Final Project Report

The Flow on Benefits of Microgrids for Agriculture

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Abbreviations

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ARENA	Australian Renewable Energy Agency
CERs	Consumer Energy Resources
DNSP	Distribution Network Service Provider
DUOs	Distribution Use of Network
ESG	Environmental, Social, and Governance
FCAS	Frequency Control Ancillary Service
kW(h)	Kilowatt/kilowatt hour
LEM	Local Energy Market
LUOs	Local Use of Network
MW(h)	Megawatt/megawatt hour
NEM	National Energy Market
NPV	Net Present Value
PV	Photovoltaics
QFF	Queensland Farmers' Federation
QREZ	Queensland Renewable Energy Zone
RIT-D	Regulatory Investment Test - Distribution
RIT-T	Regulatory Investment Test - Transmission
TNSP	Transmission Network Service Provider
TUOs	Transmission Use of Network
VPP	Virtual Power Plant

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Executive Summary

Unsustainable electricity costs are eroding the viability and productivity of many agriculture businesses and alternative solutions are needed. Tariffs are often ill-suited to the seasonality of ag energy use and on farm renewables are often underutilised without retailer options to share energy across meters on site or incentives to share locally. Reliability, increased electrification, power of choice, and decarbonisation present additional drivers for farmers to pursue greater energy independence and business resilience.

The *Flow on Benefits of Microgrids for Agriculture* Project explored the feasibility of microgrids as an alternative solution across four different farming scenarios in Queensland and New South Wales, each representing a practical and replicable microgrid archetype.

- Archetype 1: Single Enterprise, Pokolbin NSW, winery
- Archetype 2: Edge of Grid, St George QLD, cotton farm
- Archetype 3: Large Microgrid, Mackay QLD, cane farmer cluster
- Archetype 4: Anchor/Hybrid, Wee Waa NSW, mixed commodity farm

Archetype 1 demonstrated marginal benefit on purely project economic terms, Archetype 2 and 4 presented viable grid connected but islandable microgrid scenarios, and Archetype 3 presented a viable virtual microgrid scenario with recommendations to instead consider yielding wider local benefit via a Local Energy Market (LEM). Once secondary value streams were presented the investment proposition of microgrids improved to varying degrees pending individual farmer priorities. Alternative 'lowest cost' solutions were also presented to each participant.

The Project found considerable underutilisation of substations at each case study location demonstrating the opportunity agriculture microgrids can present to regional grids if appropriately integrated into network revenue models and strategic planning. Acting like energy dams on regional grids, microgrids can offer grid firming services and emergency supply. Enabling state and federal regulation is necessary to unlock the full value stack for microgrids however distribution upgrade deferral payments are a good example of existing valuation mechanisms that could revaluate their remit and better value microgrids and other dispatchable Consumer Energy Resources (CERs).

Learnings, opportunities, and recommendations include ag tariffs anchored to productivity levers, regulatory innovation mechanisms, TUOs/DUOs/DUOs or other network tariff reforms, microgrid tariff modelling and trials, energy data rights and standards, accessible connection processes for microgrids and other dispatchable non-network loads, and the inclusion of local energy solutions in regional grid planning. Progress on all fronts is poised to bolster the productivity of agriculture in Australia and the resilience of regional communities as we navigate the energy transition.

The Project consortium is currently undertaking further works based on the results of this study including advancing project development of viable microgrids, follow-on research, and advocacy.

Introduction

The Energy Transition in Agricultural and Regional Communities

With energy as a core productivity input, the energy transition has the potential to disrupt the levers of agricultural production. Queensland Farmers' Federation members report reduced planting and irrigation due to energy pricing via tariffs not suited to agriculture's seasonality and reliability issues are an increasing function of Australia's aging grid. Farmers and regional communities are seeking to improve their energy resilience after subsequent years of extreme weather events and food producers are under pressure to decarbonise to help reduce Scope 3 emissions for their corporate buyers.

The power of choice enabled by distributive energy resources (DERs) means access to affordable, reliable, resilient, and clean energy is increasingly democratised, transitioning from the bottom up. Farmers have adopted energy efficiency changes and solar in pursuit of that energy independence. However, as feed-in tariffs continue to diminish and energy sharing between meters or farms is not permissible, on farm DERs are increasingly underutilised. Depending on the priorities of the farm, that underutilisation is acceptable due to other values such as back up supply and decarbonisation. But the tension between rising energy prices and improving CER affordability is leading many farmers and regional consumers to consider smart energy innovations like microgrids, community batteries, hydrogen production, virtual power plants (VPPs) and other energy sharing and optimising mechanisms.

The network impact of democratised energy infrastructure is difficult for utilities to metabolise into their legacy networks and financial modelling while maintaining equitable grid participation. Reduced utilisation of the network due to consumer DERs can result in similar dynamics to a death spiral if not appropriately integrated or mitigated. Distribution Network Service Providers (DNSPs) are therefore challenged to find ways to generate revenue should consumer energy systems like microgrids enter the energy market, while simultaneously transitioning utility scale generation to renewables.

There is no doubt the proposition of grid modernisation throughout this transition is complex and requires considerable investment. However, the appetite for democratised community energy infrastructure, like VPPs and community batteries, in regional communities creates opportunities to reduce demand on transition networks, build local resilience, and optimise local use via various grid services. Local energy ensures benefit remains local in ways utility scale wind and solar will struggle to deliver. The integration of community energy could change the investment profile of the transition, should regulation enable their valuation across the national energy market.

The Microgrids for Agriculture Working Group

The *Flow on Benefits of Microgrids for Agriculture* project ran from July 2020 to June 2022 supported by a working group comprised of the project consortium: The Queensland Farmers' Federation, Cotton Australia, ReAqua, and Constructive Energy.

The Project Advisory Committee and the Project Board consisted of professionals from the following organisations:

- Clean Energy Council
- Constructive Energy
- Cotton Australia
- Energy Queensland
- Essential Energy
- Infinite Energy Analytics
- National Irrigator's Council
- National Farmers Federation
- NSW Farmers Association
- Queensland Farmers Federation

- ReAqua
- Sustainable Energy Design
- VSUN

The Purpose and Scope of this Final Report

The *Flow on Benefits of Microgrids for Agriculture* project assessed whether microgrids can offer benefits to electricity consumers and networks such as reduced costs in the rural and ag irrigation sector, stable network energy flows, increased network utilisation, and increased uptake of decarbonised and distributed energy systems.

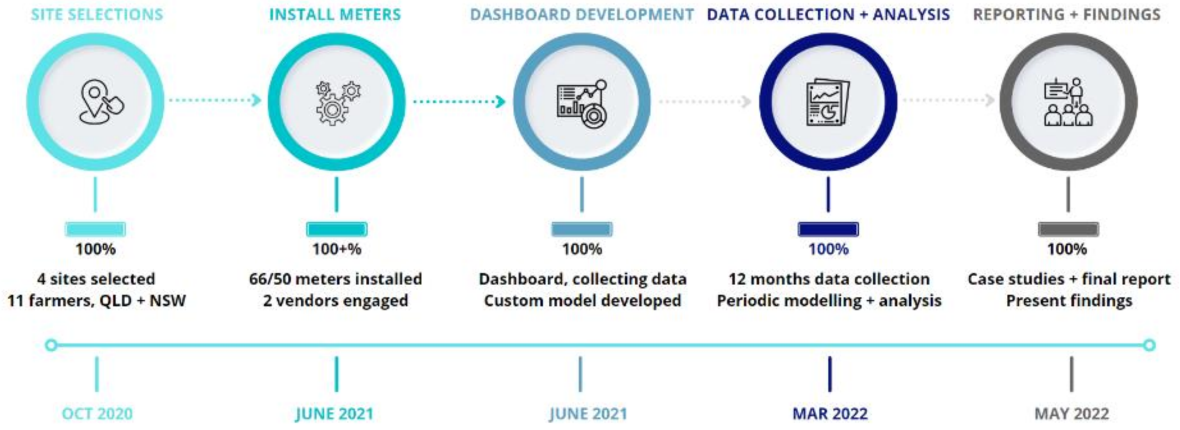
The project modelled four demonstration virtual microgrids across four farming regions in Queensland and New South Wales. Each site evaluated a unique microgrid archetype and tested the following overarching questions:

1. Can microgrids enhance the competitiveness of agricultural industries, particularly irrigation by optimising energy consumption and generation across multiple sites?
2. At what scale and in what locations could microgrids benefit agricultural enterprises, communities, and energy networks?
3. How should microgrids in agricultural communities' best be approached in relation to embedded solar generation, storage and energy sharing models such as Peer to Peer trading?
4. What are the benefits to local networks from understanding energy flows in real time, including the opportunity to stabilise networks and increase network utilisation?

The purpose of this final report is two-fold, 1) to fulfil reporting obligations to the Grantmaker, and 2) to discuss and share the methodology, findings, learnings, and recommendations of the project with the hopes of offering insights to farmers, networks, regulators, and other relevant stakeholders.

The Microgrids for Agriculture Workstream

The workstream for the The *Flow on Benefits of Microgrids for Agriculture* project is as below. COVID-19 resulted in some delays to project delivery including installation of smart meters. This impacted the completion of reporting which commenced in Q1 2022 and was completed in September 2022 with an extension granted by the grantmaker.



Modelling and Analysis Methodology

Microgrid Types and Archetypes

A microgrid is defined here as a controllable energy network that generates and distributes energy within its own footprint. Microgrids can be stand-alone or grid connected, with grid connected configurations often able to switch to 'island-mode' as needed; typically in the event of a grid outage.

The project evaluated four microgrid archetypes representing commonly occurring agricultural energy users. Each archetype and corresponding case study had to show the potential to benefit from practical, impactful, replicable, and scalable microgrid scenarios.

The four archetypes explored were:

1. Single Enterprise
2. Edge of Grid
3. Large Microgrid
4. Anchor/Hybrid

Identifying common archetypes could help de-risk microgrids, prove scalability, and bolster their value proposition to the agricultural industry, while demonstrating the application of disruptive technology for network planning.

Energy Data Collection

Entry Surveys

Baseline entry surveys were conducted to understand the current levels of knowledge and attitudes of the farmers participating in the microgrids study so that changes could be identified over time.

The project team were able to identify motivations for participating in the study, current energy literacy, what the participant's ideal energy use scenario looked like and their level of risk in joining a microgrid that could be disconnected from the grid. The survey included operational insights and facts about what is on site, how it is used across the farm/season, which later informed the project's data dashboard and modelling opportunities.

Key insights included:

- **Electricity is seen as too expensive, and growers can quickly list their biggest on-farm energy users.**

  "Pumps for irrigation."

  "Cool room costs us $5K a month but it's very old, about 25 years old."

- **Further impacting on business sustainability is the parallel pressure of the rising price of water for irrigation, causing them to look for solutions.**

  "Spending twice as much to extract to have as much water, had to look into how to be more efficient on farm."

  "Normally I would irrigate at night but with the addition of solar a couple of years ago, I now start at 6am instead of 6pm and turn the pumps off at 5:30pm at night; last year this cut my bill by 50%."

- **Farmers are keen to understand alternative energy solutions and ways to share energy across their farm and with neighbours.**

  "If the whole community is gaining out of it, less power costs for everyone is probably the main thing."

  "It goes back to costs. The more people you get involved in it the better the cost. Collective [action] helping to drive the price down."

- **There are a range of motivators for participating in the microgrids project and not just about reducing energy costs but also securing more reliable energy.**

  "Had some issues with power dropping out during hottest months in 2018 and 2019. Usually for 10 to 40 minutes in peak of rolling blackouts. We have had threats of "may lose power" during harvest which is a big worry."

  "We lost power for five hours a few days ago, they were working on the poles. It's the second time in three weeks."

- **Wanting to decarbonise has also been cited as a motivation for participants.**

  "Lots of people are aware of their impact on the environment, who would want to source green and local energy."

  "We could power everything with the 65kW solar if we could share it both across National Meter Identifier (NMI) and the full 24 hours."

  "Everybody would like to be able to share the power they make. Where we are, we're dragging power from the power station, and they lose about 30 + 40% of the power getting it here! Doesn't make sense."

- **While only the start of the project and their level of knowledge around how microgrids work and their benefits is low, growers are keen to share their knowledge as they learn more about renewables, microgrids and energy sharing.**

  "Everyone's got an open mind. A couple of the neighbours have got pretty big solar on their pumps already. They might want to share it!"

  "A lot more people are going greener these days. And if they are supporting their local farmers – people would support that."

Real-time Smart Metering

Real time energy data over a 12-month period was essential to establishing an energy profile that fed into consumer dashboards. More than 65 smart meters were installed across the four case study sites. Two vendors were selected to provide the smart meters, Redback Technologies and CarbonTRACK, with local electricians managing installation.

The use of two vendors demonstrated the variable maturity in Australia's smart meter market including the ability to reliably deliver data where regional consumers had patch connectivity and the ability to translate data into usable information. Where energy data gaps existed, energy bill or extrapolated data was used.

