Regional and Remote Communities Reliability Fund - Microgrid

MyTown Microgrid

Heyfield local energy options: techno-economic analysis

Part 2 Boundary options: revised results

Milestone 3.4b – January 2022

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Wattwatchers Digital Energy
AusNet Services
Heyfield Community Resource Centre
Latrobe Valley Authority

About the project

MyTown Microgrid is an innovative, multi-year, multi-stakeholder project that aims to undertake detailed data-led microgrid feasibility for the town of Heyfield (Victoria), built on a platform of deep community engagement and capacity building.

The project received funding under the Australian Government's Regional and Remote Communities Reliability Fund Microgrids stage 1 funding round. It also received funding from the Latrobe Valley Authority as part of the Gippsland Smart Specialisation Strategy.

Citation

Shah, M.D., Rutovitz, J., Langham, E. (2022) Heyfield local energy options: techno-economic analysis. Part 2. Boundary options: revised results. Prepared for the Regional and Remote Communities Reliability Fund.

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Executive Summary

This report presents research output on the potential boundary options of microgrid solutions for the town of Heyfield, Victoria, revised from the report in June 2021, which predates the information from AusNet Services on network assets and network structure, including a detailed network diagrams.

Microgrids could be a feasible alternative for network investment in rural and remote communities such as Heyfield. The outlying farms and smaller communities are reportedly poorly served by the weak grid. However, recent expansion at the Australian Sustainable Hardwoods (ASH) timber mill led to an investment in voltage regulation on the incoming feeder, reducing the occurrence of persistent outages and reliability issues.

While Heyfield residents have reported issues with network reliability, it remains unclear to what extent this reflects historical problems. The Maffra zone substation is operating near capacity in summer, but AusNet Services is not proposing any capacity upgrades or expecting substantial growth in the region. Network constraints in the Heyfield region need to be considered while planning the microgrid boundary for the region.

Boundary options

Four boundary options were examined, ranging from Boundary 1, which is a selection of critical sites in the centre of Heyfield to Boundary 4, which includes Heyfield, Denison, and Winnindoo. An option referred to as Boundary 0 is also considered (which is not a microgrid). Boundary 0 involves increasing the efficiency and flexibility of home and business energy use[1].

Boundary 0 Energy efficiency

Boundary 1 BTM at critical sites

Boundary 2 Heyfield town centre

Boundary 3 Heyfield Town

Boundary 3 Heyfield Town

Figure 1 – Boundary options for a Heyfield microgrid (revised)

[1] Increasing ‘flexibility’ of when energy is used helps manage the variability of renewable energy sources.

It was considered desirable to examine a microgrid encompassing only the town centre, which was to be Boundary 2. However, the physical characteristics of the network meant the centre of town could not be separated on the medium voltage network as there are no suitable connection and disconnection points, and areas outside the town would be left without power. Smaller options taking in just a couple of feeders (2A, 2B, 2C, 2D), were briefly considered, but these are unlikely to be possible without excessive technical difficulty and expense. Boundary 2 was therefore abandoned.

Boundaries 3 and 4 remain as potential microgrids, with boundary 4 having considerably greater geographical coverage. After consultation with the CRG and project stakeholders, it was decided that Boundary 3 should be the option for further technical and economic feasibility studies.

The approach used to identify these boundary options is described in order to provide a guide for others. However, a certain level of proficiency in electricity networks and power engineering is required, with the project team relying on experts from Federation University Australia and the University of Technology Sydney. Crucially, defining and assessing these boundaries required information from AusNet Services.

Five previous boundaries and the energy efficiency plus option were proposed in June 2021 based on the LV/MV network map publicly available from the AusNet Services web portal, and without being able to identify the open points (see Appendix 1 for a description of the previous options). The options for energy efficiency (Boundary 0), and critical sites (Boundary 1) remain the same. Boundary 3 has been modified to take account of available switch points, and has smaller geographic coverage than the previous boundary. The other three options proposed previously have found to be infeasible now that detailed information is available from AusNet Services.

Community feedback

The boundary options and the importance of open points where any microgrid could be connected or disconnected were discussed with the Community Reference Group in two workshops in October 2021. The smaller options within the town centre (2A, 2B, 2C, 2D) did not meet the community aspirations for a town microgrid, as well as having considerable technical challenges, so these options were dropped for further investigation. It was decided to test the revised boundary option 3, as it was the smallest microgrid that met community aspirations to include most of the town.

Next steps

The next phase of the project will assess these options for their suitability for Heyfield, including:

- An assessment of a “no regrets” options (Boundary 0: energy efficiency +)
- An initial assessment of an islandable microgrid at Boundary 3; if this appears economic, feasible, and desirable, then a more detailed assessment will be undertaken.
- An assessment of critical sites and other local energy options, depending on the Boundary 3 initial assessment outcomes.

Suitability will depend on multiple factors: whether it is technically feasible, whether a business case is viable, and whether the options deliver the community's aspirations.

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List of abbreviations

Abbreviation	Description
CRG	Community Reference Group
DAPR	Distribution Annual Planning Report
DELWP	Department of Environment, Land, Water & Planning
DER	Distributed Energy Resources
ICT	Information and communication technology
kV	Kilovolts
LV	Low voltage
MFA	Maffra Zonal Substation
MV	Medium voltage
MVA	Mega-volt ampere
MW/MWh	Megawatt /Megawatt Hours
OLTC	On-load tap changer
PV	Photovoltaic (Solar)
RIT-D	Regulatory Investment Test – Distribution
SWER	Single wire earth return
VAR	Volt ampere reactive

1 Introduction

The Heyfield MyTown Microgrid project aims to undertake a detailed data-led microgrid and energy solutions feasibility for the town of Heyfield (Victoria), built on a platform of deep community engagement and capacity building. Over the three-year duration, the project also aims to develop the knowledge and tools to make it faster, easier, and cheaper for other regional communities to understand microgrid and other energy solution propositions for their community.

This report on the boundary options for Heyfield is associated with the Techno-Economic Work Package 3 and is one element of milestone 3.4, Analysis Results (techno-economic assessment of energy portfolio options). It is Part 2 of Milestone 3.4 and should be read alongside Part 1 Energy options: initial results. During the next stage of the project the results from this work will be used for the initial feasibility study for a microgrid.

This analysis is a revision of the Milestone 2.7 Boundary Options report. An understanding of the possible microgrid boundary options and local energy options is essential for informing the next phase of the project.

The existing network assets, network performance, and planned network investments discussed reflect the current centralised network supply. The boundary options presented are more localised network supply approaches, in line with community aspirations to increase the amount of energy sourced locally to increase local resilience, increase the renewable proportion of energy consumed, and share excess renewable generation within or between neighbours.

This report covers:

- The current network situation, including an overview of network performance issues affecting the community and a discussion of whether a microgrid or other local energy options could address these issues.
- The approach taken to identify the possible network boundaries for a microgrid that includes Heyfield.
- The network topology in and around Heyfield.
- Four possible boundary options for Heyfield, plus option zero, energy efficiency.

2 Current Network Topology

2.1 Overview

Heyfield is a town with a population of approximately 2000 in the Wellington Shire of Victoria. Heyfield is located around 200 km east of the Melbourne CBD and is in the AusNet Services electricity distribution network area. The Heyfield Township and surrounding area are normally (possibility to feed from Traralgon in case of emergency) connected to the Maffra Zone Substation (MFA), which is approximately 15 km away along a 22kV Medium Voltage (MV) distribution network feeder. The 22kV is then stepped down for the customer connections to the 230/415V Low Voltage (LV) network at multiple LV transformers around the Heyfield area. Figure 1 shows the current network topology with nearby substations. Under the normal configuration, e.g., Heyfield is served from Maffra Zone Substation. Heyfield is also linked via a 22kV MV line to the Traralgon Zone Substation with the connection left open (that is, unconnected) at a point on the Cowwarr to Toongabbie Road. This enables AusNet Services to maintain supply under abnormal conditions, as they can make this connection if there is a problem with the supply from Maffra.

2.2 Load and peak demand

The Maffra Zone Substation (shorthand code 'MFA') includes town and rural residential loads, with some town-based commercial, industrial, and agriculture businesses. MFA is a summer peaking station and the peak electrical demand reached 36.1MVA in the summer of 2017/18. The recorded peak demand during the winter of 2018 was 26.2MVA. MFA demand is forecast to grow steadily at around 1% per annum[2]. The load transfer capability of the feeder interconnections between MFA and its neighbouring zone substations is 6.5 MW [2].

