average this is **33%**, smearing over the Residential class to account for existing uptake this is 0.33*(1-0.14) = 28.4% potential additional load.

75% use gas for hot water, hot water makeup for FNQ is 30% - 21% (RACQ/DEWS vs Ergon) on average this is **26%** OR 0.26*0.75 = 19.5% additional load.

99% use gas for cooking, cooking makeup for FNQ is 5% - 10% AVG **7.5%** OR 7.5%*0.99 = 7.425% additional load.

Total additional load is (1 + ((28.4 + 19.5 + 7.4)/100))*(1560) = 2422L/year
Using 11.1kWh/litre Diesel @0.28 (small diesel motor) conversion 2422*11.1*0.28 = 7527kWh/year, Cairns is 6678kWh/year (uncertain if this also contains gas or not), regional Queensland is 10,950kWh/year (two person residence, AVG Daintree from survey 2.3). With no Air Con uptake 1974*11.1*0.28 =6135 kWh/year.

Since Daintree is often overcast with a large wet season which runs from December to April (Summer months for rest of QLD) it is expected that the consumption requirements for the AC will also be lower.

Temperature from Daintree.com

Daintree Average Monthly Maximum Temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av Max C	32	31	31	30	27	26	25	27	28	30	31	32

This is similar to Cairns (slightly hotter) however significantly higher rainfall is expected thus reduced localized heating esp around the trees in the Rainforest.

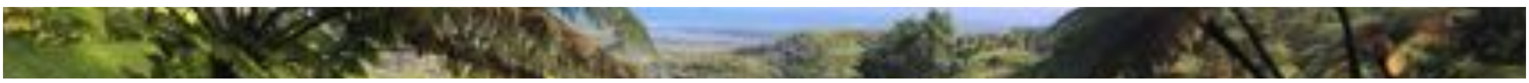
AC Reduction (slightly arbitrary) (0.5*5 + 1*7)/12 (Rainforest and Uptake) therefore 0.8*28.4% OR 22.5%.

Total AC LOAD 2330L/Year OR **7,243kWh/year EQV**.

Total Residential Homes 273 @ 7243kWh/year approx = 2M kWh/year OR **2GWh/year Residential.**

High Level Micro CHP Energy Analysis

- Total 2 GWh/year



- AC 0.45 GWh/year
- Hot Water 0.52 GWh/year
- Electrical 1.48GWh/year @ 0.285 CHP 3.9GWh/year heat 3.7GWh/year wasted (Total efficiency is (1.5 + 0.5)/(5.2) = 38.5% @ 0.33 CHP (1.5 + 0.5)/(4.48) = 44.6%.(Yanmar 5kVA vs 10kVA machines)

Rough Electrical Consumption to optimize CHP (Offset via PV RES)
Hot Water Residential Consumption is roughly 0.52 GWh/year, using Yanmar's 0.33 and 0.285 (10kVA and 5kVA Electrical output).
0.52*0.285 = 0.148 and 0.52*0.33 = 0.172GWh.

Total Electrical demand is 1.5GWh therefore (1.35GWh and 1.3GWh respectively on PV)
Approx 2.1MWp install at 3.6 Solar Peak hours this is 2.7GWh full self consumption and on all buildings.

Residential Property Profile Groups
GIS system used to find total roofed area of buildings greater than 10square meters (removed what is probably unpowered Sheds).

Existing Res PV Install Cap

Estimated installed solar capacity .... 322.85 KW

Adjusted for general efficiency factor CSIRO research 0.92... 297.02 KW

Using 297kW install and a conservative 50% spill typical range 40 - 60% with no energy storage or active hot water cylinder control.

Using 3.6 Solar Peak hours 50% self consumption this represents 82% of the community.
297/(0.82*273) = About 1.3kW install cap, probably more like 70% self consumption due to variation of install size.

1.3*3.6*365*0.7 = 1195kWh/year without storage.

Electrical consumption (1-0.26)*7243 = 5360kWh, Existing Solar 1195kWh therefore total consumption Electrical Consumption is ((5360*273 + (1195*0.82*273))/273)*(1-0.07425) = 5869kWh/year + 2294kWh/year Water Heating + 662kWh/year Cooking.

Existing Solar Pro-rata 1195*0.82 = 1000kWh/y
Estimated Average Electrical Load 4869kWhe + 2294kWht + 662kWht

Efficiency of 5 and 10kVA machines
(4869 + 2294)/(17084) = 41.9% 5kVA no Battery Storage or Additional PV
(4869 + 2294)/(14754) = 48.6% 10kVA no Battery Storage or Additional PV

Estimate 2kWh battery + another 1kWp PV (exp 300W panel enough fit)
3.6kWh therefore worst case 2 divide 3.6 or 55% self consumption
2*365 = 730kWh/year
(4869-730 + 2294)/(14522) = 44.3%
(4869-730 + 2294)/(12542) = 51.3%

Gas roughly is 12c/kWh 5kVA vs 10kVA 17084 - 14754 = 2330kWh spill or $280/year
5kVA with and without 1kWp PV and 2kWh battery 17084 - 14522 = 2562kWh or $307/year
10kVA with and without 1kWp PV and 2kWh battery 14754 - 12542 = 2212kWh or $265/year, no point.