Historical energy bill data was also used to help determine whether the observed year was an average or unusual profile for the farming enterprise in question. The process of accessing historical data from existing retail meters highlighted the importance of utilities providing a streamlined way for consumers to access their data in in real time. Many farm sites house old network metering devices incapable of providing interval data but even where good meters exist, utilities and retailers do not enable easy access to the data or an intuitive interface to understand what it means. Correspondingly, consumers have poor awareness of their energy consumption patterns, lack the tools to make informed tariff choices and are unaware of opportunities to participate in market initiatives.

Real-time Dashboard

Redback Technology and CarbonTRACK both provided real-time dashboards of the corresponding smart meters installed. Both providers enabled on-line access via computer but only CarbonTRACK enabled an app for viewing via smart phone. The data fed from smart meter to dashboard was also fed directly into the Project's modelling and analysis tool.

A bespoke version of Redback's Luceo platform was delivered to participants with limited functionality. CarbonTRACK's market ready dashboard was delivered to relevant participants with additional functionality for alerts and demand response programs should the consumer wish to engage.

Both platforms had fair engagement over the course of the project with the more energy literate participants seeking it out most, typically to verify their energy bills or that installed solar PV were functional.

Network Energy Data

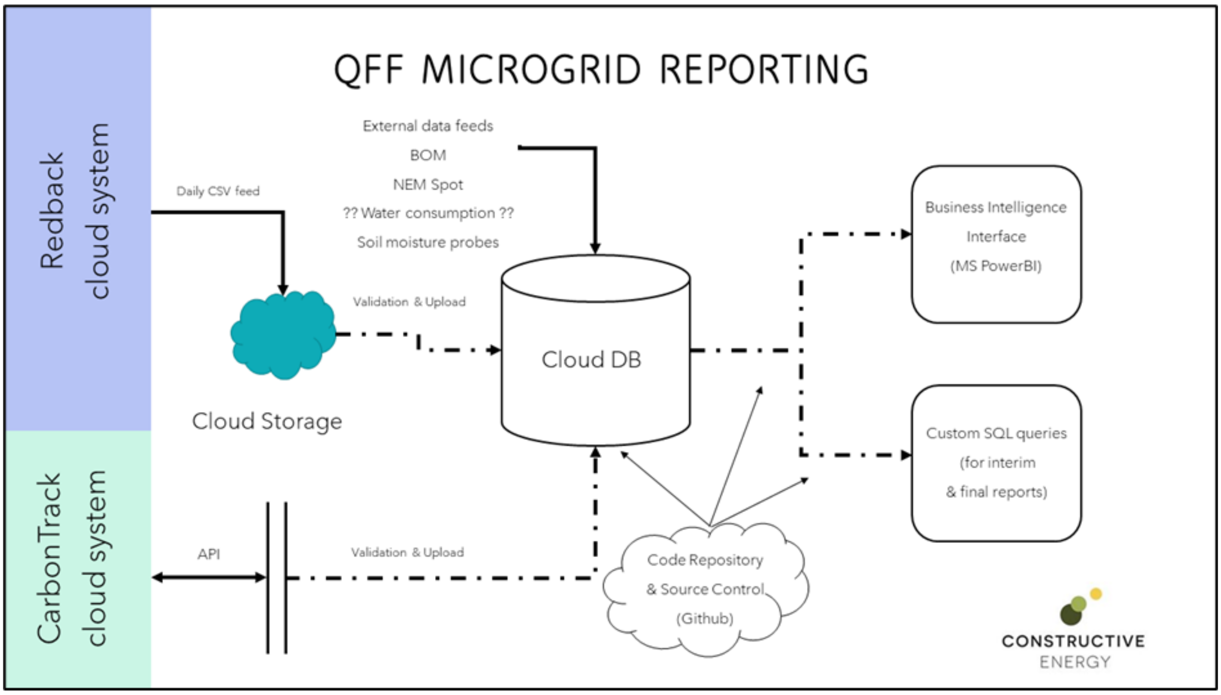
Zone substation data was collected from Ergon Energy, Essential Energy, and Ausgrid via publicly available and requested utility data sources. Annual and daily energy profiles, load duration curves, and embedded generation data were collected, where available, and analysed to determine how case studies could impact and benefit the local network.

Energy Data Modelling and Analysis

The monitoring devices were capable of recording a wide range of energy-related factors from forward and reactive power, to voltage, to frequency at minute intervals. Collecting all information for 1 year would have become unwieldy and much of the data was of marginal benefit to the study, so information was gathered in 15-minute intervals.

To test the project hypotheses a bespoke database was required to merge, store and analyse the data captured by the two types of electricity meters installed. Constructive Energy developed a database for this purpose using cloud-based technologies, the Microsoft (MS) Azure cloud platform. This platform has easy-to-use and accessible storage and analytical tools ideal for this project.

As described in the diagram below, an ETL (Export Transform Load) process was developed using MS Data Factory. Data was received from both vendors using two different methods. Redback provided the data via FTP using daily CSV import files. CarbonTrack has an API interface available for data extraction.



Once received the data was imported into staging tables. After being imported it was validated, checked for duplicates or any invalid data, then imported and merged into the reporting schema.

Once in the reporting database, the data could then be analysed using the MS PowerBI reporting tool or via custom SQL queries.

For the final report, the validated reporting database was used as the primary source and put into Constructive Energy's custom 'flow-model' which allows for accurate sizing and financial modelling of potential energy systems.

The custom Flow Model is a multi-tabular Excel spreadsheet utilising formulas, pivot tables and macros to enable manipulation and visual representation of data. Tab label and functionality included-

- Energy Flow – the main model interface with key variable fields to modify. Also the sheet which applied the powerplant control logic via embedded formulas.
- Net Flows Graphs – pivot tables and charts to visually represent load and generation profiles
- Loads – data supplied from the SQL query relating to site demand
- PV Watts – calculating platform for solar performance modelling
- NEM – spot price interval data
- Degradation – staging sheet to apply varying degradation figures to solar PV and battery tech
- Retail Charges Before – sheet to reverse engineer billing inclusive of time-based network, demand, retail and standing charges
- Retail Changes After – sheet to reflect impact of powerplant on billing
- Loan Amortization Schedule – standard accounting format to calculate repayments
- P&L – aggregation of powerplant performance data (energy flow) & financial assumptions

The custom flow model was validated both within the project group and also via two external and independent organisations. At each review the model was found to be robust and accurate.

Constructing and Simulating Energy Profiles

Load profiles were readily represented from the monitoring device data individually or in aggregate groups – an outcome which provided insight in itself. Capacity existed to time shift or invert loads.

Energy generation profiles were created from a 100kW generic, fixed solar array modelled at the site location. Keith Tulloch Wine was modelled on a north-facing fixed array, all other sites applied east-west orientation akin to the peg-mount approach. These modules were scaled by percentage to superimpose generation capacity onto the load and battery.

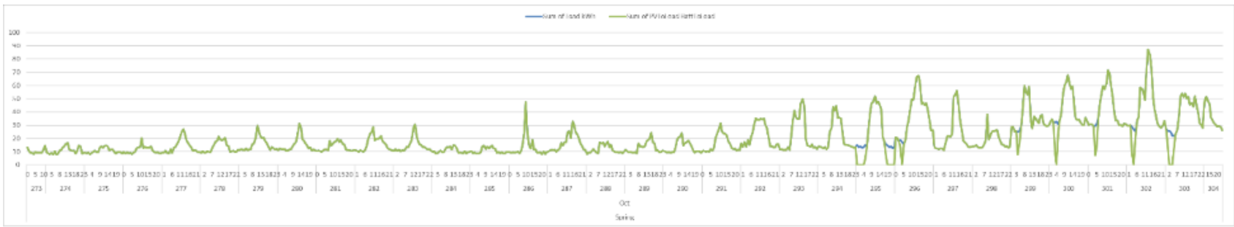
Battery performance was modelled using specifications from the manufacturers of Sungrow LiFePO batteries. Control logic was embedded into formulas in the Flow Model to both load-follow and respond to market or network signals, such as price spikes.

By altering financial variables and powerplant component sizes, the project team were able to push the model to investigate the impact of different project drivers such as carbon, versus least cost, versus best value. This gave the team a good understanding of viability thresholds and how a powerplant might work in the various microgrid scenarios.

Simulating Shortfall Events

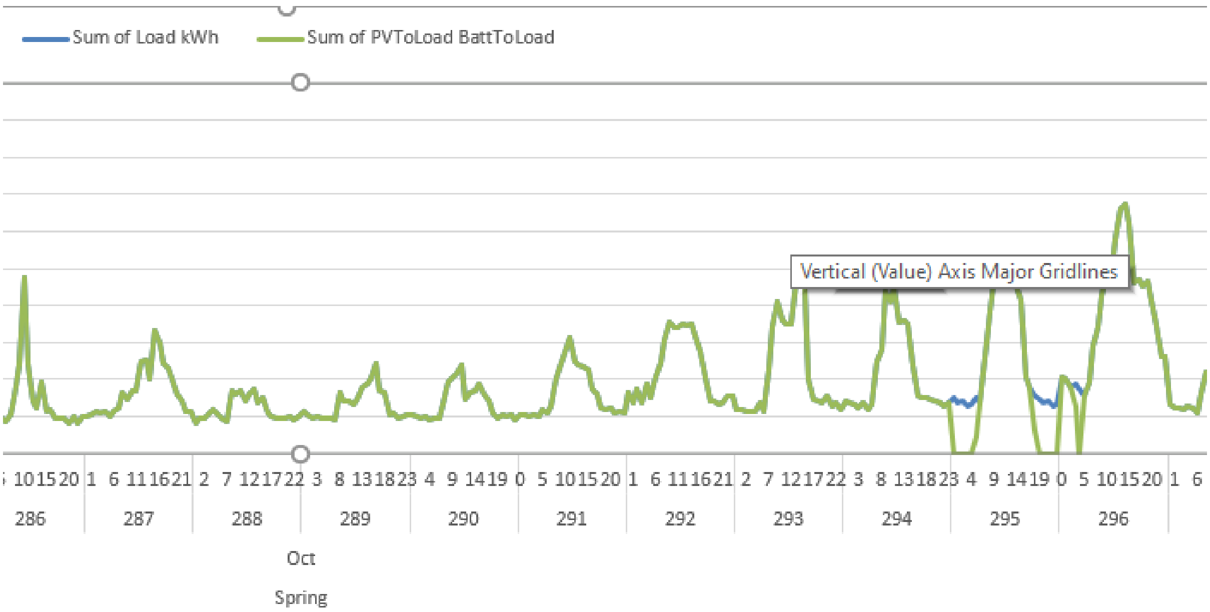
A key indicator for powerplant sizing is the presence of shortfall events which were visually represented in the Net Flows Graphs. This helped understand when shortfalls might occur and if the best strategy might be increasing the powerplant size or modifying demand.

Below is an example which is the KTW simulation for the month of October where the sum of the solar + battery (in green) has been laid over the sum of the load (in blue). It clearly shows both the daily load increasing during daylight hours and the gradual increase in demand over the month as chilling of produce and buildings begins to require more energy with ambient temperatures increasing.



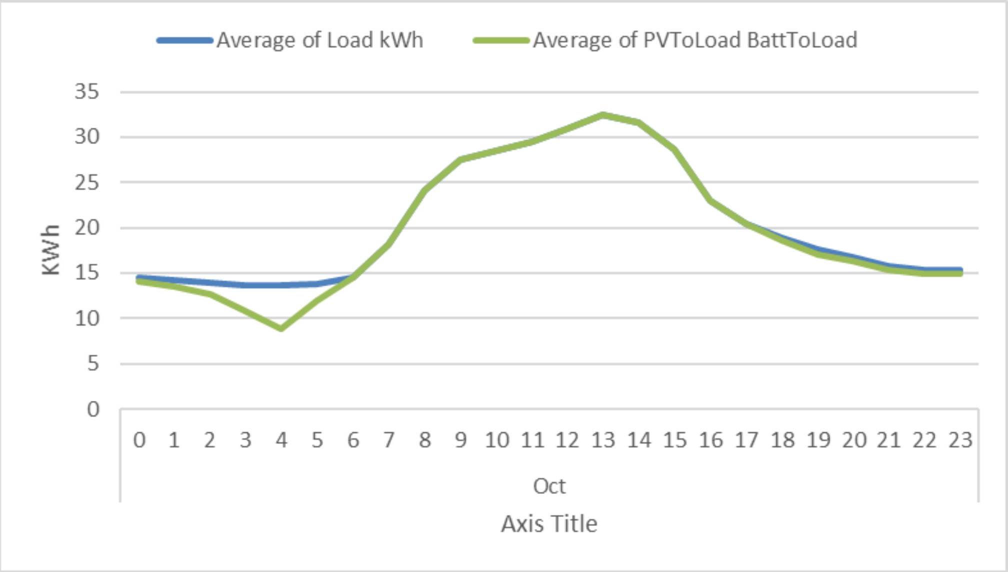
Simulation of the sum of load and solar + battery - October

For the vast majority of the month the load is fully met by the standalone system as specified below, with very little blue appearing across the month. However, the generation simulation includes variable weather and periods of low solar incidence. In the October excerpt below, the blue line represents a period when either a generator, or if connected, the grid network would be required to fulfill the demand. Alternatively, load shifting or energy efficiency measures may also have been able to reduce demand enough to avoid this shortfall.