The AusNet Distribution Annual Planning Report (DAPR) provides the following forecasts for the Maffra Zone substation:

Rating/Forecast	MVA	Explanation
Nameplate Rating	40MVA	The nameplate rating is the nominal design capacity of the Zone substation. Maffra Zone Substation was established with two 10 MVA 66/22 kV transformers in 1960. A third transformer was installed in 1998.
Firm Capacity Summer	31.1MVA	Firm capacity takes into account potential failure of one piece of equipment.
Firm Capacity Winter	37.8MVA	
Forecast 50% POE summer	36.4MVA by 2025	The 50% Probability of Exceedance (POE) is a forecast that is likely to be exceeded every second year.
Forecast 50% POE winter	26.7MVA by 2025	

2.3 Planned network investment

MFA is one of the eight zone substations where major asset replacement is expected in the next five years[2]. AusNet proposes to replace circuit breakers and current transformers during the next investment period (2020-2025). There is a current Regulatory Investment Test – Distribution (RIT-D) out for consultation regarding these works at MFA. Replacement of the two main 1960 transformers has been deferred to beyond 2026.

Microgrids can potentially reduce the need for network investment in rural and remote communities such as Heyfield. The outlying farms and smaller communities are reportedly poorly served by the

[2] Distribution Annual Planning Report, AusNet Services, 2021-2025.

weak grid. However, in Heyfield, expansion at the large timber mill led to an investment in voltage regulation on the incoming feeder, reducing the occurrence of persistent outages and reliability issues.

Heyfield residents continue to report poor network reliability, although it remains unclear to what extent this reflects historical problems. The Maffra zone substation is operating near capacity in summer but AusNet Services is not proposing any capacity upgrades or expecting substantial growth in the region. Network constraints in the Heyfield region need to be considered while planning the microgrid boundary for the region.

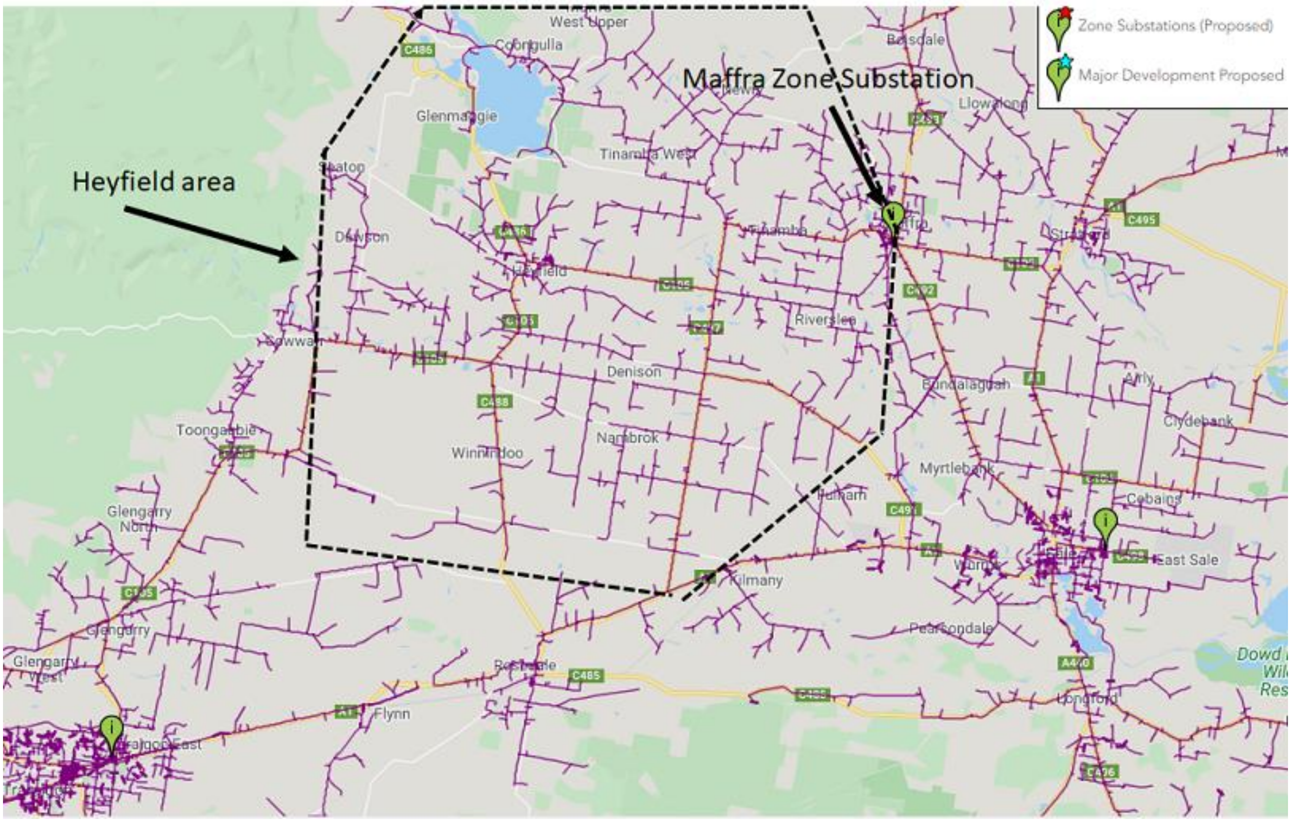

Figure 2 – Heyfield region and Maffra Zone Substation – MV network

3 Approach for identifying boundary options

3.1 Overview

This section explains the approach taken to identify the initial microgrid boundary options and the key steps to define the boundary. There has been a two-stage process, as initial boundaries were proposed without feeder, transformer, and network connection information from AusNet Services.

Figure 2 presents the steps and data sources used for boundary option selection for feasibility study. Input from the community, resource mapping from the community, and field visits to see the opportunity of creating a required generation and load balance (prerequisite for microgrid development) have been considered. The LV/MV feeder map, community vision and local generator information are used to develop the initial boundary options.

The network data and geospatial data files provided by AusNet Services and a site visit were used to identify the route of the feeder, voltage level and possible interconnection/disconnection point(s), to revise the boundary options obtained in the earlier step. Later, at a high level, the control challenges, cost of islanding (protection, network augmentation, etc.) to select the boundary option for the feasibility study.

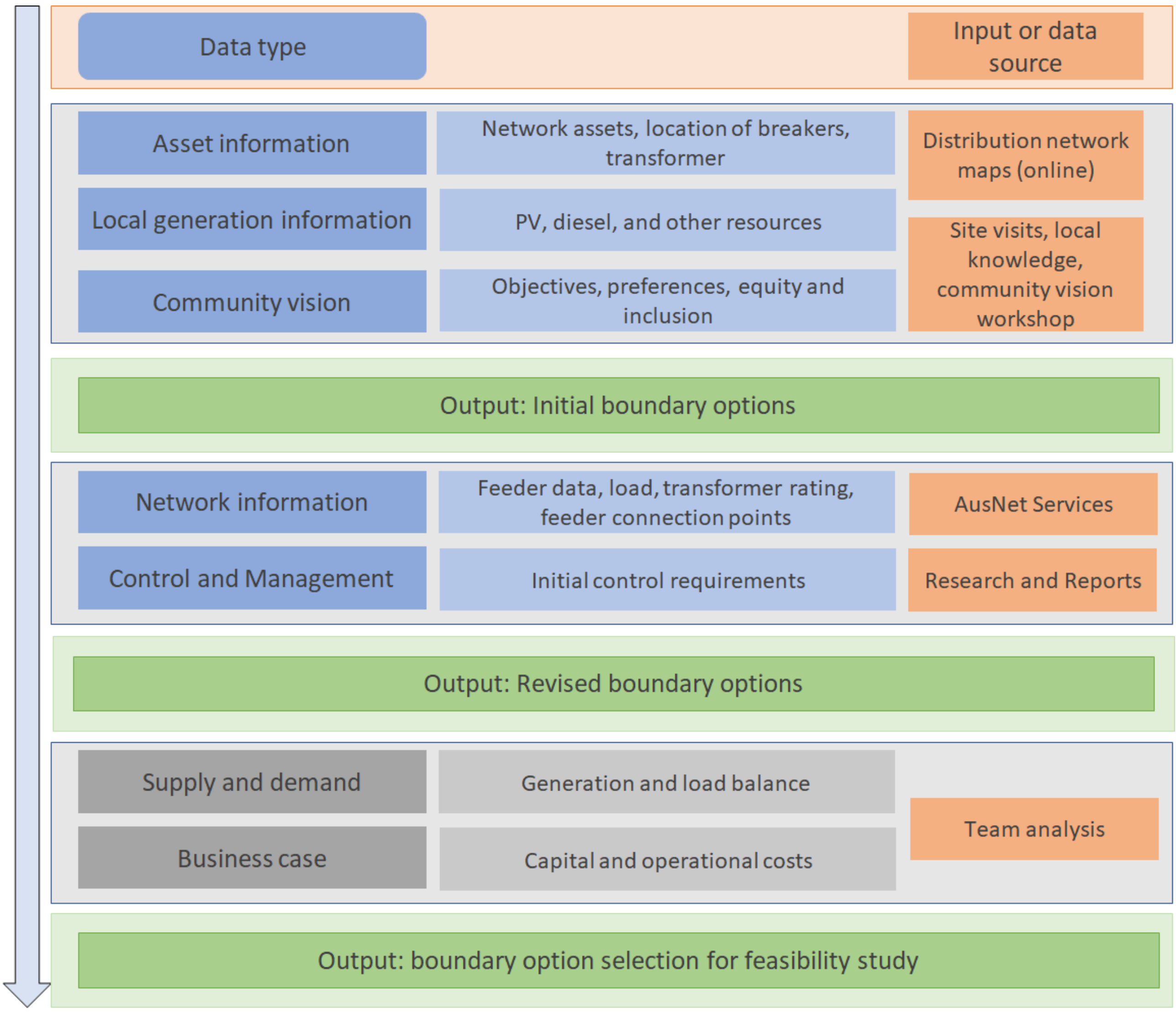

Figure 3 – Data sources for boundary option selection

3.2 Boundary design questions

Figure 3 below illustrates how design questions were used to select the microgrid boundaries. Each of the four steps is elaborated below.