Total Expected Load Full AC uptake
4862*(1+0.07425 + 0.195 + 0.225)/0.9 = 8070kWh/year OR 7787 kWh with energy efficient bulbs

- AC 2663 kWh/year
- Hot Water 2098 kWh/year
- Cooking 605 kWh/year
- Lighting 565 kWh/year Energy Efficiency Mode 282 kWh/year
- Standby (4%) 322 kWh/year
- Other 1817 kWh/year
- Electrical Load 5084 kWh/year
- Thermal 2703 kWh/year

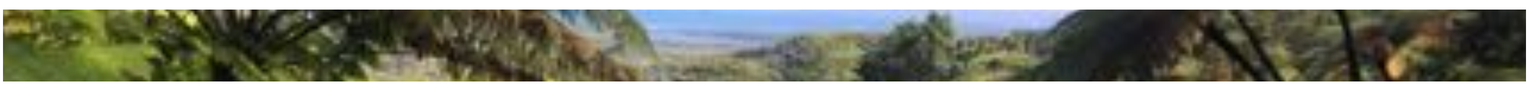
Total Expected Load Existing no AC and energy efficient bulbs
8070*(1-0.225) = 6254k - 282kWh = 5972 kWh/year

- Electrical Load 2421 kWh/year
- Thermal 2703 kWh/year

Expected Res Load High Low Site
273 Sites

- High 7787 * 273 = 2.12 GWh
- Low 5972 * 273 = 1.63 GWh

Commercial Hot Water (Using Tropics Hotels)



3.5. *The Breakdown of Hourly Water Use in the Hotel in Vietnam*

The breakdown of hourly hot and cold water use in a full and half toilet flush, in the shower and in the bath-tap at the hotel room is shown in Figure 5.

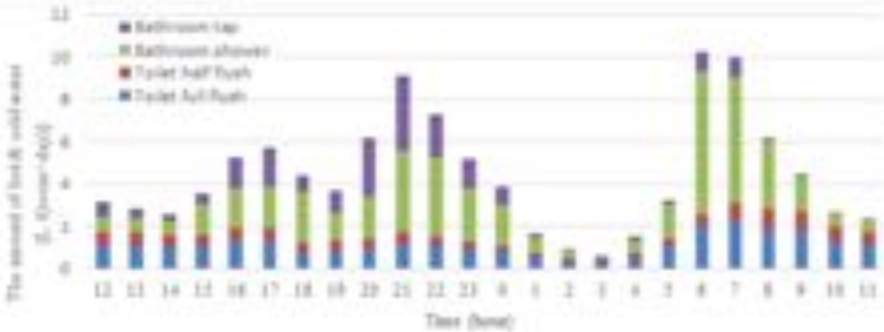


Figure 5. The breakdown of the hourly hot and cold water use.

The average amount of hot and cold water use is 144.6 L/(room per day), of which the full toilet flush accounts for 27.3 L, the half toilet flush for 17.3 L, the shower for 69.6 L, and the tap of the bath for 30.3 L. Although the tap for the sink is not included in the hot and cold water usage amount, its share in the room's total hot and cold water usage is seemingly very low. Previous studies in Japan show that the use of the sink accounts for just 5% of the total water usage. The data also reveals that each

Table 2. The operation rate and occupants per room.

Total	Operation Rate (%)	Number of Occupants (Person/Room)
Average	68.7	1.43
Standard deviation	9.1	0.08
Maximum	85.2	1.59
Minimum	58.6	1.31

Table 7. The statistical values of toilet and shower use.

Characteristic Value	Toilet Use Action per Person		Shower Use Action Per Person		
	Full Flush (Time/Day)	Half Flush (Time/Day)	Water Volume (L/Time)	Time (Min/Use)	Temperature of Hot Water (°C)
Average	3.3	3.0	48.1	7.3	37.7
Standard deviation	2.3	2.2	34.7	5.2	2.9

Table 9. Showering habits in Japan.

The Investigation Object	Shower Use Action per Person			
	Water Volume (L/Time)	Instantaneous Flow (L/Min)	Time (Min/Use)	Temperature of Hot Water (°C)
A model of a Japanese household [10]	84.6	10	Summer: 7.6 Winter: 9.4	Summer: 39 Winter: 40

Compare against NT Hotel
Gas approx 32% Energy, Hotwater consumption from Gas being 33%, Cooking 37% and 52% of Electricity being HVAC.

Hotwater Total Percentage = 0.32*0.33 = 10% of Energy demand using Darwin as a comparison.
Cooking 0.33*0.37 = 12%
HVAC 0.68*0.52 = 35%.