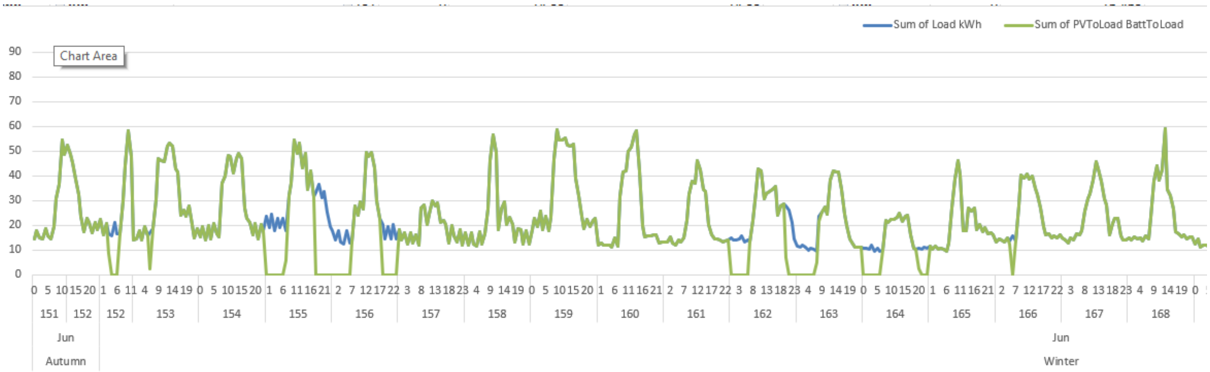
Simulation excerpt demonstrating shortfall event - October

The chart below displays the average profile for the month over a 24+hour period. This indicates that the shortfall occurs in the early morning hours when the battery has been fully depleted.



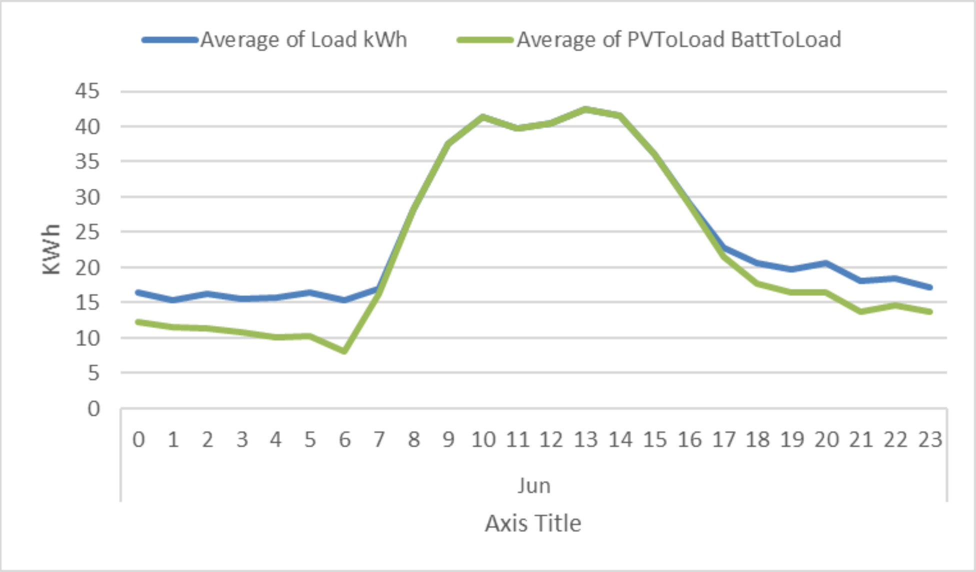
Simulated characteristics of a daily shortfall event - October

Examining the profile for June, the lowest solar production period and sustained high demand, indicates the expected increase in shortfall between load and generation capacity.



Simulation of the sum of load and solar + battery - June

Examining the daily average is useful and, in this case, indicates that there is a shortfall in supply during both the evening and the morning. Again, this could be ameliorated by either increased solar production or reduced demand. Note that both will have a cost but reducing demand is usually more cost effective than increasing supply. This is particularly true for off-grid systems as the ability to cover the last few percent has diminishing returns.



Simulated characteristics of a daily shortfall event – June

The project team were very mindful that theoretical results may be different in practice and so the model results were peer reviewed by a commercial provider of renewable energy systems including microgrids. Referring to the chart above for example, a back-up generator large enough to meet the entire load will not perform well remaining on overnight to meet the small shortfall identified in the model. In reality, a system controller would learn to run the generator at full capacity earlier in the day to ensure that the battery had enough charge to supply energy overnight.

Local Network

Interval data supplied or sought from the DNSP was visually represented in charts for the purposes of understanding zone substation energy profiles at a seasonal and daily scale. This data was for interpretive reasons only and was not integrated into the Flow Model.

Financial Modelling

To evaluate alternative approaches, each scenario was reduced to a Net Present Value over a 12 and 25-year term.

12 years was chosen as it is a reasonable horizon for farmers to make decisions on. It was also convenient because it was a timeframe over which a battery would last and over which its performance could be accurately modelled through incorporating degradation figures. Thus, the 12-year NPV calculations are made with powerplant performance modelled accurately in each year considering weather variability, reduced solar capacity and degrading battery performance. Similar variability was unable to be incorporated into the load which was projected to remain the same over the period.

The 25-year NPV was calculated more simply by taking year 1 performance and projecting that forward using the financial assumptions. This was done on the basis that it is extraordinarily hard to predict loads and markets over that period and technological changes would impact the powerplant performance. To that extent, the 25-year NPV should not be regarded as truth, rather a comparative tool to evaluate alternative scenarios.

Assumptions

Other than the assumption that the specified equipment will perform as intended, the key assumption relating to this study are financial.

Capital budget items were costed based on current industry experience and publicly reported costs. It should be noted however that during the course of the project the major factors have been at play – covid, supply constraints and the fall in the Australian dollar. The project team took the view that prices would stabilise and return to pre-disruption values so for the purposes of high-level feasibility, historical values would apply.

However, this has not necessarily occurred to date and at the time of writing the dramatic fall in the Australian dollar would exacerbate the possibility that cost assumptions made at the time of modelling are now likely to be on the low side. Diesel is another example where the assumption that prices would return to pre-covid levels as modelled may not hold true. Sensitivity testing however does encompass a wide range of values, including current costs.

Financial assumptions also changed during the course of the project. For example, at the start of the period finance was available for 2%, at the time of writing it continues to rise past the 4.5% figure applied in the models. Inflation is also high at the time of writing but the model has used a long-term average of 2.5%.

There was much debate around a suitable Discount Rate with views ranging from 3% being acceptable for long-term infrastructure to 15% being a desirable commercial return. Farmers and consortia members were consulted to arrive at the rate of 7% used in the models.

Sensitivity Analysis

After establishing a base case for each scenario, sensitivity testing was conducted to test the impact of changes to key variables. These are identified as changes in:

- Capital Expense
- Energy supply cost
- Export energy value
- Derived battery revenue

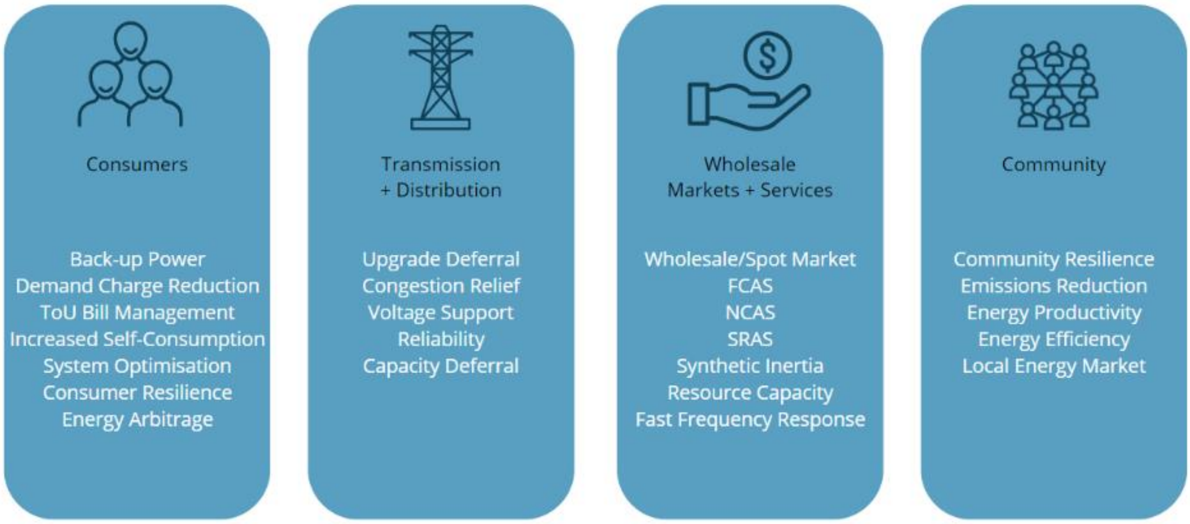
Sensitivity was tested both manually by altering powerplant design and financial inputs and also using spreadsheet tools to iterate around known values. The resulting charts are included in the case study reports.

Secondary Values

Australia's existing markets and business models for energy networks and services do not yet offer sufficient marketplaces, services, or products that capture and reward the full value of microgrids and other modern distributive smart grid technologies. This is expected to change as the National Energy Market and wider ecosystem innovate policy and business models that transform the market via pilots, trials, and rule changes.

The feasibility studies conducted use a typical project financing approach to reflect the market as it currently exists. However, by also valuing additional or secondary benefits which are then bundled or stacked, also known as 'value stacking', an expanded proposed return on investment is identified. This approach allows for a more accurate representation of the anticipated value of microgrids, de-risking the investment proposition despite current market misalignment.

With and without market alignment microgrids and other dispatchable CERs have the potential to offer the below values to stakeholders.



Stakeholders were consulted throughout the project to determine the current market appetite to value microgrid services and benefits. Findings will be articulated in the *Opportunities* section of this report.

Feasibility of Microgrids for Agriculture

Archetype 1: Single Enterprise

Case Study Description

The *Single Enterprise* microgrid archetype is defined as a single agriculture enterprise with all of its energy assets and consumption contained and simply configured within a single geographic property.

The site selected to assess this archetype was the farming enterprise, Keith Tulloch Wine (KTW). The business is a cutting edge sustainable horticultural winery – the first to become certified carbon neutral in the Hunter Valley. It is located in Pokolbin, New South Wales.

Key considerations for the enterprise include:

- Operations
    - Irrigation: Spring - Summer (low pressure sub surface system)
    - Harvesting: January – March
    - Winemaking: April – May
    - Tourism peak: March – May
- Energy
    - NMIs (metered customer connection points): 2, co-located
    - DERs: 65kW ground mounted Solar PV
    - Annual energy spend: ~$20,000
    - Annual consumption: ~120MWh

KTW is located on Ausgrid's Rothbury Zone Substation which has extremely variable loads and is significantly underutilised with demand sitting between 2-4MW for <65% of the year, despite capacity surpassing 9MW. A clear need exists for load shifting actions to reduce variability and increase utilisation of assets. The substation has ~5MW of solar PV embedded generation.