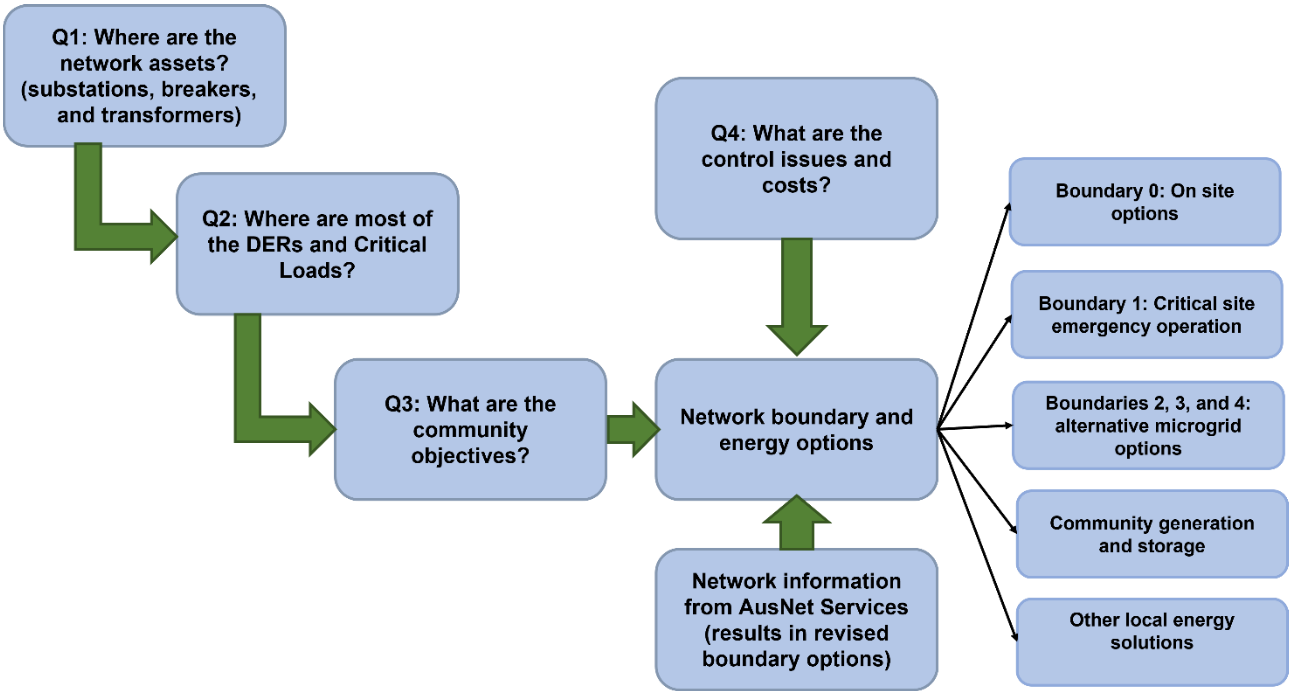

Figure 4 – Boundary option design questions

Step 1: What are the locations of the network assets?

The locations of existing network assets have a strong bearing on what potential microgrid options are plausible. Given microgrids aim to enable local energy self-sufficiency and provide the ability to operate in 'islanded' mode from the larger grid at least in emergency or abnormal situations, logical switching points for islanding need to be identified. The existing network assets such as protection devices, substations, switches and transformers were assessed to find the initial candidates for microgrid boundaries. This was initially undertaken using AusNet Services online network maps to get a rough idea about the network assets, complemented by a field visit to confirm the various network assets around the area. However, the detailed information supplied by AusNet Services led to considerable revision of these potential boundaries, illustrating the need for the information at this step to be verified.

Step 2: What are the locations of the existing DER and the critical loads?

If a microgrid is islanded (cut off) from the main grid for any period of time, it must balance the local energy generation and consumption in each moment. Therefore, it is useful to have a diverse array of energy users to ensure all consumption does not occur at the same time of day and have local energy generation that matches the daily, seasonal, and annual variation of this consumption. It is also important to note which energy users are a 'critical' or high priority to be served 24/7, particularly in times of outage or emergency. This might include hospitals, community services, emergency response facilities, or high-value businesses.

Numerous local generation sources already exist within the Heyfield and surrounding areas. Almost a third of all households and half of all local businesses have rooftop solar PV, with a cumulative capacity of 3 MW (approx.). There is also 4 MW of hydro power further north at Glenmaggie, numerous standby generators at farms and businesses, and an option to extend a bioenergy facility at the timber mill. There is a huge appetite in the community for new renewable energy generation regardless of the technology, including community battery storage. Numerous other opportunities may also exist, such as flexible loads at certain facilities that can help to balance supply and demand. Community workshops in the Heyfield region were used to determine the location of existing and potential DER sources, and the types and locations of critical load sites.

Step 3: What are the community objectives?

The boundary options are also influenced by the objectives that the community is seeking to address through local energy solutions. These objectives were ascertained via a community visioning workshop and survey. In addition to the goal of local renewable energy self-sufficiency, two additional key objectives were identified:

- *Reliability improvement:* According to the community members in the Heyfield region, the region has issues of voltage regulation and frequency over three decades. This is particularly prominent at the edge of town. While the research team will investigate the base of these claims from network data when it becomes available, a microgrid with local energy resources could be a solution to this issue. Therefore, options to include these outlying areas were considered.
- *Equity and inclusion:* It is important that the microgrid initiative seek to benefit the community in an equitable fashion. This has challenges as in many cases the larger the microgrid, the more complex and costly it becomes. On the other hand, larger boundary options have the scope to include a more diverse array of existing generations and loads, which could reduce load balancing costs. The boundary options were thus defined to include as large a number of community members and businesses as possible, within plausible bounds (particularly constrained by Step 1).

Step 4: What are the control issues and costs?

While the costs of DER (including battery storage) are dropping year-on-year, the economics of microgrids is still challenging. As such, capital cost implications such as any network reconfiguration required for microgrid establishment or operating costs associated with highly complex control and load balancing should be limited to increase chances of viability.

The important control issues that need to be considered relative to each boundary option are:

1. Developing coordinated control for the proposed microgrid;
2. Handling voltage issues for downgraded LV feeders from batteries and master inverters; and
3. Fast and robust control for master inverter used with battery to extract its inertia and deep discharge characteristics to support the LV feeder.

Downstream from Heyfield, the settlement of Seaton relies on a Single-wire earth return (SWER)[3] system. This has lower reliability and the inclusion of SWER areas are likely to require additional costs for control. Given these larger boundary options are more ambitious, and therefore have a lower likelihood of economic viability, the options with lower capital and operating costs expected will be analysed first; see Section 5 for further discussion of this approach.

[3] **Single-wire earth return** (SWER), also called single-wire ground return, is a single-wire transmission line which supplies single-phase electric power from an electrical grid to remote areas, and is relatively low cost.

4 Results – boundary options

This section outlines the five boundary options in order of ambition. A table comparing the options is also provided. These boundary options (See Figure 4) have been categorized as follows:

- Boundary option 0: Energy efficiency (this option covers energy use in both homes and businesses; there is no boundary, and it is not a microgrid)
- Boundary option 1: Critical Sites (DELWP, hospital, IGA, and others)
- Boundary option 2: Heyfield Town Centre (note that this option is not going to be investigated further)
- Boundary option 3: Heyfield Town (wider geographic area with 22 kV network)
- Boundary option 4: Heyfield Town and Winnindoo (wider geographic area, includes more solar systems and diesel generators).

