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The role of community-scale batteries in the energy transition: Case studies from Australia's National Electricity Market

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ABSTRACT

Australia's National Electricity Market (NEM) is currently undergoing a rapid clean energy transition, with battery energy storage systems (BESS) set to play an increasingly important role. This paper investigates the role of community-scale batteries (CSB) in the energy transition, through several business model case studies and a regulatory review. CSBs are found to be capable of delivering a range of monetised and unmonetised services but capturing them effectively is difficult. While regulations are already changing to enable whole-of-system services, future reforms, including network tariff reforms and capturing of local benefit, will be required if scalability for this mid-scale class of batteries is to be achieved.

1. Introduction

The Australian electricity generation landscape is currently undergoing a rapid, major transition. The share of variable renewable (including wind, utility-scale solar, and rooftop solar) generation has increased to 31.8 % by mid-2024[1] [1] in Australia's National Energy Market (NEM). This growth was initially driven by favourable government policies such as the renewable energy target (RET) [2], as well as by the increasingly favourable economics of renewable generation.

In September 2022, the Australian government legislated a new nationally determined contribution to the United Nations pledging a 43 % reduction in greenhouse gas (GHG) emissions below 2005 levels by 2030. This constitutes a "*15 percentage point increase on Australia's previous* 2030 *target*" [3]. At the same time, according to the Australian Energy Market Operator (AEMO) approximately 14 GW of coal fired generation is expected to exit the market by 2030 [4]. With the decreasing share of fossil fuel baseload generation, along with a greater reliance on variable renewable generation, the role of storage solutions and technologies will inevitably increase in the system. Among various forms of storage solutions (including for example hydroelectric energy storage, or different types of batteries), fast-reacting battery systems have gained significant importance and market share in recent years. Batteries can be segmented into residential-scale, community-scale, and large-scale battery classes.

Most front of the meter battery solutions deployed in the NEM currently are utility-scale and their main source of income originates from Frequency Control Ancillary Services (FCAS) market participation [5]. The regulatory framework and environment surrounding battery operations and services has been evolving rapidly in Australia, predominantly towards the full enablement of battery services, facilitated by the introduction of integrated resource providers (IRSs) starting in June 2024. In this rapidly changing physical infrastructure, financial and regulatory environment, the role community-scale batteries (CSBs) can play in the Australian transition and their business model is less clear.

This paper addresses the above research gap, by exploring the future roles and opportunities of the nascent CSB segment in Australia. It does this within the context of the evolving regulatory system of the NEM, and the emerging business models, using three different case studies. We contribute to the literature in several key ways. Firstly, we present and

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analyse distinct business model case studies for CSBs deployed in Australia's NEM, by using battery energy storage systems (BESS) adapted business model canvases for this purpose. Secondly, we offer integrated policy advice based on the current regulatory framework and the findings from our business model analysis. Thirdly, we assess what this means for the different stakeholders, with a focus on community benefit.

We find that current CSB business models are diverse and vary strongly depending on the type of organisation that owns them, are highly reliant on subsidies (including among others government grants and network business innovation funding), and mainly rely on FCAS and energy arbitrage as their main revenue streams. Whether the business case for CSBs will become viable depends on the continuing sustainability of those revenue sources (or the unlocking of new ones), the falling of CSB (capital and operating) costs in line with any future decreases in subsidies, and the overcoming of the various legal and regulatory hurdles that exist.

This paper is structured as follows: Section 2 presents a general background on community-scale batteries as well as a literature review on their regulation and business models. Section 3 introduces community-scale batteries in the context of the Australian National Electricity Market. Section 4 elaborates on the regulation surrounding community-scale batteries in Australia. Section 5 describes three case studies (including business models). Section 6 presents a discussion as well as policy recommendations, while Section 7 concludes.