The landholder seeks to understand how existing solar and/or additional DERs could be better shared and utilised across NMI's before being exported to the grid. KTW's appetite for a grid-connected CER system is driven by the following needs:

- Reduced cost of production
- Maintain net zero or carbon negative status as enterprise expands
- Increased electrification
- Energy resilience especially as it relates to loss of production due to poor grid performance
- Lack of network solutions

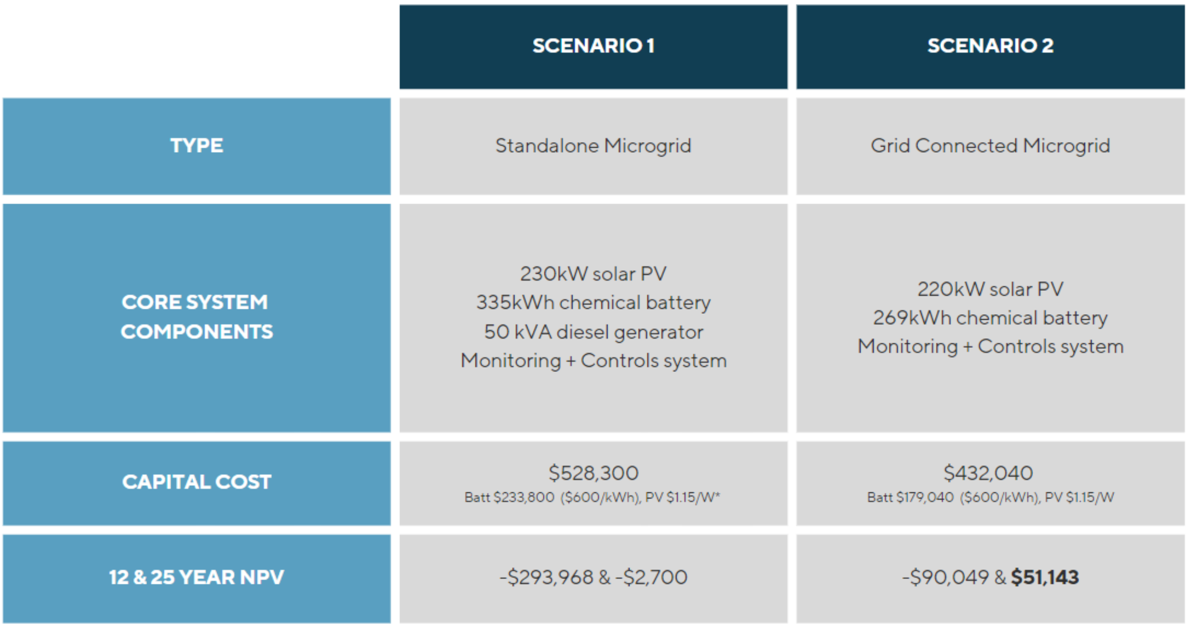
The feasibility analysis conducted is based upon consumer drivers and consumption data compiled through smart meters installed by the project team and is performed primarily from an engineering and economics perspective. Modelling does not include legal, legislative, or social constraints. The results are presented as the Net Present Value of all future cash flows for 12 and 25 years.

The model under consideration is driven by 3 basic questions.

1. Can KTW disconnect from the grid and operate a standalone renewable microgrid?
2. Is there value in remaining grid connected with the capacity to operate independently, and if so to whom?
3. Would it be better to operate as an embedded network or Virtual Network?

Key Findings

The following two microgrid scenarios were assessed:

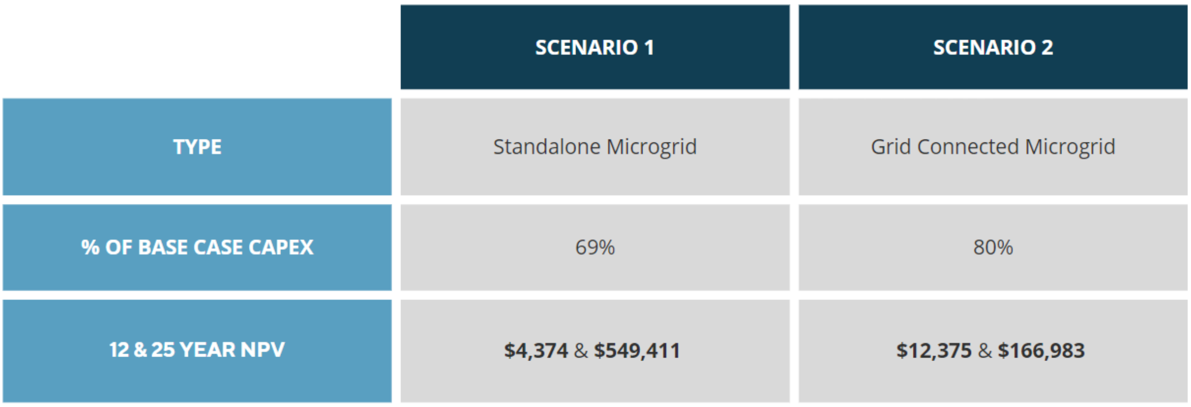


	SCENARIO 1	**SCENARIO 2**
TYPE	Standalone Microgrid	Grid Connected Microgrid
CORE SYSTEM COMPONENTS	230kW solar PV 335kWh chemical battery 50 kVA diesel generator Monitoring + Controls system	220kW solar PV 269kWh chemical battery Monitoring + Controls system
CAPITAL COST	$528,300 Batt $233,800 ($600/kWh), PV $1.15/W*	$432,040 Batt $179,040 ($600/kWh), PV $1.15/W
12 & 25 YEAR NPV	-$293,968 & -$2,700	-$90,049 & **$51,143**

The *grid connected scenario* does recoup the capital within the term and is close to meeting the indicative loan repayments. Consequently the 25-year NPV is positive. Whereas at the *standalone scenario* delivers a negative NPV.

If the grid-connected project was funded by KTW with cash then this would be the equivalent of an investment that yielded ~3%. Combined with carbon, resilience, and 'story' values, this may represent acceptable performance.

A sensitivity analysis was then conducted with the following results:



	SCENARIO 1	**SCENARIO 2**
TYPE	Standalone Microgrid	Grid Connected Microgrid
% OF BASE CASE CAPEX	69%	80%
12 & 25 YEAR NPV	**$4,374** & **$549,411**	**$12,375** & **$166,983**

The *standalone scenario* is capable of meeting repayments of capital and interest on the full amount at 4.5% and delivering a modest surplus that exceeds the investment hurdle of 3%.

The *grid connected scenario* is capable of meeting repayments of capital and interest on the full amount at 4.5% and delivering a modest surplus that exceeds the investment hurdle of 7%.

Based on these findings there is value to the farmer in remaining grid connected with added benefits of a grid-connected microgrid offering easing of local network constraint, new on-site consumption (increased production, EVs, or hydrogen), and spot market trading.

Farmer Recommendations

Due to spacing limitations for solar PV, including unsuitable roofing, the project consortium recommends the following actions be adopted should KTW seek to implement a smart energy system on-farm:

- Do not pursue standalone or grid-tied microgrid as modelled by this study
- Consider a combination of the following:
  - Meter consolidation or virtual net metering
  - Participation in a VPP
  - Install a battery to gain a measure of redundancy
  - Investigate an agrivoltaics trial to see if additional solar could be integrated with the vineyard.

Archetype 2: Edge of Grid

Case Study Description

The *Edge of Grid* microgrid archetype is defined as a microgrid and primary consumer located at the end of a distribution line.

The site selected to assess this archetype was the cotton enterprise, 'Burgorah', which is situated at the end of a feeder line. The business has fostered a long-standing enthusiasm for energy innovation with a tendency towards early adoption and energy independence. It is located just outside of Saint George, Queensland.

Key considerations for the enterprise include:

- Operations
  - Cotton is grown every 5-7/10 years depending on water availability
  - Pumping occurs 1 month in the year to support flood irrigation
- Energy
  - NMIs (metered customer connection points): ~14
  - DERs: ~500kW solar PV, an off grid solar + battery system for a small orchard
  - Annual energy spend: ~$85,000
  - Annual consumption: ~3-400MWh

Burgorah is located on Ergon Energy's St George Zone Substation which is considerably underutilised. For example, child substation St George Town performs at 1.5-3MW of 5+MW capacity 80% of the time and experiences multiple negative flow events annually. The substation has ~3.7MW of solar PV embedded generation which may be contributing to voltage fluctuations.

The landholder is constrained by the inability to share energy between loads owned and operated by the same enterprise without incurring network transmission costs which apply regardless of context.

The landholder seeks to understand the feasibility of a system that can share excess energy of existing and additional DERs' across his property with potential to share locally if a grid-connected system is recommended. The appetite for this is driven by the following needs:

- Highly seasonal consumption and underutilisation of DERs
- Bolstered energy reliability and independence
- Lack of network and regulatory solutions valuing energy exports and cost of energy for ag productivity
- Energy resilience especially as it relates to loss of production due to poor grid performance
- Innovation: share excess energy locally or produce ammonia

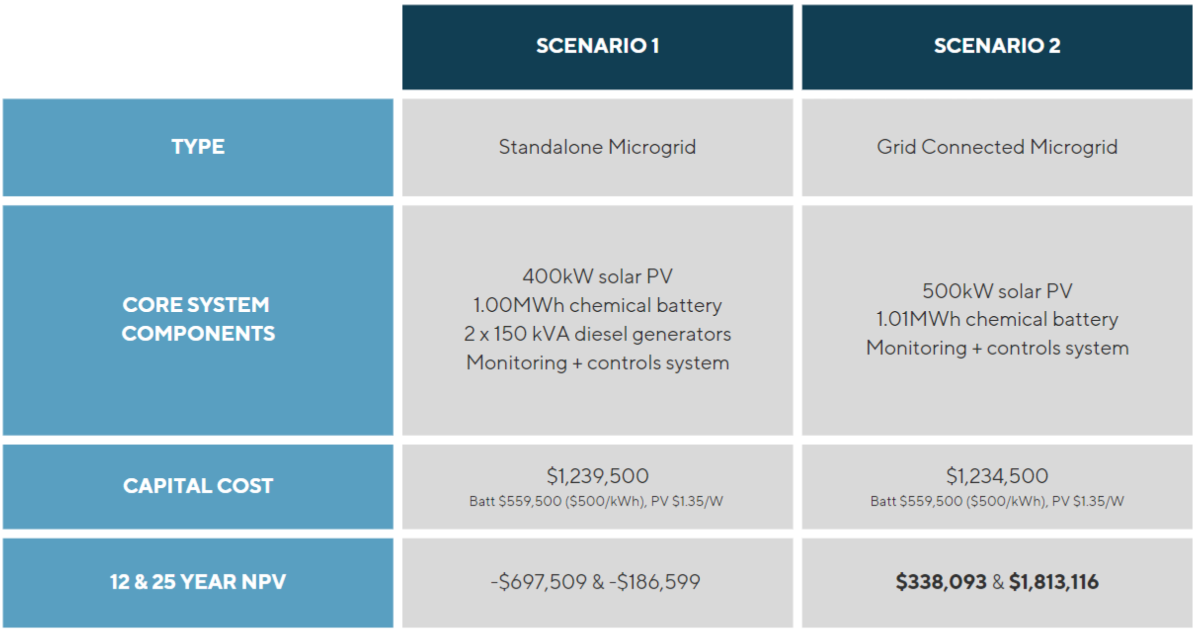
The feasibility analysis conducted is based upon consumer drivers and consumption data compiled through smart meters installed by the project team and is performed primarily from an engineering and economics perspective. Modelling does not include legal, legislative, or social constraints. The results are presented as the Net Present Value of all future cash flows for 12 and 25 years.

The model under consideration is driven by 3 basic questions.

1. Can Burgorah disconnect from the grid and operate a standalone renewable microgrid?
2. Is there value in remaining grid connected but operating independently, and if so to whom?
3. Would it be better to operate as an embedded network or Virtual Network?

Key Findings

The following two microgrid scenarios were assessed:



	SCENARIO 1	SCENARIO 2
TYPE	Standalone Microgrid	Grid Connected Microgrid
CORE SYSTEM COMPONENTS	400kW solar PV 1.00MWh chemical battery 2 x 150 kVA diesel generators Monitoring + controls system	500kW solar PV 1.01MWh chemical battery Monitoring + controls system
CAPITAL COST	$1,239,500 Batt $559,500 ($500/kWh), PV $1.35/W	$1,234,500 Batt $559,500 ($500/kWh), PV $1.35/W
12 & 25 YEAR NPV	-$697,509 & -$186,599	**$338,093** & **$1,813,116**

The *standalone scenario* presents negative NPVs at 12 and 25 years with the approximate value of loan repayments based on the full Capex at 4.5% for a 12-year term. Project net profit falls well short of meeting this amount.

The *grid connected scenario* reflects a positive NPV at 12 years meeting a simple payback period of ~ 7 years and covering the full capital repayments at 4.5%. The 25-year positive NPV recovers sunk costs midway and the continues with solid performance for the remaining term. Existing solar PV investments on Burgorah are not assumed in this analysis.

A sensitivity analysis was conducted with the following results:

	SCENARIO 1	SCENARIO 2
TYPE	Standalone Microgrid	Grid Connected Microgrid
% OF BASE CASE CAPEX	77%	75%
12 & 25 YEAR NPV	**$28,107** & **$1,392,855**	**$22,222** & **$1,555,285**

The *standalone scenario* falls just short of meeting repayments of capital and interest on the full amount at 4.5% but with some finance/taxation 'tweaking' the investment may pay off and meet the investment hurdle of 3% within 12 years.

The *grid connected scenario* pays back in simple terms at around 9 years and is capable of meeting repayments of capital and interest on the full amount at 4.5%.

Based on these findings a grid connected system is most useful to the farmer. There are four core mechanisms required to deliver this value: exposure to pricing in the National Energy Market, suitable retailer and network tariff structures, emerging markets such as demand response and FCAS, and specific local infrastructure measures such as deferred upgrade investment payments.

Remaining grid connected presents a clear opportunity for the farmer however the current rules around energy sharing within the farm and the wider grid would push the farmer into a high voltage connection and large customer tariff which is cost prohibitive to remaining productive. However, with significant embedded generation reducing external demand, Ergon will receive reduced revenue from fees and charges. Ultimately the cost of operating the network is 'washed out' over all consumers which also presents an ethical challenge – who bears the costs and the benefits?