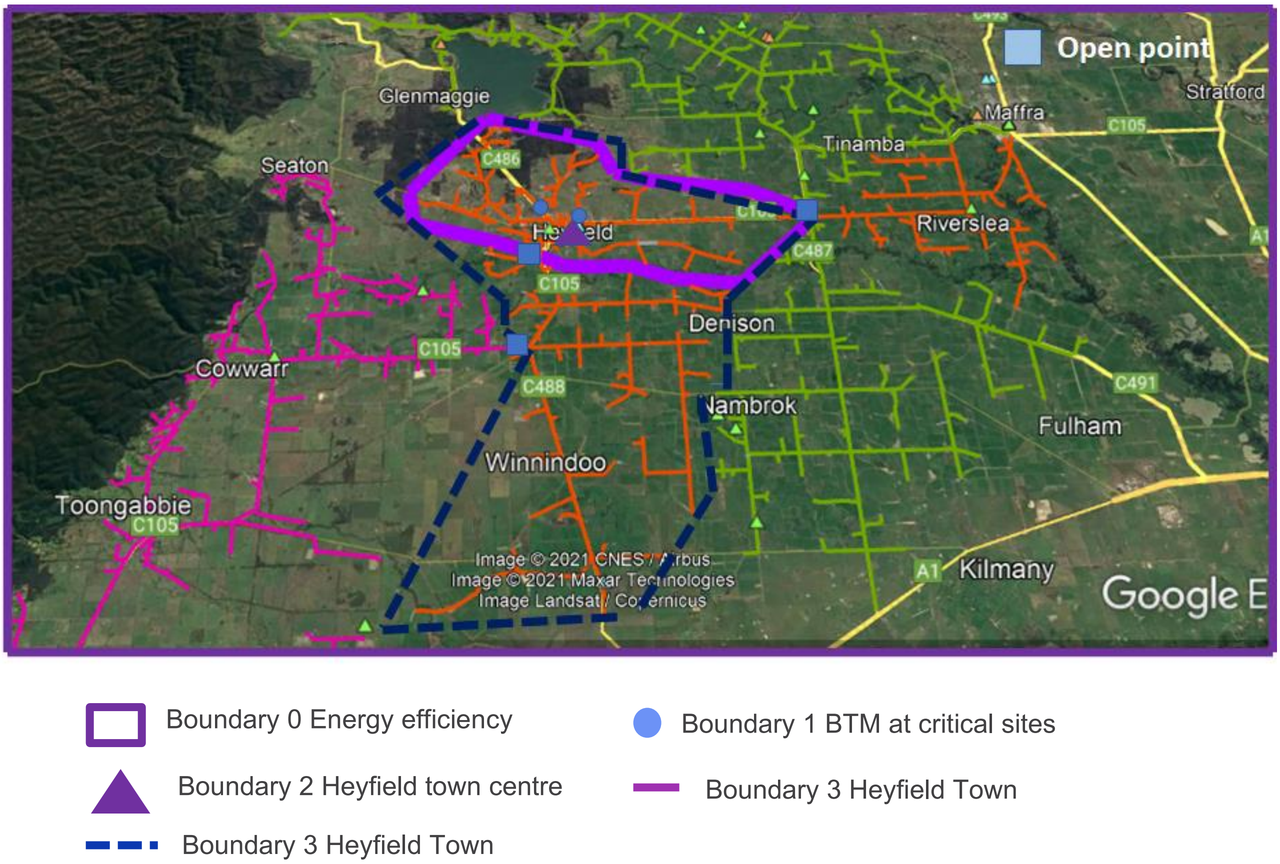

Figure 5 – Boundary options for a Heyfield microgrid (revised)

4.1 Boundary Option 0: Energy efficiency

Energy efficiency has no effective boundary (i.e., location does not matter, anyone can participate), and of course, is not a microgrid. Energy efficiency will reduce energy use and costs in both homes and businesses. Decreasing the amount of electricity consumed means renewables can provide a greater share of the town's demand and reduces the capital cost to provide renewable generation to meet any particular share or future microgrid solutions (i.e., show the link to the microgrid theme).

As well as measures to reduce consumption, control measures can be used to increase the *flexibility* of when energy is used, which can help manage the variability of renewable energy sources by shifting the load to when there is most generation (for example, by heating water in the day when the many solar panels are generating). These energy efficiency and load control mechanisms helps to reduce the peak demand in both LV and MV feeders, which reduces the amount of grid electricity that is needed at these times. This reduces the amount of energy which must be 'bought in' – either by individual customers or by the entire microgrid – and is critical when a microgrid is in the 'islanded' model, working independently of the grid.

4.2 Boundary Option 1: Behind the meter at critical sites

This is the simplest approach to providing some emergency electricity supply at sites in Heyfield. This can be explored for multiple locations as behind-the-meter (BTM) microgrids for critical sites, which are islandable in cases of emergency (see figure 5). Behind the meter, the microgrid can be formed in locations such as the local Victorian Government Department of Environment, Land, Water & Planning (DELWP) office with emergency response facilities, Heyfield Hospital, Heyfield IGA supermarket, and Australian Sustainable Hardwoods (ASH) based on the available generation sources and energy storages.

Since these microgrids would be behind the customer meters, there are low to zero network augmentation issues or costs. The main issues with this option are the limited provision of improved services across the community, and the fact that storage and load balancing requirements will need to be met entirely at each site.

There has been some feedback from the community about which sites should be included, and this is expected to be discussed further by the Community Reference Group.

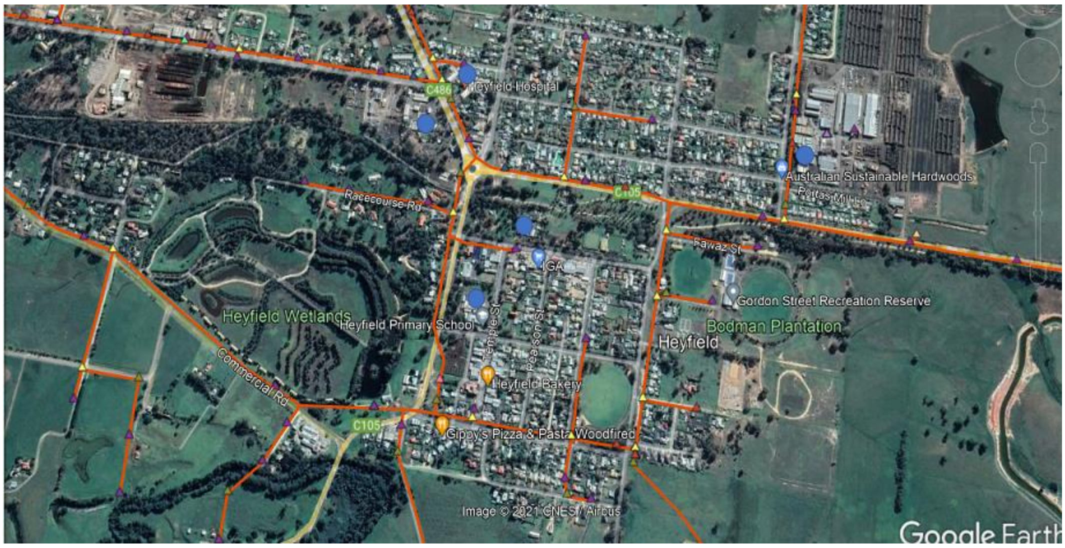

Figure 6 – Heyfield critical sites (Boundary Option 1)

4.3 Boundary Option 2: Heyfield town centre

The next obvious topology to investigate for a microgrid in Heyfield would be one that included the Heyfield town centre, and the critical sites mentioned in Boundary Option 1. However, the actual circuit breakers meant there was nowhere that could isolate just the town centre without cutting of supply to other lines (see Figure 6), so a desired Boundary Option 2 was not physically feasible with the current network configuration.

Figure 6 shows the desired option 2, as well as potential boundaries that could in principle be implemented (2A, 2B, etc). It can be seen that if option 2 was implemented in entirety, the sites along the C486, Riverview Road, Allman St, and Tyson St would require alternative route for power supply if this option was implemented as an islanded microgrid, otherwise these consumers would left without power.

Based on the MV network switch and circuit breaker locations, there were four possible options for microgrids within the town centre: 2A, 2B, 2C, 2D (See Figure 7). It is worth noting that these options do not include most of the critical sites identified by the community and the research team.