2. Background on community-scale batteries

The total volume of battery use globally within the energy sector has been rapidly increasing in recent years. Recent IEA figures show that the global market for battery storage doubled in 2023 alone, with now >190 GWh of battery storage in use [6]. Of these, 35 % of the annual growth is from behind the meter and 65 % in front of the meter or standalone. Notably, the IEA numbers do not distinguish between community-scale and utility-scale batteries – all front of meter applications are termed utility scale. Worldwide, CSBs have been garnering attention since the early part of the 2010's with several pilot projects initiated in Germany starting in 2013 [7]. While other countries, including China, Japan, and South Korea have also seen several CSB programs kick-off towards the end of the previous decade, CSBs are still considered to be in their infancy [8].

This section introduces general CSB definitions and services and provides a background on regulatory and business model literature globally.

2.1. Community-scale battery definitions and services

Community-scale batteries are not necessarily community-owned and/or operated – the term "community" instead refers to location, which is often a source of misconception. Their purpose is often defined with a focus on local benefits to the network and the consumer. Definitions for CSB, (which may also be called neighbourhood batteries, or mid-scale battery storage) vary across the literature. Shaw [9] has defined CSB as batteries that are connected to the distribution network (in-front of the meter) and up to 5 MW of power capacity [9,10]. Others have defined them as local, in front of the meter storage, without specific reference to capacity [11]. The three key common features used in definitions by Australian policy makers [12–14] include:

- Placement in front of the meter,
- Power capacities from 100 kW to 5 MW,[2] and
- Connected to the distribution network.

[2] We note that the Australian Government defines CSBs in terms of power capacities not in energy capacities.

As part of this paper, we more broadly consider a CSB to be any battery energy storage system co-located within a community and connected to the distribution network, that seeks to derive benefits either directly or indirectly for that community. This allows us to consider a broader range of mid-scale battery types, their business models, types of community being served, and the implications for the policy and regulatory framework.

Community-scale battery storage can provide a range of services. For example, the Australian Government's [12] *Energy Innovation Toolkit* categorises their potential service delivery model as follows:

- *"services provided to the customer, such virtual storage service (use of the battery to store locally generated electricity for later use by the community) and virtual sharing service (peer-to-peer trading);*
- *services provided to the network, such as network support service (for example, peak demand reduction, minimum demand smoothing and voltage management); and*
- *services provided to the market, such as market generation service (export of locally generated electricity for sale in the wholesale market) and market ancillary services (export or import of locally generated electricity for sale in ancillary services markets, for example, frequency control services)."*

On the other hand, Shaw [9] bases their CSB classification on potential revenue-generating services including:

- *customer demand management (e.g.: [15]);*
- *demand management for the distribution network service provider (DNSP)*
- *arbitrage from the spot market (e.g.: [16])*
- *frequency and ancillary markets (FCAS) (e.g.: [17]); and*
- *network support (e.g.: [18])*

While both of the above categorisations present valid angles, in this paper we adopt a different approach and expand on the categories provided by Csereklyei et al. [5] in the context of utility-scale batteries. Csereklyei et al. [5], drawing on IRENA [19] and Anuta et al. [20] listed the categories of services for utility-scale batteries as follows:

- *"services for variable renewable generators;*
- *services for overall energy system operations;*
- *services for allowing deferral of network investment."*

While not all sub-categories are overlapping, many services offered by CSBs fall under the same categories as their utility-scale counterparts. As a novelty to the above categorisation, we add:

- *services to local communities;*

to describe the extended scope of services delivered by community-scale batteries. This category highlights the localised nature of CSB services and benefits. Unlike grid-scale batteries, which can provide services to transmission networks and large-scale generation, CSB are more suited to support local demand management and distribution grid management and planning. We will elaborate on all the subservices contained in each of these categories in Section 4.

2.2. Literature on CSB regulation and business models

Given the nascence of the CSB segment worldwide, literature engaging with the regulatory and business model analysis of this class of battery is limited. The relevant literature on regulation and business models surrounding CSBs can be divided into several strands. Due to the relatively early stages of technology development and implementation, there are still significant gaps in the literature in all of the below categories.