The creation of a grid connected, dispatchable, microgrid makes more economic sense provided additional benefits can be realised. These might include:

- Valuing of time-based generation or load in the market
- Easing of network constraints or power quality issues to the DNSP.
- Additional on-site consumption such as EVs or Hydrogen loads

Farmer Recommendations

The Project consortium recommends the following actions be adopted should Burgorah seek to implement a smart energy system on-farm:

1. Implement the grid connected dispatchable microgrid energy system as outlined above:
    - Make a connection application to Ergon Energy for the above project and request consideration of any network upgrade deferral and benefit that might accrue as a result of expected local network benefits
    - Build the system in the centralised configuration and avoid over engineering so it can retain capacity for modular improvement
2. Seek ARENA RAMPP funding to assist in managing some of the financial risks of the project,
3. Gain support to trial specific market and tariff elements associated with the project in AER's Regulatory Sandbox,
4. Explore the appetite for Ergon to trial or approve:

    - a non-network solution for an upgrade deferral agreement
    - local energy trading with the gin
    - wholesale or ancillary market participation, and;
    - trial microgrid tariff or network charge reforms using LUOS.

  or a corresponding state or market pilot funds.

Archetype 3: Large Microgrid

Case Study Description

The *Large Microgrid* archetype is defined as a microgrid that serves multiple consumers within its closed network rather than a single enterprise or consumer.

The site selected to assess this archetype was a pump station belonging to Pioneer Valley Water's (PVW) Palmyra irrigation scheme and a co-located cluster of seven sugar cane farmers who are also PVW customers. PVW follows a co-op model. This site is located just west of Mackay, Queensland.

Key considerations for the selected cane producers include:

- Operations
    - Summer irrigation (December – February),
    - Winter irrigation (May – August), and;
    - Main harvest and milling operations (late May – November)
    - Some crop rotation pending input costs and market prices
- Energy
    - Project smart meters installed: 36
    - DERs: various <30kW solar PV installations, pumps and residential
    - Annual energy spend/farmer: ~$10 - 20,000
    - Annual consumption: ~383MWh farmers, 133MWh Pioneer Valley Water supply pump

The case study group is located between Ergon Energy's West Mackay and Pleystowe substations connected by 2 feeder lines. Underutilisation has been observed at both substations. Demand trends are variable and 'peaky' (sharp highs and lows) in January to March, steady and low in autumn and winter months, and ramping to 'peaky' from spring to summer. Groups of rural residences and agricultural pumping define the load profile in this region as well as a hospital and a sugar mill, which supplies bioenergy to the grid. Approximately 4MW of solar PV embedded generation has been installed in the area. Mackay falls within the northern Queensland Renewable Energy Zone.

Cane experiences a more direct correlation between the water-energy nexus and its link to productivity than many other commodities. Interdependent outcomes between local farmers occur due to collective behaviour's impact on resource availability, processing, and yield. This in turn informs the viability of irrigation schemes like PVW. As such cane farming regions, and co-located enterprises up- and downstream of the supply chain, are well positioned to benefit from improved affordability across the water-energy nexus including via energy sharing mechanisms.

The PVW customers seek to understand the feasibility of a system that can share energy within the cluster, with potential to share externally if a local trading mechanism is viable. The appetite for this is driven by the following:

- High correlation between energy affordability, water use, and yields
- Highly seasonal consumption and underutilisation of existing or planned DERs
- Lack of tariffs that suit agricultural demand profiles and incentivise productivity

- Lack of network solutions to enable power of choice in a minimally-competitive market
- Regulatory limitations on sharing energy with the local mill's cogeneration bagasse plant, powered by local cane waste

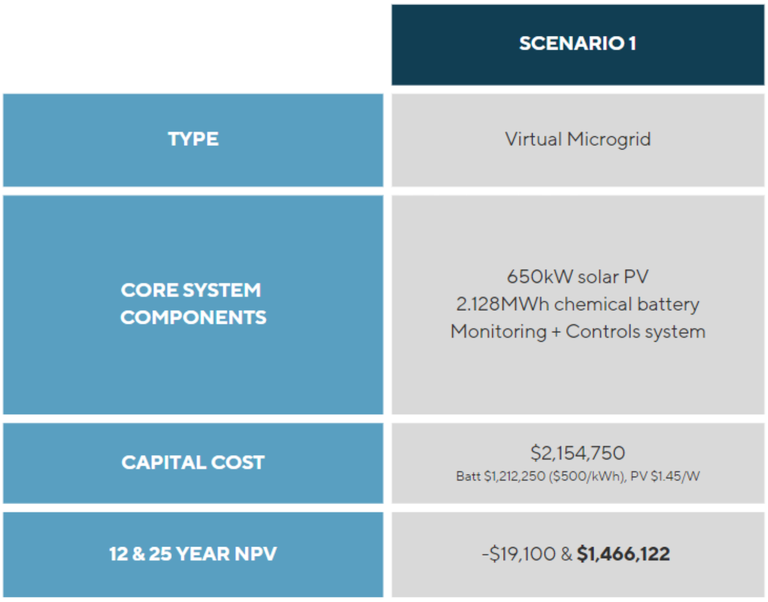
The feasibility analysis conducted is based upon consumer drivers and consumption data compiled through smart meters installed by the project team and is performed primarily from an engineering and economics perspective. Modelling does not include legal, legislative, or social constraints. The results are presented as the Net Present Value of all future cash flows for 12 and 25 years.

The model under consideration is driven by 2 basic questions.

1. Is it feasible and/or desirable to create standalone microgrids with individual or sub-groups of PVW customers?
2. Can farms operate collaboratively as a regional virtual microgrid to the benefit of farmers, PVW, and/or the DNSP?

Key Findings

A standalone scenario was not considered technically reasonable, as such a virtual microgrid with a physical load following solar + battery system upstream of the farmer group was assessed:



	SCENARIO 1
TYPE	Virtual Microgrid
CORE SYSTEM COMPONENTS	650kW solar PV 2.128MWh chemical battery Monitoring + Controls system
CAPITAL COST	$2,154,750 Batt $1,212,250 ($500/kWh), PV $1.45/W
12 & 25 YEAR NPV	-$19,100 & **$1,466,122**

These high-level results reflect a slightly negative 12-year Net Present Value meeting a simple payback period of ~ 8-9 years and covering the full capital repayments at 4.5%. The positive 25-year reflects the reality that sunk costs have been recovered by the midway point and the system is still capable of solid performance for the remaining term.

The sensitivity analysis showed that simple pay-back occurs in years 8-9 and the project is capable of meeting loan repayments at 4.5% while also providing a modest surplus.

Based on these findings a clear case for energy systems oriented to collective ag consumer behaviour could have a material positive impact on the distribution network as well as the farming group. With dynamic control of generation, storage, and pumping loads it would be possible to adapt system usage to fit network and farm usage requirements. A grid facing battery will also enable provision of FCAS and the ability to ease constraints through Pioneer Valley selectively acting as a load or generator could be helpful – particularly if multiple farmers acted in aggregate. There are 4 core mechanisms to deliver this value: exposure to pricing in the National Energy Market, retailer and network tariff structure; emerging markets such as demand response and FCAS; and specific local infrastructure measures such as deferred investment payments. However, the ownership and benefit distribution model would require significant consideration.

Farmer Recommendations

Due to the considerable investment relative to the number of beneficiaries the project consortium does not recommend pursuing the virtual microgrid outlined in the feasibility study.

Instead, the project consortium recommends the following actions be adopted should a wider group of Pioneer Valley Water customers seek to implement a system that maximises benefit derived from a smart enabled energy sharing investment:

1. Determine the feasibility of a Local Energy Market scenario for Pioneer Valley Water farmers on the West Mackay/Pleystowe distribution network, with consideration for the Racecourse Sugar Mill and the town of Walkerston.
2. Explore the appetite for Ergon to trial or approve:
    - a non-network solution for an upgrade deferral agreement
    - wholesale or ancillary market participation, and;
    - trial microgrid tariff or network charge reforms using LUOS.
3. Gain support to trial specific market and tariff elements associated with the project in AER's Regulatory Sandbox.
4. Seek ARENA RAMPP and state microgrid pilot funding to assist in managing some of the financial risks of the project.

Archetype 4: Anchor/Hybrid

Case Study Description

The *Anchor/Hybrid archetype* is defined as a) a microgrid that operates as a significant dispatchable load to external local consumers or virtual networks, and/or, b) a combination of any of the other archetypes including *Single Enterprise*, *End of Line*, or *Large Microgrid*.

The site selected to assess this archetype was a mixed commodity producer of grain, fibre, and horticulture. The fifth-generation family enterprise is continually looking for ways to improve cost of productivity, decarbonisation, and resilience while encouraging local benefit. It is located just outside of Wee Waa, New South Wales.

Key considerations for the enterprise include:

- Operations
    - Potatoes, peanuts, wheat, and cotton
    - Potato irrigation: July – November
    - Peanut irrigation: October – November
    - Cotton irrigation: October - March
- Energy
    - NMIs (metered customer connection points): ~12
    - DERs: none
    - Annual energy spend: ~$150,000 on electricity, ~$350,000 on diesel
    - Annual consumption: 630MWh

The farm is located on Essential Energy's Wee Waa Zone Substation which is extremely underutilised, operating at 50% capacity or less for ~95% of the time. The substation has ~3MW of solar PV embedded generation with 97% of Wee Waa-Narrabri residents in favour of establishing a renewable energy industry in their region with potential for 622MW of solar, 175MW of wind, bioenergy, and storage. There is also appetite for a local energy trading mechanism.

The landholder is constrained by the inability to share energy between loads owned and operated by the same enterprise and with other local energy consumers without incurring network transmission costs, which apply regardless of context.

The landholder seeks to understand the feasibility of a system that can share excess energy of existing and additional DERs' across their property with potential to share locally if a grid-connected system is recommended. The appetite for this is driven by the following drivers:

- Self-imposed and market obligations to sustainability and decarbonisation targets
- Rising cost of productivity inputs
- Desire to participate in a local clean energy initiative
- Grid unreliability, particularly phase failures
- Energy resilience, especially as it relates to loss of production due to grid failure events
- Limited network and regulatory solutions enabling ag productivity or power of choice

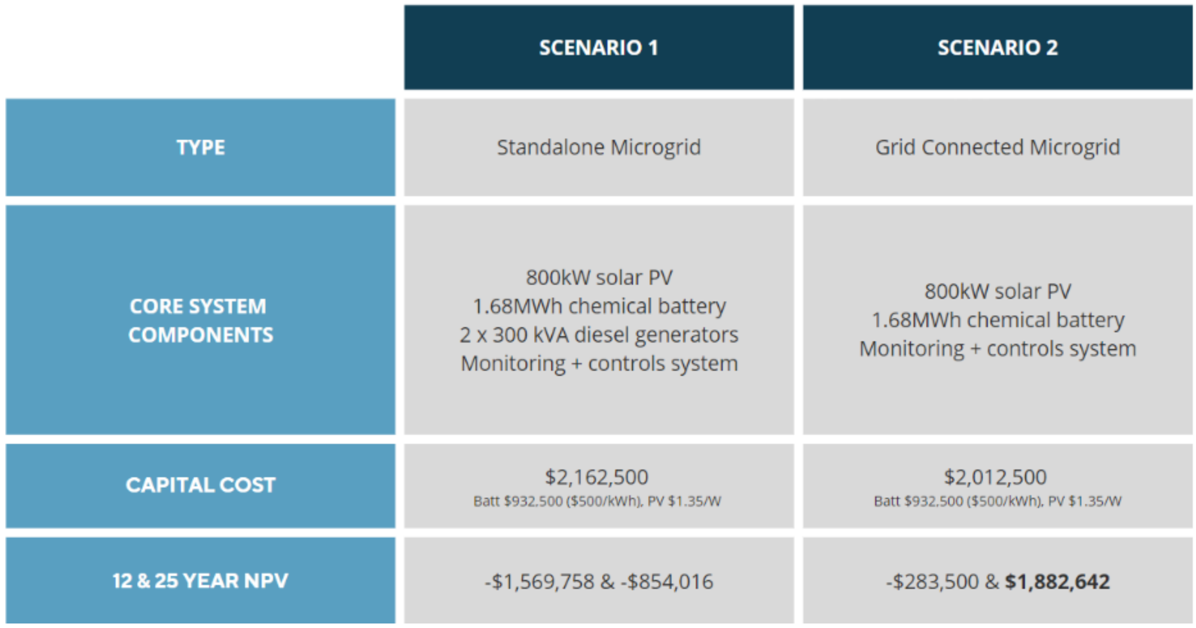
The feasibility analysis conducted is based upon consumer drivers and consumption data compiled through smart meters installed by the project team and is performed primarily from an engineering and economics perspective. Modelling does not include legal, legislative, or social constraints. The results are presented as the Net Present Value of all future cash flows for 12 and 25 years.