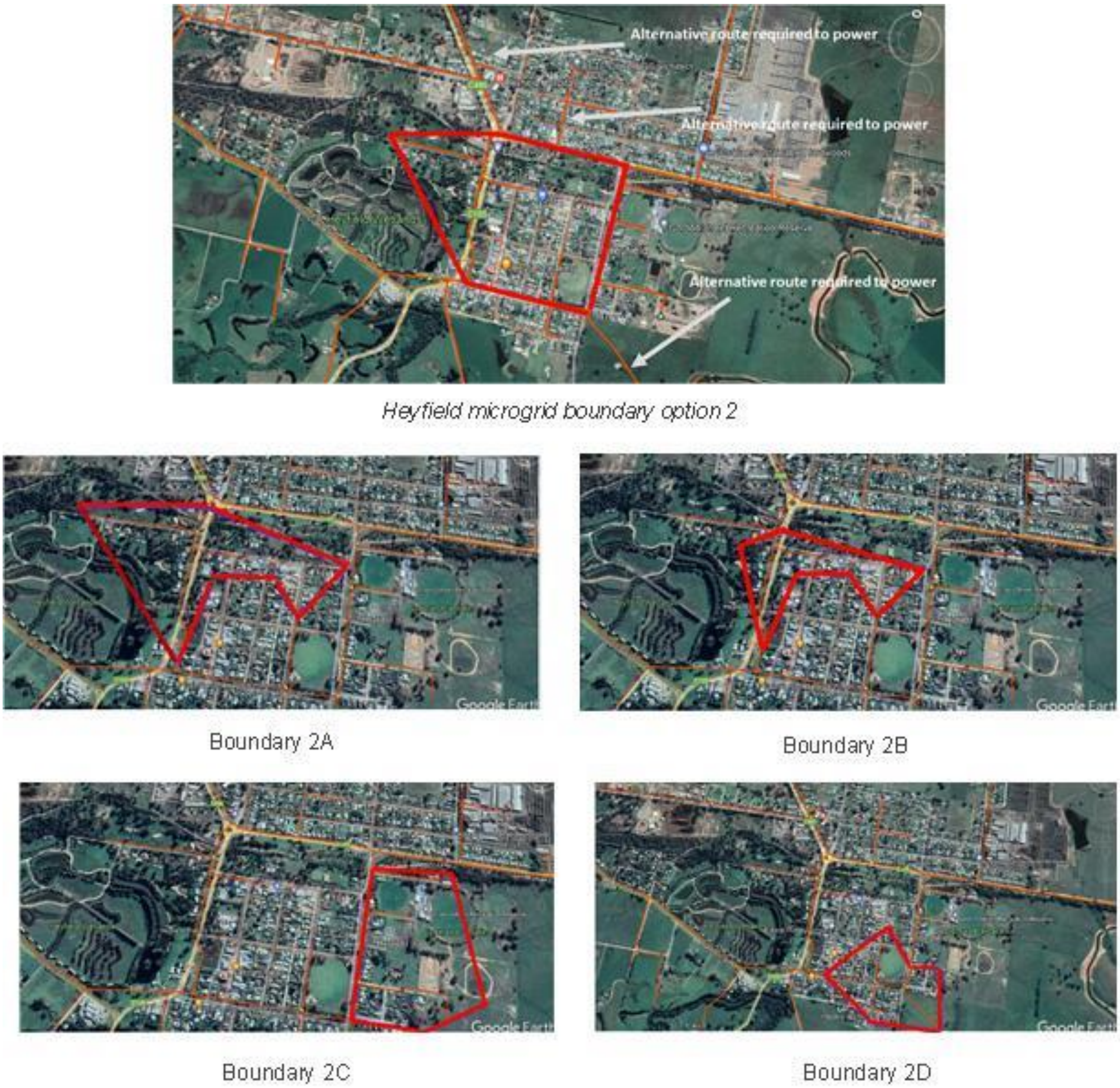

Figure 7 – Heyfield town centre microgrid options (Boundary Option 2)

4.4 Boundary Option 3 – Heyfield town

Boundary Option 3 covers the whole town while also stretching north to the southern banks of Lake Glenmaggie, southeast towards Denison, south to Broadbent's motor inn, and east beyond the Heyfield Golf Club.

Network augmentation would be relatively low cost as it uses two existing switch points (i.e., SL016 and SL015) on the network and islanding would be easy to maintain and operate from a technical and control perspective. Technical feasibility can be undertaken to determine whether such a microgrid would provide better supply reliability to the main part of town, and enhance resiliency against extreme weather and grid interruption. The inclusion of the ASH timber mill could reduce the requirement for storage by including dispatchable bioenergy, although it is unclear if this will work with the business model for the timber mill. However, even with the timber mill, the boundary includes a relatively small number of loads, which means highly correlated and fast variations of renewable generation sources (such as occur with a system dominated by solar energy) could make secure and reliable operation challenging.

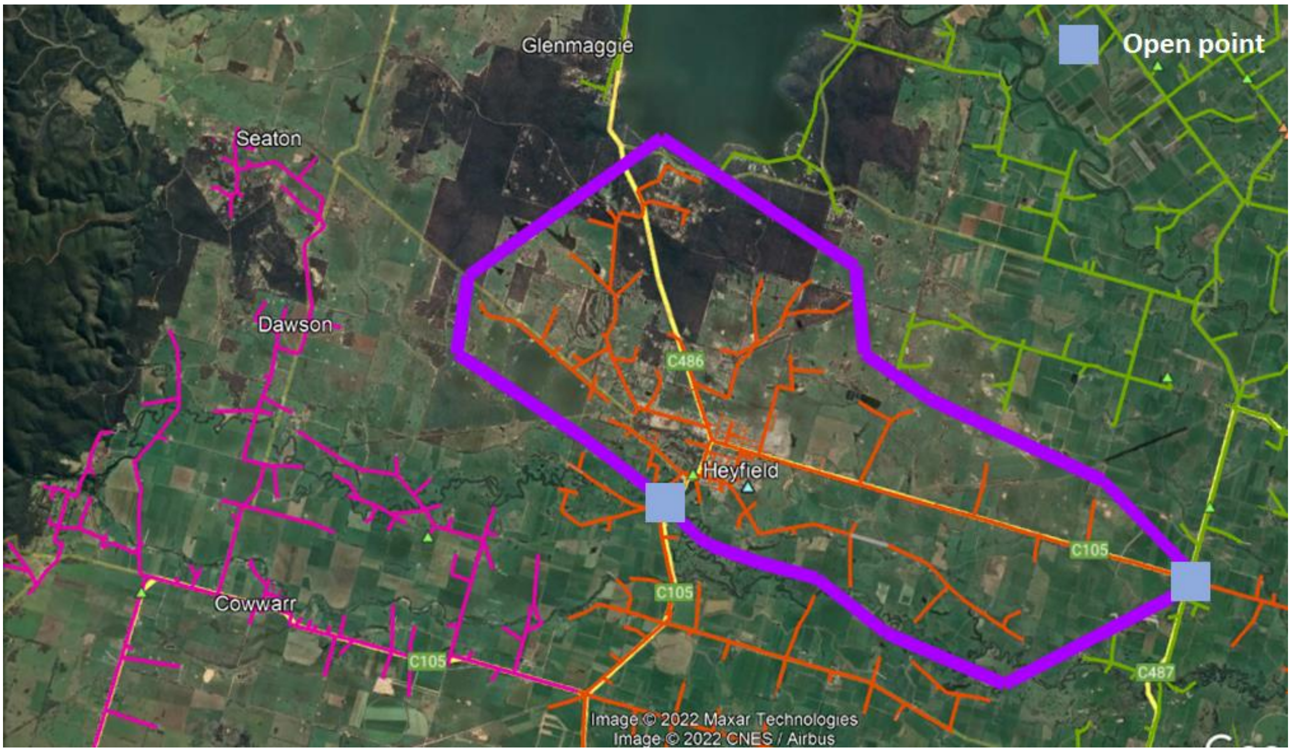

Figure 8 – Heyfield Town microgrid (Boundary Option 3)

4.5 Boundary Option 4 – Heyfield, Denison, and Winnindoo

Figure 9 shows the largest option for the microgrid which includes Heyfield and the surrounding area, including Denson and Winnindoo, and quite a large number of dairy farms and irrigation facilities. Two existing open points (SLO16 on the east and SWTN 052 on the south-west) can be used for this option.

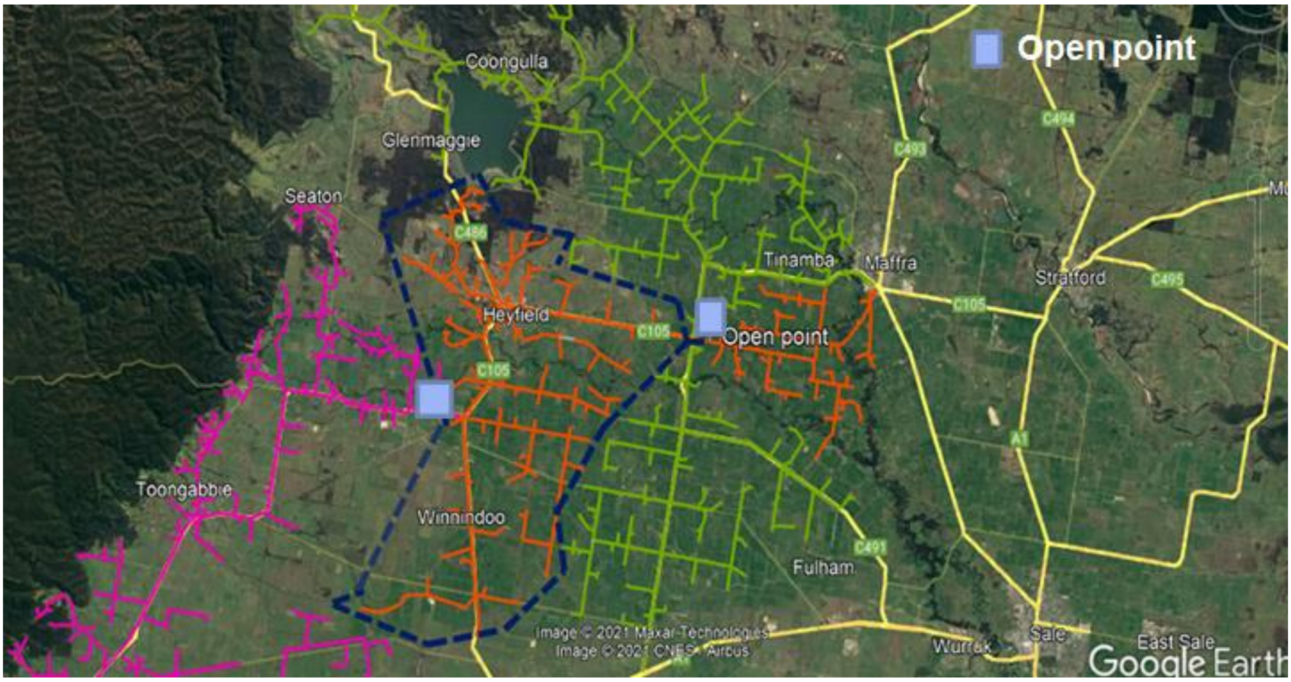

Figure 9 – Heyfield Denison and Winnindoo microgrid (Boundary Option 4)