Firstly, several recent studies include an assessment of battery regulation and policies. The general unsuitability of existing legal frameworks for storage solutions is often named as a key barrier to battery deployment (see e.g. [20–24]). However, there is little focus on the challenges faced by community-scale batteries specifically. Studies such as Kumar and Shrimali for California (2021a) and Hawaii (2021b), and Ramos et al. [25] for Finland, while identifying front of the meter business models, are not specifically separating regulatory challenges for mid-scale batteries.

Secondly, a rich body of European literature is also emerging around business models for "*citizen energy communities*" (see e.g. [26–28]). Energy communities are a new type of entity, specifically enabled in the European Directive 2019/944 [29] to allow for citizen-owned and operated energy solutions. These studies usually include storage as one element of an energy community, but do not separately assess business models for community batteries by themselves, as our study is providing. We note that this literature could inform future energy community formation in the Australian context. A few studies examining storage regulation and policies, including CSB storage, do so in the context of renewable energy community business models [30,31], showing that standalone storage, (which would align with our focus) is currently not feasible in this context [31]. Parra and Mauger [32] argue that the exposure to grid charges for front of the meter community batteries in a number of European countries can offset potential benefits, and call for access to flexibility markets. Our analysis of the Australian regulatory example can be informative to other jurisdictions, showcasing how Australian regulators have tackled the issues of double-charging and providing access to markets.

Notably only limited literature is available in the Australian context. A study on potential business models and barriers for CSB by Müller and Welpe [33] assessed only the Western Australian jurisdiction (as well as German examples). Western Australia has a separate regulatory framework to the NEM, the focus of our study. A report by Shaw et al. [10] provides an overview of different ownership options for CSBs in Australia's NEM, but does not expressly unpack business models beyond this feature.

A number of studies cover the various business models of energy storage solutions, including among others, Kalkbrenner [34] for Germany, Kumar and Shrimali [35] for California and Hawaii, Li et al. [82], Martins and Miles [36] for the United Kingdom, Ramos et al. [25] for Finland. While the choice of analysis technique differs, most of these studies classify business models based on scales and value proposition (including revenue forms). Apart from the study by Müller and Welpe [33], none of the provided examples is exclusively addressing the unique challenges faced by a CSB. Our study uses a well-established method - Osterwalder and Pigneur's [37] business model canvas -, to apply it to Australia's NEM, as well as the extended service categorisations of Csereklyei et al. [5]. Furthermore, we present our CSB business models hand in hand with the analysis of the regulatory settings surrounding the potential revenue streams of community-scale batteries.

3. Community-scale batteries in Australia

Community-scale batteries are a relatively new approach to providing energy storage in Australia, which to date has favoured mostly residential and utility-scale batteries. Since 2015, 180,000 residential batteries have been installed in Australia, equivalent to 1.9 GWh [38] storage (or energy) capacity. In 2022, 19 large-scale battery energy storage projects were under construction totalling 1.4 GW power and 2 GWh of energy capacity alone [39]. However, the CSB market is much less developed, with mostly heavily subsidised pilots or proof of concept projects underway, driven by government or electricity network innovation funding.

CSBs are being deployed around Australia by various types of organisations with differing objectives. They are being sought by communities as a visible statement of making the best use of locally produced renewables. Governments support them for their ability to maximise the value from increasing levels of distributed energy resources (such as solar PVs) in the energy system. Solar PV installations increased in Australia to approximately 3.7 million with a combined capacity of 34 GW by the end of 2023 [40]. Distribution network service providers (DNSPs) are viewing them as innovative non-network solutions that can help manage high solar PV penetration and defer expensive network upgrades now, while offering additionality in the future. Finance companies are pursuing them as part of their portfolio of renewables and storage assets that enables them to offer differentiated products to investors and energy customers. CSBs are also playing a central asset role in microgrid design.