The model under consideration is driven by 3 basic questions.

1. Can the enterprise disconnect from the grid and operate a standalone renewable microgrid?
2. Is there value in remaining grid connected but operating independently, and if so to whom?
3. Would it be better to operate as an embedded network or Virtual Network?

Key Findings

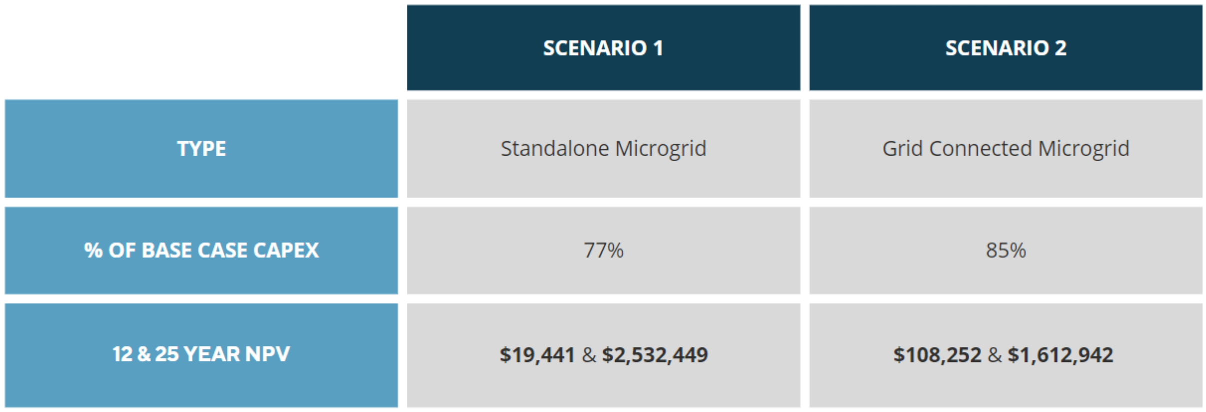
The following two microgrid scenarios were assessed:



	SCENARIO 1	**SCENARIO 2**
TYPE	Standalone Microgrid	Grid Connected Microgrid
CORE SYSTEM COMPONENTS	800kW solar PV 1.68MWh chemical battery 2 x 300 kVA diesel generators Monitoring + controls system	800kW solar PV 1.68MWh chemical battery Monitoring + controls system
CAPITAL COST	$2,162,500 Batt $932,500 ($500/kWh), PV $1.35/W	$2,012,500 Batt $932,500 ($500/kWh), PV $1.35/W
12 & 25 YEAR NPV	-$1,569,758 & -$854,016	-$283,500 & **$1,882,642**

The *standalone scenario delivers negative NPV and* net profit falls well short of meeting loan repayments, even if high carbon values are included. Whereas the *grid connected scenario* presents a negative 12-year NPV but does recoup the capital within the term and is reasonably close to meeting the indicative loan repayments. Consequently the 25-year NPV is positive, reflecting the reality that sunk costs have been recovered by the midway point and the system is still capable of solid performance for the remaining term.

A sensitivity analysis was conducted with the following results:



	SCENARIO 1	**SCENARIO 2**
TYPE	Standalone Microgrid	Grid Connected Microgrid
% OF BASE CASE CAPEX	77%	85%
12 & 25 YEAR NPV	**$19,441** & **$2,532,449**	**$108,252** & **$1,612,942**

The *standalone scenario* falls just short of meeting repayments of capital and interest on the full amount at 4.5% but with some finance/taxation ‘tweaking’ the investment may pay off and meet the investment hurdle of 3% within 12 years.

The *grid connected scenario* is capable of meeting repayments of capital and interest on the full amount at 4.5% and delivering a modest surplus that exceeds the investment hurdle of 7%.

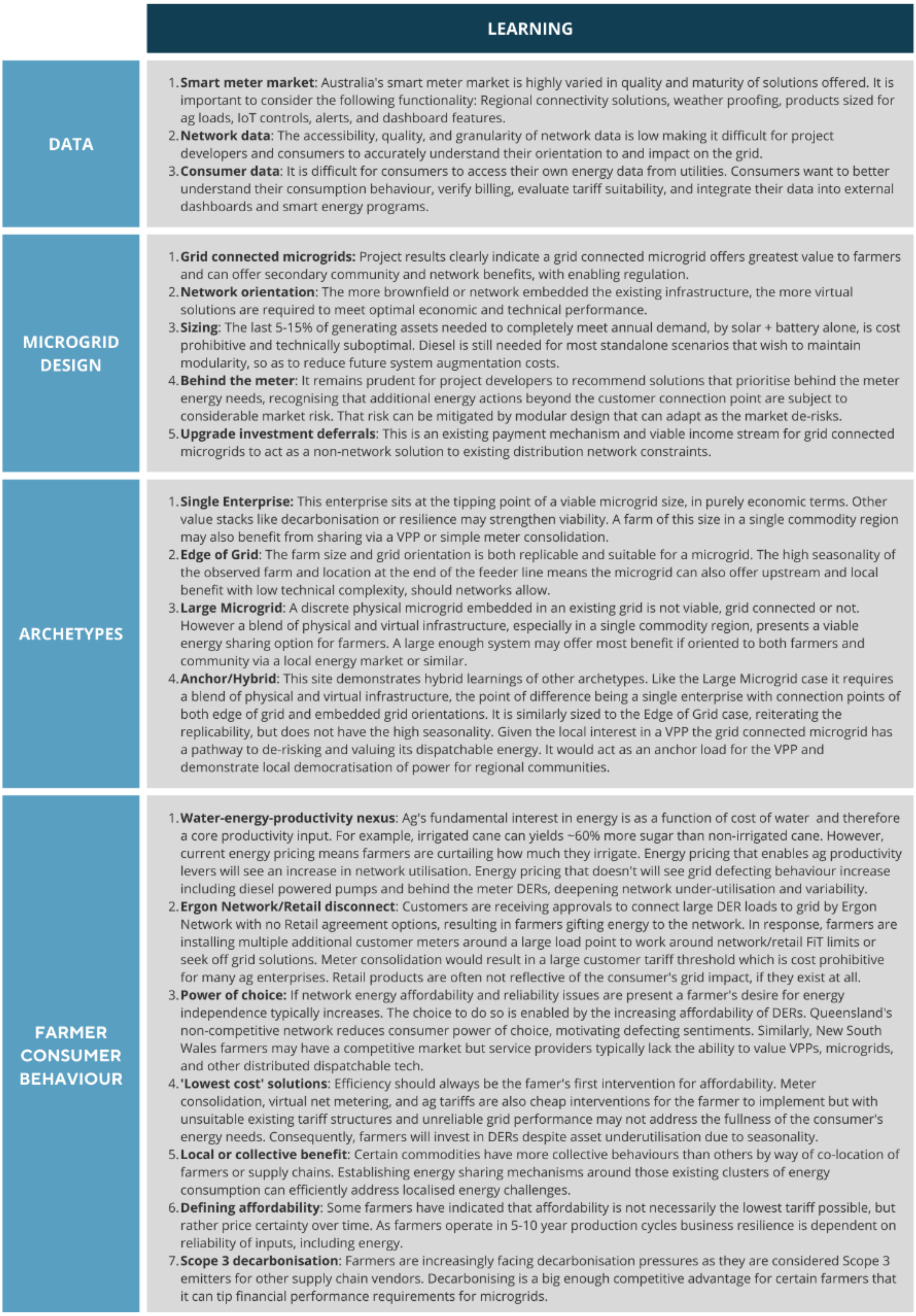
Based on these findings a standalone system or an embedded network scenario would be of particular operational risk due in part to its complex grid orientation ie. HV asset ownership and management. A standalone system that doesn’t reduce DNSP demand and therefore revenue, requires a market mechanism to incentivise integration of dispatchable loads and generation.

Farmer Recommendations

The project consortium recommends the following actions be adopted should the Wee Waa landholders seek to implement a smart energy sharing system between farms:

1. Implement the grid connected dispatchable microgrid energy system as outlined above:
    - Make a connection agreement to Essential Energy for the above project and request consideration of any network upgrade deferral and benefit that might accrue as a result of expected local network benefits.
    - Build the system in the centralised configuration and avoid overengineering so it can retain capacity for modular improvement.
2. Seek ARENA RAMPP funding to assist in managing some of the financial risks of the project,
3. Gain support to trial specific market and tariff elements associated with the project in AER’s Regulatory Sandbox,
4. Explore the appetite for Essential Energy to trial or approve:
    - a non-network solution for an upgrade deferral agreement
    - local energy trading with Wee Waa/Narrabri’s community VPP
    - wholesale or ancillary market participation, and;
    - trial microgrid tariff or network charge reforms using LUOS.

Lessons Learned



	LEARNING
DATA	1. **Smart meter market**: Australia's smart meter market is highly varied in quality and maturity of solutions offered. It is important to consider the following functionality: Regional connectivity solutions, weather proofing, products sized for ag loads, IoT controls, alerts, and dashboard features. 2. **Network data**: The accessibility, quality, and granularity of network data is low making it difficult for project developers and consumers to accurately understand their orientation to and impact on the grid. 3. **Consumer data**: It is difficult for consumers to access their own energy data from utilities. Consumers want to better understand their consumption behaviour, verify billing, evaluate tariff suitability, and integrate their data into external dashboards and smart energy programs.
MICROGRID DESIGN	1. **Grid connected microgrids:** Project results clearly indicate a grid connected microgrid offers greatest value to farmers and can offer secondary community and network benefits, with enabling regulation. 2. **Network orientation**: The more brownfield or network embedded the existing infrastructure, the more virtual solutions are required to meet optimal economic and technical performance. 3. **Sizing**: The last 5-15% of generating assets needed to completely meet annual demand, by solar + battery alone, is cost prohibitive and technically suboptimal. Diesel is still needed for most standalone scenarios that wish to maintain modularity, so as to reduce future system augmentation costs. 4. **Behind the meter**: It remains prudent for project developers to recommend solutions that prioritise behind the meter energy needs, recognising that additional energy actions beyond the customer connection point are subject to considerable market risk. That risk can be mitigated by modular design that can adapt as the market de-risks. 5. **Upgrade investment deferrals**: This is an existing payment mechanism and viable income stream for grid connected microgrids to act as a non-network solution to existing distribution network constraints.
ARCHETYPES	1. **Single Enterprise:** This enterprise sits at the tipping point of a viable microgrid size, in purely economic terms. Other value stacks like decarbonisation or resilience may strengthen viability. A farm of this size in a single commodity region may also benefit from sharing via a VPP or simple meter consolidation. 2. **Edge of Grid**: The farm size and grid orientation is both replicable and suitable for a microgrid. The high seasonality of the observed farm and location at the end of the feeder line means the microgrid can also offer upstream and local benefit with low technical complexity, should networks allow. 3. **Large Microgrid**: A discrete physical microgrid embedded in an existing grid is not viable, grid connected or not. However a blend of physical and virtual infrastructure, especially in a single commodity region, presents a viable energy sharing option for farmers. A large enough system may offer most benefit if oriented to both farmers and community via a local energy market or similar. 4. **Anchor/Hybrid**: This site demonstrates hybrid learnings of other archetypes. Like the Large Microgrid case it requires a blend of physical and virtual infrastructure, the point of difference being a single enterprise with connection points of both edge of grid and embedded grid orientations. It is similarly sized to the Edge of Grid case, reiterating the replicability, but does not have the high seasonality. Given the local interest in a VPP the grid connected microgrid has a pathway to de-risking and valuing its dispatchable energy. It would act as an anchor load for the VPP and demonstrate local democratisation of power for regional communities.
FARMER CONSUMER BEHAVIOUR	1. **Water-energy-productivity nexus**: Ag's fundamental interest in energy is as a function of cost of water and therefore a core productivity input. For example, irrigated cane can yields ~60% more sugar than non-irrigated cane. However, current energy pricing means farmers are curtailing how much they irrigate. Energy pricing that enables ag productivity levers will see an increase in network utilisation. Energy pricing that doesn't will see grid defecting behaviour increase including diesel powered pumps and behind the meter DERs, deepening network under-utilisation and variability. 2. **Ergon Network/Retail disconnect**: Customers are receiving approvals to connect large DER loads to grid by Ergon Network with no Retail agreement options, resulting in farmers gifting energy to the network. In response, farmers are installing multiple additional customer meters around a large load point to work around network/retail FiT limits or seek off grid solutions. Meter consolidation would result in a large customer tariff threshold which is cost prohibitive for many ag enterprises. Retail products are often not reflective of the consumer's grid impact, if they exist at all. 3. **Power of choice:** If network energy affordability and reliability issues are present a farmer's desire for energy independence typically increases. The choice to do so is enabled by the increasing affordability of DERs. Queensland's non-competitive network reduces consumer power of choice, motivating defecting sentiments. Similarly, New South Wales farmers may have a competitive market but service providers typically lack the ability to value VPPs, microgrids, and other distributed dispatchable tech. 4. **'Lowest cost' solutions**: Efficiency should always be the famer's first intervention for affordability. Meter consolidation, virtual net metering, and ag tariffs are also cheap interventions for the farmer to implement but with unsuitable existing tariff structures and unreliable grid performance may not address the fullness of the consumer's energy needs. Consequently, farmers will invest in DERs despite asset underutilisation due to seasonality. 5. **Local or collective benefit**: Certain commodities have more collective behaviours than others by way of co-location of farmers or supply chains. Establishing energy sharing mechanisms around those existing clusters of energy consumption can efficiently address localised energy challenges. 6. **Defining affordability**: Some farmers have indicated that affordability is not necessarily the lowest tariff possible, but rather price certainty over time. As farmers operate in 5-10 year production cycles business resilience is dependent on reliability of inputs, including energy. 7. **Scope 3 decarbonisation**: Farmers are increasingly facing decarbonisation pressures as they are considered Scope 3 emitters for other supply chain vendors. Decarbonising is a big enough competitive advantage for certain farmers that it can tip financial performance requirements for microgrids.