Due to the size of the microgrid, this option would require additional control mechanisms such as protection devices, coordinated Var control[4], ICT[5] requirement for coordinated operation, and microgrid energy management. There are several dairy farms in the Winnindoo region. Due to the operation and the type of load in dairy farms, this boundary could experience power quality issues in the microgrid (e.g., "non-linear" loads and phase imbalances).

4.6 Comparison of boundary options

Table 1 summarizes the advantages and challenges associated with all the boundary options. Further analysis on balancing aggregate demand and potential local generation and the associated financial assessment will need to be conducted to understand which microgrid boundaries are feasible and desirable.

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[4] VAR is an abbreviation of voltage-ampere reactive, a term that is used extensively in the definition and measurement of reactive power within electrical circuits. VAR control is used to manage the relationship of varying current and voltage that collectively originates from active electrical components.

[5] Information and Communication Technologies (ICTs) is a broader term for Information Technology (IT), which refers to all communication technologies, including the internet, wireless networks, cell phones, computers, software.

Table 1: Advantages and challenges associated with different boundary options

Option	Description	Approx. size (& community assets included)	Need for network augmentation	Maintenance requirement	Pros	Cons
1	**Critical sites in Heyfield**	Very small (behind the meter microgrids at each site, including DELWP, community centre, timber mill, hospital)	None/Very Low	Low	Simple operation and control due to behind the meter structure, no network augmentation.	Network connection issue, regulatory issue with power export and import, separate storage requirements for each of the sites as they are all behind the meter consumers.
2	**Heyfield Town Centre**	Several homes, business and commercial consumers corresponding to the MV network encompasses Mart St, Davis St, Gordon St, MacFarlane St.	Due to the ring structure of the MV Heyfield network, major modification would be required.	Low	Not applicable as microgrid not feasible.	The network topography means it would be prohibitively expensive to create this microgrid.
2A, 2B, 2C, 2D	**Mini-microgrids within the town centre**	Series of small microgrids, each with a few homes & businesses corresponding to elements of the LV/MV network that could be isolated without disrupting supply to other locations.	Low	Low	Larger than the option 1, include more consumers.	Network control challenges – voltage and frequency regulation in a small network. These options do not include most of the critical sites identified by the community and the research team.
3	**Heyfield Town**	Moderate-to-large (homes, business, timber mills)	Low to medium	Moderate	Moderate to a large network, better reliability and security of operation, greater generation and demand flexibility.	Complex control is required, network limits are not known. Additional DERs may be required.
4	**Heyfield Denison & Winnindoo**	Moderate-to-large (homes, business, timber mills, Gippsland Water pumping station, Water tower, Dairies in the Winnindoo area)	Very high likelihood	Moderate to High	Large network – able to supply a large number of consumers, better reliability and security of operation, integration of more DERs from Winnindoo region.	Complex control issues, including power quality and security issues for weak network, additional line and assets.

4.7 Feedback from the community

The community was involved in reviewing and selecting the preferred boundary options, and informed about the necessity for revision after receiving the AusNet Services information. The Community Reference Group (CRG) met with the technical research team on 16 November to revisit information about:

- Boundaries
- Resources
- Critical Sites

The meeting was also to ensure that the modelling team understands CRG priorities and the CRG understands the reasons for the different parts of the modelling exercise. The following feedback was recorded from the CRG meeting:

- Some CRG members had concerns about Boundary option 2.
- The CRG wants to see the network as a community asset and make it work for the community's benefit.
- The technical team will model Boundary 3.
- Investigate the constraints of different transformers in Heyfield.
- The project team will look at technical feasibility, and also at the ownership and governance aspects of the project.

The CRG also wants the research team to explore:

- Issues about ownership and operation of the microgrid.
- How much energy will we produce and how much does Heyfield need from Maffra or other transmission lines.
- What would be the best tariffs for the modelled option (Boundary 3).
- Considering the excess generation within the Heyfield, the CRG group also like to know about the limits to export and the potential for using generation within the local market.

5 Conclusion and next steps

A sequential approach to modelling the boundary options will allow the project to begin by analysing options that are most likely to be viable and feasible while meeting community aspirations, and only extend to more ambitious options if data suggests this may yield a positive result.

Option 0 (energy efficiency) has zero augmentation costs, delivers some community aspirations, and is likely to enhance the viability of any microgrid option, so will be investigated in parallel.

Option 1 (critical sites) has zero augmentation cost but only delivers limited community aspirations, although it does provide some emergency powered sites. Option 2, the centre of town, was not technically feasible as the microgrid could not be separated on the medium voltage network as there are no suitable connection and disconnection points, and some areas outside the town would be left without power. Options 2A, 2b, 2C, and 2D included only small segments of the town centre, were technically complex, and did not meet community aspirations.

Boundaries 3 and 4 remain as potential microgrids, with the community goals matched by Option 3, which has a more limited geographical coverage and therefore somewhat lower complexity. For example, it will be less complex to maintain secure and reliable operation of the microgrid for Boundary 3, and there is a lower requirement for ICT to maintain energy management than Option 4. Boundary Option 3 was therefore chosen for further technical and economic feasibility study, and will be the starting point to model the supply/demand balance and provide an initial sense of cost-effectiveness, key sources of value, and local seasonal constraint challenges.

Modelling of Boundary option 4 may be undertaken at a later stage, depending on the initial assessment of the feasibility of Boundary 3, and the results of techno-economic analysis comparing load/supply balancing options and costs.

Undertaking an approximate pre-feasibility study for the Boundary Option 3 microgrid is intended to enable the community to make a decision on whether to pursue further feasibility studies for a microgrid, or to focus on non-microgrid energy solutions.

Appendix 1 Boundary options as described in June 2021

This section outlines the five initial proposed boundary options in the report of June 2021. These options are developed based on the LV/MV network map publicly available from the Ausnet Services web portal. These options were identified to initially examine the opportunities and possibilities of various microgrids in Heyfield and its surroundings. However, most of these identified boundary options encompass a wider network area and multiple circuits to be integrated together. These would increase the complexity and cost associated with the network upgrade. Therefore, these options deem not suitable for further investigation.

Crucially, these options were described in advance of the network topography from AusNet Services. These are described in detail in the *Milestone 2.4 report: Options List – Boundary Options, June 2021.* These options were categorized as follows:

- Boundary option 0: energy efficiency (this option remains, see Section 4.1)
- Boundary option 1: Behind the meter at critical sites (this option remains, Section 4.2)
- Boundary option 2: Heyfield Town centre;
- Boundary option 3: Wider area without SWER network (wider consumers with 22 kV network);
- Boundary option 4: Heyfield town with Glenmaggie SWER network (wider consumers with different network structure);
- Boundary option 5: Multiple towns with SWER network (large variety of consumers with different network structures).

Boundary 0 (energy efficiency) and Boundary 1 (critical sites) are described in Section 4.1 and 4.2. The previous options 3, 4, and 5, representing various sizes of microgrid, are described below.