3.1. CSB technology costs and factors affecting financial viability

In this section we outline and compare the current costs and cost trends of batteries at utility-, residential- and community-scale, and the implications on their financial viability. In this paper we focus on the capital expenditure (CapEx) required to make the battery operational, i.e., due to the limited information available on operational expenditures (OpEx).[3]

In general, the fundamental technology costs of battery systems have been steadily declining over the past decade [41]. In this paper we define after the Energy Information Administration [42] the energy capacity of a storage system as "*the maximum energy that could be stored at these sites*", and the power capacity as "*the maximum power that could be provided to the grid from these sites at any given moment*" [42]. The EIA [42] also notes that the cost of battery storage is significantly impacted by the storage duration of the system.[4] While battery capital and storage costs are readily available for utility-scale installations, estimating these metrics for the much smaller, community-scale battery systems poses a challenge due to the relatively low number and heterogeneity of installations to date.

3.1.1. Battery cost trends

Battery cost trends have been steadily decreasing. Lazard [41][5] reports the levelized cost of front of the meter utility-scale storage depending on size between 249 and 323 USD/MWh (utility-scale, standalone, 100 MW, 1 h) and 200–257 USD/MWh (utility-scale, standalone, 100 MW, 4 h). Behind the meter installations were substantially more expensive, both for commercial and residential applications, with levelized costs up to 1215–1348 USD/MWh (residential, standalone, 0.006 MW, 4 h).

3.1.1.1. Utility-scale. Utility-scale battery costs in Australia are well-documented. CSIRO's GenCost report, shows a steady decline in utility battery storage costs for 1-hour batteries from 1029 AUD/kWh in 2019 to 775 AUD/kWh in 2022, and from 648 AUD to 516 AUD/kWh for 2-hour batteries [43]. Utility-scale battery cost projections from NREL [44] expect battery costs to decline between 30 % and 70 % by 2050.

Comparing project-specific costs of established and planned Australian utility-scale batteries show similar trends. For example, the Melton Renewable Energy Hub, [45] planned to become operational in

[3] All numbers are expressed in AUD/kWh which is the ratio of CapEx in AUD (unless otherwise stated) to the total amount of energy the battery can store in kWh. For example, a battery with CapEx of AUD500,000 may be described as 100 kW/400kWh. This means the battery can supply 100 kW of power for 4 h (a total of 400kWh) and the installed cost is 1250 AUD/kWh. "Capacity" in this section refers to energy capacity unless stated otherwise.

[4] Csereklyei et al. [5] note, that "*according to the EIA, while battery systems with shorter durations had lower power capacity costs measured in AUD/kW, systems with longer duration had lower energy capacity costs measured in AUD/kWh, as total system costs were distributed over more stored energy [42].*"

[5] Lazard [41] claims to have a US focus.

2024, is costed at AUD 1.9 billion for a capacity of 600 MW/2400MWh, amounting to about 800 AUD/kWh. Stage one of the Hornsdale Power Reserve provides 100 MW/129 MWh and was costed at AUD 90 million [46], while stage two was costed at AUD 82 million for 50 MW/64.5 MWh [47] averaging 889 AUD/kWh for the entire project do date.

In 2022 the Australian Renewable Energy Agency (ARENA) has announced conditional funding for 8 grid-scale batteries worth AUD 2.7 billion [48]. According to ARENA [48] "*each battery will be equipped with grid-forming inverter technology*". This "*enables them to provide essential system stability services, traditionally provided by fossil fuels such as coal and gas*". The projects are expected to have a total value of AUD 2.7 billion and a capacity of 2.0 GW / 4.2 GWh, which averages at 643 AUD/kWh. Known cost parameters from existing projects and 1-hour storage estimates from CSIRO are summarised in Table 1.