UTILITIES + REGULATION

1. **Substation utilisation**: Significant under-utilisation was identified across all case studies with some experiencing or approaching negative flow events. Given the ag energy-productivity link, there is opportunity for utilities to establish pricing products and services that are linked to the affordability of productivity drivers, encouraging utilisation.
2. **Grid modernisation in regions**: Support is needed to encourage smart meter roll out, connectivity resilient solutions for smart energy tech, and grid flexibility in regions and ensure modernisation is equitably achieved.
3. **Network charges**: Dispatching local DERs can contribute to efficient and optimised energy networks, reducing transmission losses many regional networks experience. The current structure of TUOs and DUOs in network charges does not account for the real value dispatchable DER loads offer local grids. This is a fundamental market risk for grid connected DER investments.
4. **Valuing non-network solutions**: Beyond tariffs, sub-utility dispatchable DERs are not adequately accounted for in eligible connections processes, REZ planning, and unsolicited upgrade deferral submissions. Valuing batteries and other DERs like rooftop solar, via a simple FiT, instead of a grid integration strategy will likely result in ongoing under-utilisation of network and non-network assets as battery prices fall. Integrating non-network assets improves value stacks for microgrids but also reduces unnecessary investment for DNSPs.
5. **Markets vs. tariffs**: There are considerable benefits to dispatchable loads being valued in a wholesale or local energy market versus via tariffs. Individual prosumers may likely seek a cost reflective reward for the value their asset offers.
6. **Regulatory innovation**: Regulatory progress is not keeping up with the pace of energy innovation. State alignment with the federal regulatory sandbox could help streamline the trial to rule change process.

Discussion

Opportunities

On Farm Efficiency

All farmers involved in this study were aware of, if not implementing, energy efficiency measures on farm. Typically, this involved knowledge around soft-start or Variable Speed Drives on pumps, application of newer energy efficient refrigeration, and lighting upgrades.

Energy efficiency is important in the context of a microgrid and CER involving storage must consider the volume of electricity as well as the demand as the cost of generation and storage infrastructure will be reduced. That is, for an efficient operation, less energy will need to be produced and stored, or, greater output can be provided by the same infrastructure. Both kilowatts and kilowatt-hours matter.

Peak demand charges are also painful for farmers who may have no choice about operating a device for a very short period of a month or year and yet have the demand charge apply across the full term. Microgrids present the opportunity to pair peak demand with peak supply locally, reducing the instantaneous demand on the wider network.

To be able to power the loads effectively using as much local generation as possible, it will be advantageous to reduce overall electricity consumption as well as demand because of the need to generate, transport and store electricity. The volume of electricity is important as well as the demand. This will in-turn reduce the capital and operating cost of infrastructure by reducing the size of generation and storage infrastructure - thereby reducing costs by not oversizing.

Managing a collaborative energy system such as a microgrid therefore involves three strategies to ensure that the infrastructure is the right use and best utilised:

1. Energy Conservation and Efficiency: reducing the need for electricity by good design, behavioural measures, and the use of efficient appliances.
2. Peak Demand Management: reducing the amount of power required at any point in time by turning off appliances at peak times.
3. Load Shifting: move major loads to other times; such as operating machines and appliances at a different time to avoid a peak demand.

'Lowest Cost' Solutions

Microgrids are not always an ideal mechanism for optimising on farm energy infrastructure. The following alternative energy solutions should also be considered by agricultural producers:

- *Meter consolidation*: A customer with multiple NMIs or meters consolidates their metered grid connections to a single meter that the utility bills all energy generation and consumption from.
- *Virtual net metering:* A customer with multiple NMIs or meters enters into an agreement with the retailer where consumption and generation across all meters are netted off against each other before billing. This is essentially an accounting exercise with no engineering required.
- *CER installation:* The adoption of additional solar PV, batteries, demand response applications, smart meters, EVs, and other smart energy tech.
- *Local VPP:* A virtual power plant aggregates independent energy producers, via a virtual network, into a local energy distribution system. Depending on the design, VPPs can also trade excess energy locally, or in wholesale or ancillary markets.

- *Local Energy Market*: A local energy market (LEM) can be a more engineered solution than a VPP. A LEM is a delineated segment of a distribution network that orchestrates local DERs and consumers in a real time energy market that trades energy locally and with wholesale and ancillary markets.[1]

Given the considerable cost of microgrid solutions, alternative 'lowest cost' solutions have also been presented in the table below, including a high-level summary of what range of benefit each offers.

Solution	**Affordability**	**Reliability**	**Asset Utilisation**	**Decarbonis-ation**	**Back-up Energy**	**Local Grid Benefit**
Meter consolidation	No	No	Maybe	No	No	No
Virtual net metering	Yes	No	Maybe	No	No	No
CER installation	Yes	Yes	Yes	Yes	Yes	No
Local VPP	Yes	No	Yes	Maybe	No	Yes
Local Energy Market	Yes	Yes	Yes	Yes	Yes	Yes
Microgrid	Yes	Yes	Yes	Yes	Yes	Yes

- *Meter consolidation*: This is a relatively simple and cheap intervention provided the utility and local technicians offer this service. However, if a farmer is in a small user tariff threshold, then meter consolidation may place them into the large customer tariff range which is cost prohibitive for many farmers and QLD but can work to the farmers advantage in NSW. This solution does not improve energy reliability, decarbonisation, backup energy or benefit beyond on-farm use.
- *Virtual net metering*: This is a very low-cost intervention as it is merely an administrative change with the retailer. However, many retailers do not currently offer this product. If available this solution, while lowest cost, does not improve reliability, decarbonisation, backup energy or provide benefit to the local grid.
- *CER installation*: Installing additional batteries or solar PV behind the meter can further reduce energy costs during peak periods but deepens oversizing and the present issue of off-peak asset utilisation. Reliability, decarbonisation, and backup energy are improved by this scenario and opportunities to export may also exist pending utility approval. Depending on the farmer's energy priorities, this may offer sufficient benefits to justify investing in additional underutilised assets ie. meeting decarbonisation targets.
- *Local VPP*: Should a farmer have access then improved affordability, asset utilisation, and local grid benefits are possible. As this is typically more of a trading mechanism rather than a grid firming opportunity, decarbonisation, backup energy, and reliability are unlikely to improve without additional investment. This is a low-cost solution that is currently being trialled in parts of the NEM.
- *Local Energy Market:* As a considerably engineered solution, an LEM would offer what a VPP does with the additional investment enhancing decarbonisation efforts and improved local grid performance. It would require special exemptions from state and federal authorities that are currently not readily available to Queensland regional networks.
- *Microgrid*: The cost of energy is understood in this study as debt repayments as tariff equivalent terms until payback is achieved where cost of energy then improves dramatically. The repayments-as-tariffs reported in these studies indicate varying degrees of improved affordability. A microgrid also improves the remaining criteria. This is a highly engineered solution that is expensive and will demonstrate varying degrees of economic value. However, the benefit of other criteria may be a significant enough driver to justify implementation beyond project economics.

In summary, the best solution depends entirely on the value a farmer places on each benefit criteria. A farmer experiencing frequent unreliability events will likely consider CER adoption as the lowest cost solution. Farmers already in a large customer tariff tier who experience good reliability may consider meter consolidation the lowest cost solution. Farmers driven by energy resilience,

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[1] Centrica and Western Distribution's Cornwall Local Energy Market https://www.youtube.com/watch?v=WX6zRuD_LRw

optimised asset utilisation, and a pressure to decarbonise may likely see a microgrid as a worthwhile intervention.

In the case of an infrastructure investment for a collective of consumers, careful consideration must be given to the structure of the ownership model. If an ownership proposition cannot be agreed upon between farmers, then an external investor model or individual interventions may be preferred.

Value Stacking

This feasibility study has identified the below as the most relevant value streams microgrids can currently offer the farmer and other beneficiaries - despite some values requiring enabling regulatory conditions. By stacking a combination of these value propositions on top of the base economic case, microgrids can quickly become a compelling piece of infrastructure for the vitality of agricultural production, regional communities, and networks.

	FARMER	COMMUNITY	DISTRIBUTION	TRANSMISSION
UPGRADE DEFERRALS	✓	✓	✓	
BUSINESS + LOCAL RESILIENCE	✓	✓		
EMISSIONS REDUCTION	✓	✓		
ANCILLARY + WHOLESALE MARKETS	✓	✓	✓	✓
LOCAL ENERGY MARKETS	✓	✓	✓	
SELF CONSUMPTION ENERGY SERVICES	✓			

Upgrade Deferral Payments

Transmission and distribution upgrade deferral payments are annual payments made by TNSPs and DNSPs to non-network solutions that solve investment queries at a cheaper price and with greater benefit than that of a network upgrade solution. Network challenges include replacement of aging infrastructure, meeting changing demand patterns, and reliability issues.

The opportunity for upgrade deferral payments to non-network solutions are typically identified via consultations following Regulatory Investment Tests (RIT-T and RIT-D). However, projects can also submit unsolicited proposals to utilities for consideration, however the process is likely limited.

Business and Local Resilience

Energy resilience has typically been understood in terms of traditional centralised network outages. However, more frequent extreme climate events, democratisation of energy, and the productivity impacts of rising energy costs have regional energy consumers take greater agency in their approach to resilience.

Farming Insurance and Business Resilience

Resilience in agriculture is mostly synonymous with business resilience as energy and climate vulnerability impact productivity. Insurance companies are struggling to continue offering traditional insurance products that adequately transfer and mitigate customer risk.

Insurance companies evaluating agricultural enterprises assess how businesses manage vulnerability, stability, adaptability, and recovery when impacted by a range of risk factors. Subsequently, resilience is considered the ability to achieve reliability. Microgrids, as an asset enabling resilience, offers the following reliability:

- Back-up power during network outages,
- Energy independence during extreme weather events and resistance to energy market price shocks,
- Localised climate mitigation due to renewable energy generation and consumption,
- Product loss reduction across the supply chain due to improved energy reliability,
- Efficiency and productivity increases (like increased number of irrigation days) due to optimised/smart-enabled energy systems.

Insurance advisor company Willis Towers Watson offered the following commentary on the resilience opportunity microgrids currently present in the market and where value may be gained as ground truthed data emerges from implemented projects.

> The resilience benefits of a microgrid may not have a tangible impact on traditional property insurances in the short term, given the existence of the microgrid itself may not inherently reduce the overall probability of loss to the physical assets insured. However, there may be some longer-term benefit to insureds in terms of premium and/or terms and conditions negotiations if there is sufficient data linking the overall resilience of farming operations that use a microgrid to lower occurrence probability of claims. There might be some smaller value opportunities to microgrid operators where policy terms relating to spoilage events can be improved, for example: reduced deductibles for spoilage of refrigerated goods where insureds can demonstrate resilience to power outages.
>
> Traditional “farmpack” insurance policies are unlikely to cater for business interruption/ loss of revenue following physical loss or damage to public utilities, and similarly, there would be no business interruption cover arising from insured damage to a microgrid installation. It would therefore be essential for microgrid owners/operators to extend the wording of their property insurance policy to cover this business interruption contingency.
>
> Providers of non-traditional insurance products, like parametrics, might recognise the value of consistent power supply to minimise crop loss (i.e. not being able to irrigate) in the underwriting of specific trigger events, such as drought, and deliver a more immediate value to microgrid owners/operators.

Regional Communities

Bushfires and flooding have demonstrated to regional and remote communities the vulnerability posed by their orientation to the grid, with communities left disconnected from the grid for weeks in extreme events. Whether publicly, privately, or community owned, integrating localised assets can act like energy dams that support, firm, and optimise existing electricity network services. It can provide a buffer to national market price spikes while helping communities achieve emissions reductions targets, should the assets be renewable.