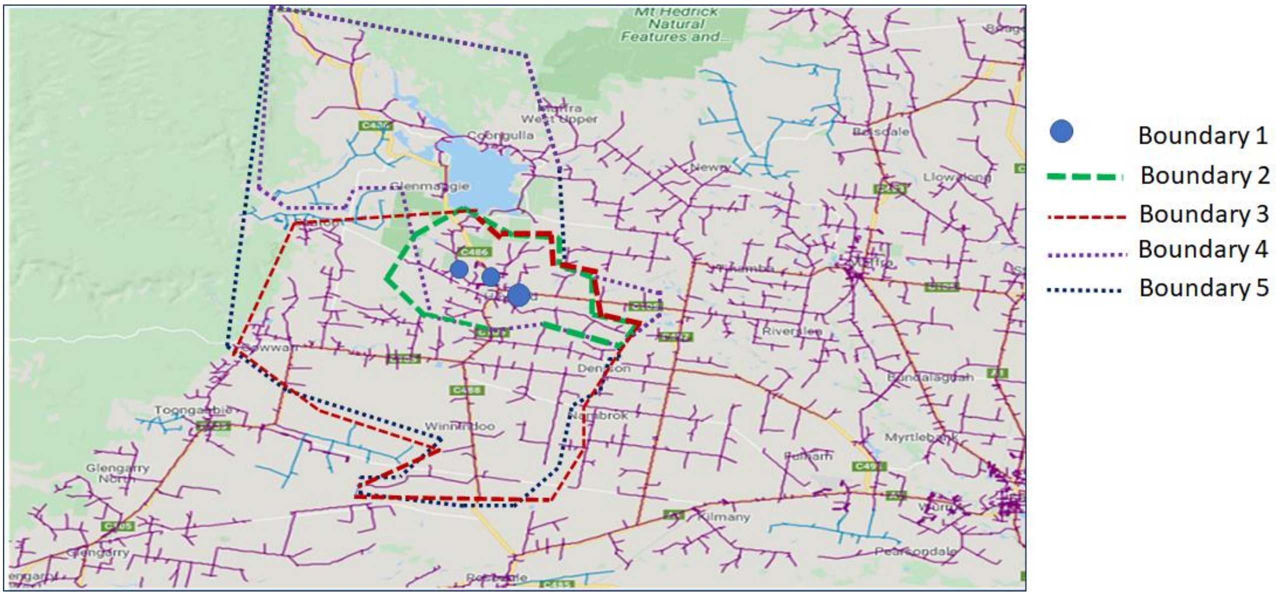

Figure 10 – Initial boundary options (identified in advance of network topography).

Initial boundary Option 2: Heyfield town centre (no longer active)

The next simplest topology for a microgrid in Heyfield would be one that includes much of the Heyfield town centre (see Figure 11). This encompasses boundary option 1 (critical sites) above. Boundary option 2 includes the whole town, while also stretching north to the southern banks of Lake Glenmaggie, south-east towards Denison, south to the Sale-Heyfield Road, and east beyond the Heyfield Golf Club).

Based on the criticality of the load and the available generation, there could be a number of cluster grids within this boundary under the emergency condition (see option 1). It would be relatively low cost as it uses two existing switching points on the network, and easy to maintain and operate from a technical and control perspective. It could also provide better supply reliability to the main part of town, enhance resiliency against extreme weather and grid interruption, and reduce the requirement for storage by including the dispatchable bioenergy at the ASH timber mill. However, it still includes a relatively small number of loads and highly correlated and fast variations of renewable generation sources could make secure and reliable operation challenging.

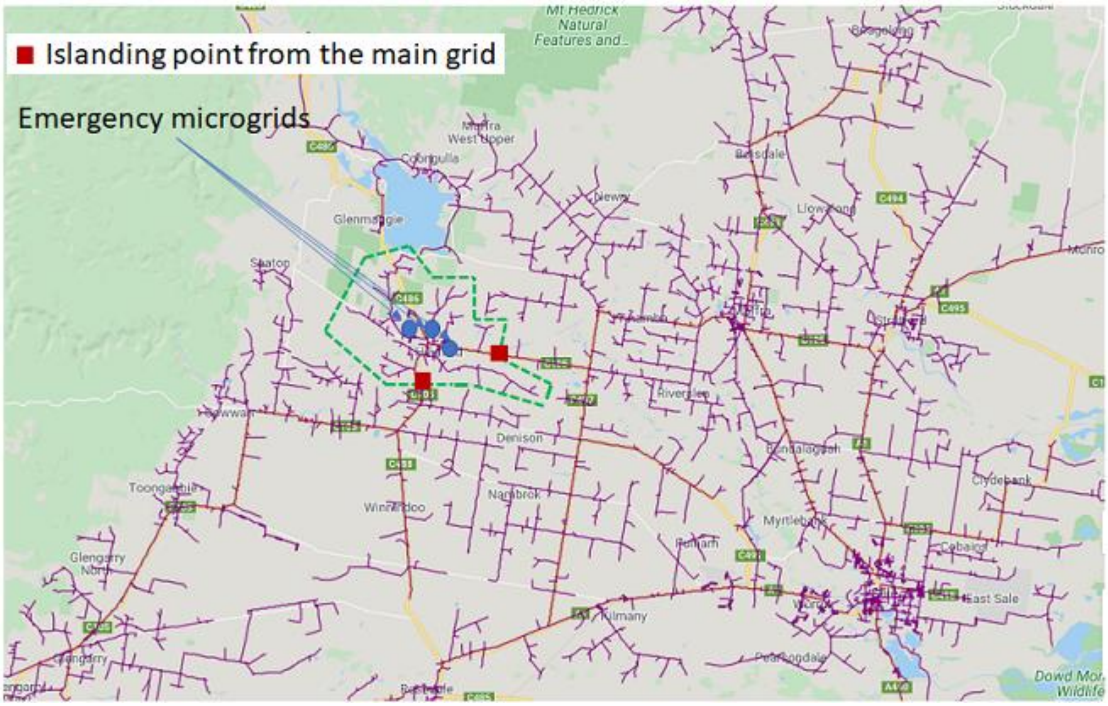

Figure 11 – Heyfield original microgrid boundary option 2 (no longer active).

Initial Boundary Option 3: Wider area without SWER lines (no longer active)

The third boundary option of the proposed network is given in Figure 12. It includes much of the town of Heyfield and additional nearby locations (from Seaton and Cowarr to the west, to Winnindoo to the south, to parts of Denison and Nambrok to the east).

The area could be disconnected from the rest of the network at the mid of C105 roadway (at the voltage regulator). In the south, the disconnection could be made at the Cowwarr side. There are approximately 30-35 transformers in the selected area. Only the Var control mechanism of the transformers is required to change to host the local generation.

This area includes a number of pre-existing diesel gensets, but the relatively small number of loads and highly correlated and fast variations of renewable generation sources still make the secure and reliable operation challenging. Moreover, the microgrid in the rural and remote network may suffer from a very low "short circuit ratio", which means that a small change in configuration, such as start-up and shutdown of diesel gen-sets, could result in significant voltage and frequency deviations. Furthermore, the existence of dairy farm loads within this boundary could jeopardize the power quality of the microgrid due to "non-linear" loads and phase imbalances.

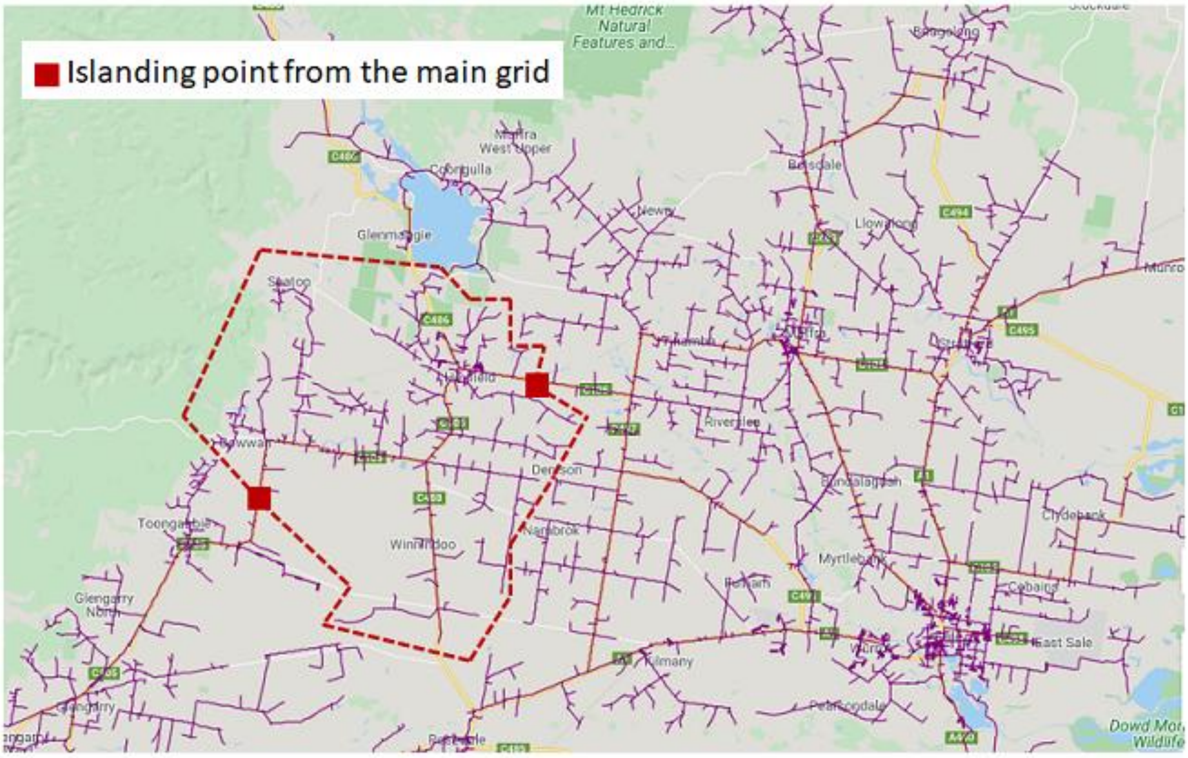

Figure 12 – Heyfield original microgrid boundary option 3 (no longer active)

Initial boundary Option 4: Heyfield town with Glenmaggie SWER lines (no longer active)

Although Boundary Option 3 (Figure 13) mostly included the Heyfield region's critical load, including the industrial loads and the irrigation facilities. However, the loads in the SWER network are left out of the proposed microgrid, as is the existing hydro generation. According to the AusNet Services report, the rural long feeder in the region has reliability and security issues. The SWER network is the farthest at the end of the network with poor voltage regulation and power quality issues.