The remit of the fund for this project was in response to those same vulnerabilities as is the Victorian Government’s Community Microgrid and Sustainable Energy Program, NSW utility Endeavour Energy’s fringe of grid community microgrids, and ARENA’s Regional Australia Microgrids Pilots Program. Each initiative is an opportunity to demonstrate the local benefit microgrids unlock as consumers use their freedom of choice to pursue community, business, and energy resilience.

Emissions Reduction

Agricultural commodities are experiencing varying degrees of pressure and incentive to reduce on farm emissions.

Pressure to decarbonise supply chains (scope 3 emissions) has a growing and tangible impact on Australian agriculture. Landholders are currently experiencing this pressure from corporate buyers. Decarbonising energy inputs offers a substantial reduction opportunity for farms and a competitive advantage in export markets as they increasingly impose carbon premiums on commodity pricing.

Anecdotal evidence from a case study participant illustrates how they enjoy a tangible competitive advantage by achieving carbon neutral status but must purchase credits elsewhere to do so. A grid tied microgrid can help the producer metabolise large energy loads without compromising their net zero status.

Some commodities do not have Environmental, Social and Governance (ESG) requirements to fulfil but recognise it will likely become a premium function of future commodity markets. The ability to decarbonise on farm empowers farmers to maximise this benefit as the market deepens the value placed on emissions.

Peripherally, local climate mitigating actions contribute to community decarbonisation objectives as they exist.

Ancillary, Wholesale, and Local Markets

Australia’s energy ecosystem is still coming to terms with the breadth of benefits distributed energy technologies can offer the NEM while also improving the investment proposition. South Australia’s Hornsdale Big Battery is an example of the increased revenue earned once it was apparent it could offer FCAS services to the NEM. FCAS services were not factored into the initial investment proposition due to the lack of understanding by the market of the full value of integrated DERs. The Hornsdale Battery has also begun offering inertia services to the NEM.

Ancillary Markets

Additional ancillary markets and services are being considered or expanded within the National Energy Market including the introduction of two new Fast Frequency Response Ancillary Service markets also known as “very fast FCAS”. Additional markets like very fast FCAS present further opportunities for inverter-based energy systems like microgrids and large batteries to dispatch energy and be rewarded for diversified services provided to the national market. Ancillary services to the grid broadly include:

- Frequency and voltage regulation,
- Ramping,
- Resource adequacy,
- System restart, and;
- Inertia or spin/non-spin reserves.

The integration of new network participants currently requires a connection process that is prohibitive for most sub-utility scale distributive systems in time, expertise, and money terms. Enabling regulation is required to adequately enable and incentivise new participants like agriculture microgrids to join the NEM.

Wholesale and Local Markets

While some sub-utility scale distributive energy systems may not be able to engage some NEM ancillary markets due to insufficient scale, they stand to offer considerable stability and efficiency to local networks with adequate grid planning and integration.

Due to the increasingly localised generation and consumption of emerging energy systems many sub-utility dispatchable loads will not end up using the transmission network and will reduce use of the broader distribution network. Reforming network charges to reflect actual use of network by way of TUOs and DUOs discounts or the introduction of LUOs (local use) charges considerably improves the investment proposition for dispatchable loads and signals network efficiency.

Currently, network charges are prohibitively high for many dispatchable loads like community batteries, VPPs, and grid connected microgrids to stay competitive in wholesale or local markets. Should local trading be enabled then what is lost in transmission utilisation will likely be made up for in local utilisation, so long as integrative technical and financial planning is implemented. In turn, this signals what transmission and distribution investments are needed.

Microgrids present a considerable opportunity to engage wholesale and local markets, particularly with enabling reforms to network charges. Local Energy Markets on regional grids are configured to local consumer profiles including linking an on-farm microgrid to a community VPP or linking multiple farm-based microgrids. This will require federal and state level participation in innovating, trialling, and integrating new participation models on regional grids.

Self-Consumption Energy Services

The microgrid's ability to offer affordable, reliable, optimised and secure energy on site first improves a farm's energy independence with additional security of access to the grid, if connected. Excess energy generation provides farmers the opportunity to expand productivity and consumption onsite including expanding operations, electrifying transport, and on farm ammonia production.

Energy Data

The collection and use of granular energy data is not just critical to microgrids but the wider smart and renewable energy transition. During the rapid change of increasingly interconnected networks, it is important for clear standards and best practices for energy data to be established to help reduce operational and market risk.

A current market risk is the maturity of Australia's smart meter market. Connectivity solutions, product sizing to support ag loads, and smart meter upgrade costs remain a barrier to smart meter adoption in regional communities. Consequently, grid modernisation in regions will lag unless enabling efforts are taken. In September 2022 the Queensland State Government committed to 100% smart meter adoption by 2030, effectively recognising the tech as foundational infrastructure for grid modernisation.[2] This data is important for networks to collect the more granular network data needed to implement grid flex strategies and upgrades.

There is also opportunity to establish consumer data rights including real time access and privacy rights to enable power of choice. Again, some state and federal energy authorities have begun broaching this matter.

Ag Tariffs and Substation Utilisation

With substation underutilisation occurring across all four case studies and farmers indicating a causational link between energy affordability and increased utilisation, a clear opportunity exists to

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[2] https://www.epw.qld.gov.au/__data/assets/pdf_file/0029/32987/queensland-energy-and-jobs-plan.pdf

address utilisation of network assets in regions via tariff products suited to agricultural energy consumption and productivity levers. As solar has augmented the daily demand profile, certain commodity groups have the flexibility to augment their irrigation behaviours if appropriately rewarded.

Some Australian agricultural energy advocates have taken another approach by seeking a tariff structure reflective of ag energy consumption practices with a price ceiling that ensures agriculture remains competitive throughout the energy transition.[3]

Either tariff structure would not necessarily enable decarbonisation, reliability, or consumer choice for farmers who are motivated by additional value streams.

Ag Energy Consumer Clusters

Many farming regions contain interdependent groups of producers in the form of single commodity regions like cane, or co-located supply chains like horticulture production and processing. These clusters of consumers often have existing relationships and varying degrees of interdependence.

Clusters of ag energy consumers present an opportunity for local and efficient energy sharing and are of worthwhile consideration for project developers or aggregators. Learnings from the Large Microgrid archetype would be best applied here.

Networks may also consider offering clusters negotiated pricing agreements to incentivise collective consumption behaviour that can help solve localised grid constraints.

Regulatory Innovation Mechanism

In 2022 the AER launched the Energy Innovation Toolkit which, among other services, included the launch of a Regulatory Sandbox.[4] As illustrated by the feasibility studies, microgrids and other new smart energy technologies require regulatory change that is innovative and streamlined. The sandbox is a mechanism to waive federal rules and temporarily trial those innovations.

Due to energy issues spanning across federal and state government jurisdictions, there is clear opportunity for states to establish regulatory reform mechanisms that align with the AER's mandate in order to maximise learnings and progress.

Challenges

Policy and Regulatory Barriers

- Distributed energy resources as well as efficiency and load shifting have the ability to manage network challenges such as peak and low demand events. Groups of energy users (or prosumers) can collaborate to manage loads to absorb solar power during the day and reduce evening peaks.
- Demand charges are fixed and formulaic and designed to manage network peaks for around 5% or less of the year. That is, they apply mostly to above-threshold businesses (ie large customers) at fixed times whether or not there is a live constraint.
- Existing charges and tariffs do not support local investment in community battery installation to manage load locally. Current regulations and charges favour DNSPs installing the infrastructure which may not optimise benefit sharing.

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[3] https://www.irrigators.org.au/wp-content/uploads/2022/03/Election-Platform-2022.pdf

[4] https://energyinnovationtoolkit.gov.au/about#trials

- With the structure of Queensland Energy tariffs and the methodology for valuing CER benefits, it is more cost-effective for farms to manage energy behind the meter at present although there are significant potential benefits in allowing farms and other energy prosumers to collaborate to share or trade energy across the networks. This leads to oversizing and may distort grid demand patterns so it may be a greater cost to the economy than allowing collaborative systems. That is, more customers purchasing larger systems and then compensating with larger batteries and knock-on effects for networks with increasing evening peaks and declining minimum operational demands.
- The current network rules do not support brownfield microgrids as they would involve DNSPs ceding some or all aspects of their obligations under the Distribution Authority.
- Mechanisms in place, such as Demand Management Incentive Scheme (DMIS), allow for network benefits to be paid where there is an identified constraint. Where there is no clear constraint, there is some scope for valuing the project through the DMIS which appears to be focussed on R&D or trial projects.

Project Implementation and Equitable Energy Access in the Regional NEM

- Connectivity unreliability makes smart enabled tech adoption difficult.
- Consumer real time access to their data is difficult if available.
- Market maturity variability in Australia solution providers.
- Access to skills for nascent and advanced smart energy systems may not be readily available for putting cost and operational pressures on construction and maintenance.
- Best practices and standards are minimal at best, national guidance is needed to reduce substandard developers from accessing the market.
- Over or highly engineered solutions make it difficult for systems to adapt to the changing market risks.
- Monopolised energy networks like regional Queensland may prevent power of choice and the democratisation of energy.
- Prioritisation of publicly owned assets and investments in network and energy market planning disadvantages.
- New network connection processes are expensive and slow for mid-scale ag energy DERs.

Utility Business Model Reform

- Lack of access to network data and utility revenue modelling opacity make it difficult for project developers and other non-network entities to value and advocate for consumer centric reforms.

Recommendations

1. **Implement viable microgrid case studies as demonstration projects**
    a. Seek approval from Wee Waa and St George participants to advance the project
    b. Determine the feasibility of a Local Energy Market for the Pioneer Valley project
    c. Recommend and support alternative solutions for the Pokolbin participant
2. **Seek regulatory trials for demonstration projects to test**
    a. Microgrid tariffs for Wee Waa and St George, including testing network performance impacts.
    b. Network charges reforms (ie. LUOs or similar) with all 3 viable projects with scope for local trading, including testing network performance impacts.
    c. Expansion of process to value non-network assets as upgrade deferral solutions
    d. Opportunities to streamline the new connections process for mid-scale prosumers.
    e. Diversifying wholesale or ancillary market participation.
3. **Seek funding to help manage project financial risks**
    a. Apply to ARENA's RAMPP Fund
    b. Apply to relevant state initiatives
4. **Advocate for**
    a. State regulatory alignment with the federal regulatory sandbox to keep up with the pace of innovation.
    b. Consumer energy data rights including; updating Section 7.8.2 of the National Energy Market rules to incorporate a provision for real time access to NMI data, streamlined request processes, and the right to export to third party entities.
    c. Support to ensure affordable adoption of smart meters in regions.
    d. Dynamic customer connection types to reflect the flexibility of consumer owned technology and participation.
5. **Develop 'low cost' products and services that solve many of the issues that incentivise consumers to consider energy independence interventions**
    a. Large energy user solar soaker tariffs for load management where demand charges may be restructured or waived at certain times to encourage pumping during solar generation times including the larger pump stations.
    b. Ag tariffs that are linked productivity levers that also help mitigate underutilisation on regional substations.
    c. Amend the provisions of *Section 225A* of the *Queensland Electricity Regulation 2006* to allow that a *small photovoltaic generator* can export up to 30kW. This changes from the existing provision which specifies a maximum inverter size of 30kW. It recognises improvements in technology and allows for efficiently sized systems to be installed with export limits capped. It allows a feed-in tariff for a maximum of 30kW which may be changed as network conditions change due to technological improvements such as implementation of dynamic operating envelopes.
6. **Ensure local/community owned energy assets are integrated into and valued by the NEM**
    a. Transparency of grid performance and asset data to streamline the integration of participants.
    b. Establish authorities for local/community power.
    c. Make provisions in REZ planning for sub-utility dispatchable assets.
    d. Develop robust coexistence and subsidence standards to ensure benefits remain in regions.

Future Work

The following future work products would build upon the learnings of this Project:

Pioneer Valley Local Energy Market Feasibility Study

The project team will adjust the scope of the Large Microgrid case study to explore the viability of a Local Energy Market as per the feasibility study recommendations.

ARENA RAMPP Submission

Submissions for ARENA's Regional Australia Microgrid Pilots Program will be prepared for the Edge of Grid and Anchor/Hybrid case studies. The Large Microgrid case study will also be submitted should the Local Energy Market feasibility study generate positive results.

The Project team will also seek to have RAMPP projects included in the AER's federal regulatory sandbox with necessary reciprocal state exemptions.

Dispatchable CER Market Research

QFF is currently undertaking research to identify the emerging market for microgrids, community batteries, and VPPs across Queensland's Renewable Energy Zones. The project is funded by Energy Consumers Australia and will survey 110 councils, farmers, and businesses in regional Queensland. The project commenced in September 2022 and is expected to be completed June 2023.

Advocacy and Further Research

Project partners have indicated varying interests in pursuing further research and advocacy for the following topics:

- State regulatory sandbox for federal alignment
- Microgrid/dispatchable load tariff trials
- Network tariff modelling reforms
- Productivity levers at the water-energy nexus and ag electricity tariffs
- Agrivoltaics trials

The flow on benefits of **microgrids for agriculture**

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