Thus, Boundary 4 extends the focus of the microgrid boundary to include irrigation loads and the SWER network to the north (Figure 13). This option would likely require the installation of voltage regulator or on-load tap changer (OLTC) transformer type,[6] although this has capital cost implications.

Three connection/disconnection points would be required. In the south, the disconnection could be made at roadway C105. On the north side, it could be disconnected on the east side of Lake Glenmaggie, and a new line connection would be required to connect the two parts of the network at the south side of the lake. On the east side, it could be disconnected along the east-west section of roadway C105.

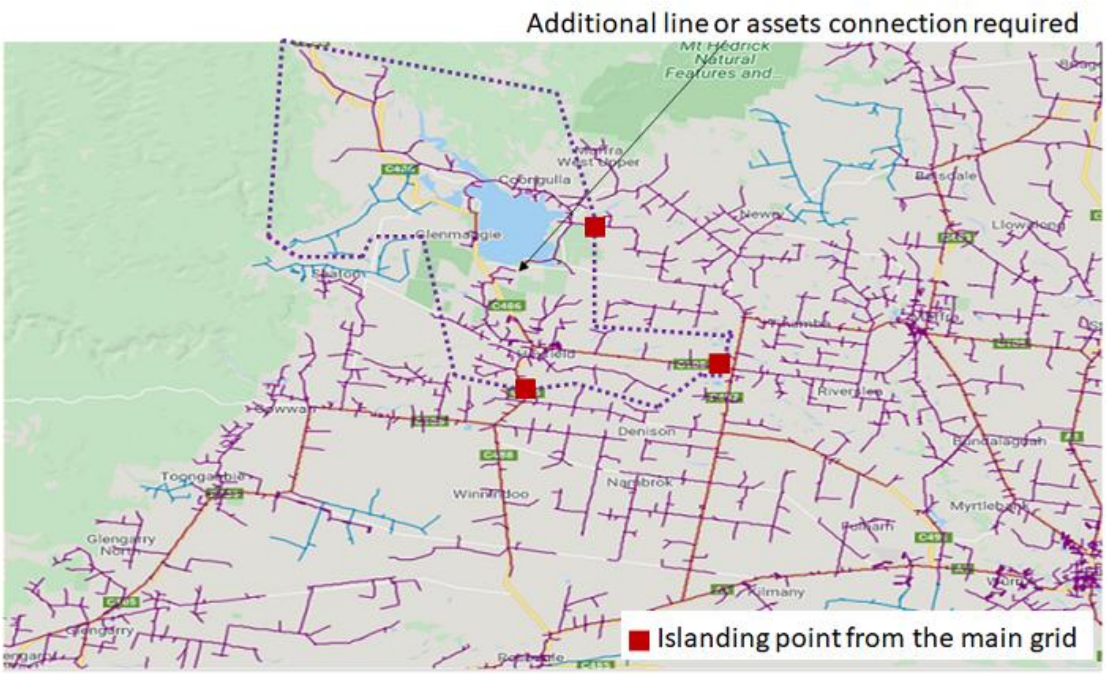

Figure 13 – Heyfield original microgrid boundary option 4 (no longer active).

[6]In areas where customer load density is very low and distances between customers are high, 12.7 kV or 19.1 kV SWER feeders are used. A SWER feeder is a unique distribution line that consists of a single conductor energised at high voltage. Typically, SWER feeders are 12.7 kV or 19.1 kV in Australia. The SWER voltage used in Heyfield is 12.7 kV. Lines of this type typically have a leading power factor at light load with high losses due to higher resistive value. A typical SWER system could be based on a voltage regulator with 10% or 8% steps, and an OLTC transformer with 5% steps to boost or buck the voltage level.

Initial Boundary Option 5: multiple towns with SWER lines (no longer active)

Figure 14 shows the largest option of the microgrid which includes Heyfield and surrounding area, dairy farms and irrigation facilities from Denson and Winnindoo, and Cowwarr.

Three connection/disconnection points would be required. In the southwest, the disconnection could be made at the Cowwarr side. On the north side, it could be disconnected on the east side of Lake Glenmaggie, and a new line connection would be required to connect the two parts of the network at the south side of the lake. On the east side it could be disconnected along roadway C105.

Due to the size of the microgrid, this option required significant investment in infrastructure such as protection devices, coordinated Var control, ICT requirement for coordinated operation, and microgrid energy management. As per Option 3, the existence of dairy farm loads within this boundary could jeopardize the power quality of the microgrid due to “non-linear” loads and phase imbalances.

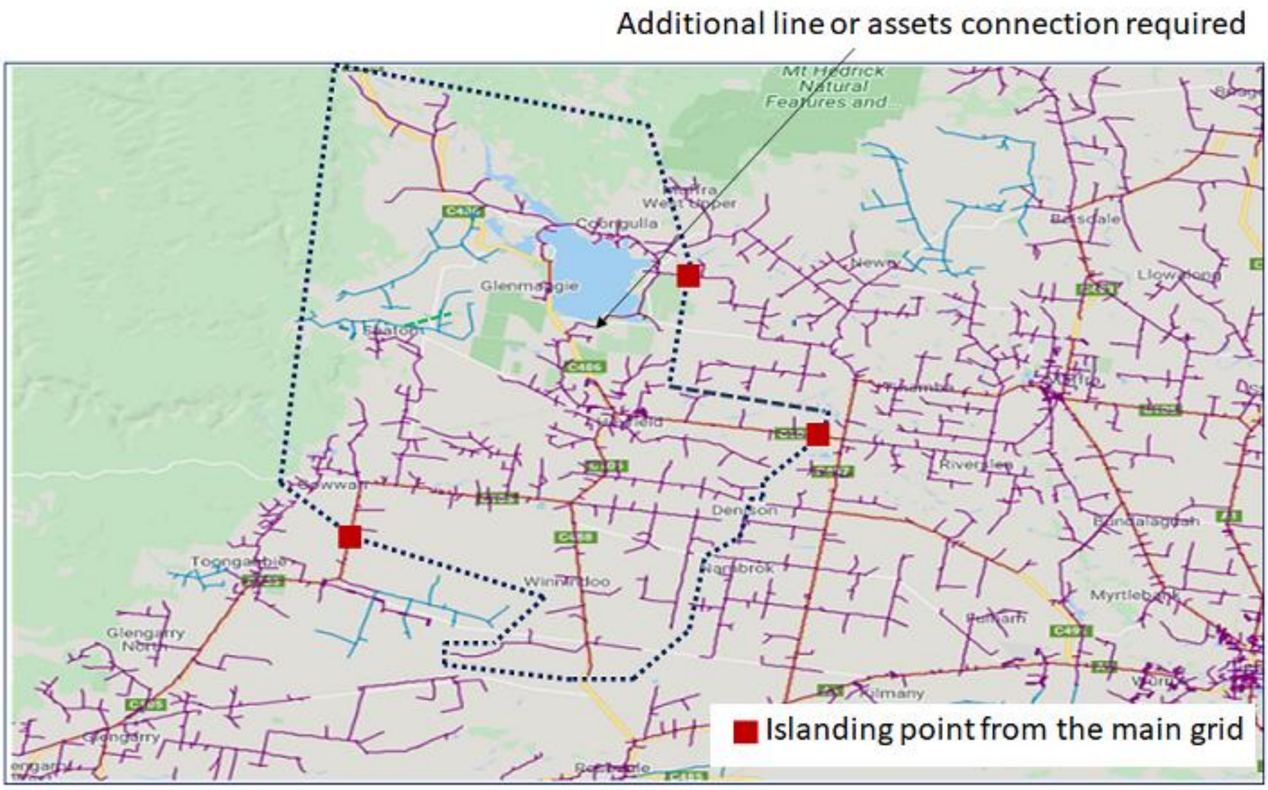

Figure 14 – Heyfield original microgrid boundary option 5 (no longer active).

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