3.1.1.2. Community-scale. Data on community-scale battery system costs is highly variable and dependent on the characteristics and approach of each installation. Current implementations in Australia are predominantly subsidised, and are one-of-a-kind, bespoke installations, which do not readily yield good quality data for comparisons. A summary of the estimated CapEx for different community-scale batteries in provided in Table 2. These are taken from reports on installed batteries and supplier quotes. In addition KPMG's Ausgrid report estimates neighbourhood battery costs upward of 1250 AUD/kWh [49], with a potential to decline in line with larger energy storage capacities.

Table 2 indicates that the real and quoted capital cost per kWh installed for community-scale batteries varies greatly across different projects, ranging from 1135 AUD/kWh to 2817 AUD/kWh. There is no clear trend of reducing costs on newer projects, though larger installations tend to be less costly per kWh. The large variations in cost may reflect the bespoke nature of these early community-scale battery projects.

3.1.1.3. Residential-scale. Solar Choice has been tracking the average cost of residential batteries across Australia using their database of over 200 solar installers to come up with their Battery Price Index since 2017. The average prices of residential solar batteries ranged between 1200 AUD/kWh and 1320 AUD/kWh of capacity installed depending on brand, size, and location [55]. The average price per kWh has remained fairly constant at around AUD 1300 since 2018, despite battery costs dropping for utility-scale batteries. Solar Choice [55] also breaks down the costs for different sized systems, as shown in Table 3.

3.1.1.4. Operating expenses and state of health. There is little publicly available information available on the operating expenses of community-scale, or utility-scale batteries in Australia at the time of writing. The most detailed account appears from the Yarra Energy Foundation's (YEF) experience final report [53,54]. According to Wallin et al. [53,54] (page 28), the operating costs for a single system were estimated at 17000 AUD annually. This estimate included: "*administration of the community battery business, IT operations, for hosting, management, and maintenance, metering, system maintenance, insurance and site maintenance.*" Further operating costs, named but not estimated here, also include "*software licence fees, off-line analysis and research, retailer/aggregator costs, and land lease fees*".

Further, the Australian National University Battery Storage and Grid Integration Program [56] assessed several neighbourhood battery models supported by the Victorian Government in 2022. Their estimated OpEx shows a wide range from 10 AUD/kWh to 60 AUD/kWh, due to the large variety of pilot projects supported under this initiative. Results from more case studies in future will provide further insight as rolling out CSBs becomes more standardised. The YEF report [53,54] suggested that OpEx could be reduced if there were multiple physical batteries at a single site.

Another factor to consider is the trade-off between CapEx and replacement expenditure (or RepEx). For example, a flow battery may have capital costs are several times higher up front than nickel manganese cobalt battery costs, but also has a much higher expected charge/discharge cycle life. How this trade-off is made will vary according to scale, project timescale, the sophistication of the project participants, and their financial profile.

Related to the RepEx/CapEx trade-off is accounting for the gradual degradation of BESS over time, often termed as "state of health" (SoH). The SoH is directly affected by battery cycling patterns and strategies. Battery degradation decreases the ability of the battery to store energy, and thus directly impacts on long-term profitability. Lazard's [41] levelized cost of storage assumes annual battery degradation of 2.6 % for lithium iron phosphate (LFP), lithium nickel manganese, and cobalt oxide (NMC) stationary batteries. To compensate, batteries may be over-dimensioned so that after a predetermined period they still provide

Table 1
Utility-scale battery costs.

Source	Scale	Energy capacity (MWh)	CapEx (AUD m)	AUD/kWh	Year operational
Hornsdale stage 1	Utility	129	90	698	2017
GenCost (1 hour duration)	Utility	–	–	1029	2019
Hornsdale stage 2	Utility	64.5	82	1271	2020
GenCost (1 hour duration)	Utility	–	–	775	2022
Melton	Utility	2400	1900	791	2022

Hornsdale Stage 1 appears to be an outlier and was possibly installed at reduced cost by Tesla for market positioning. We have used GenCost overall cost/kWh rather than deriving this from individual battery projects, hence there is no MWh or cost for these entries.
Source ARENA [48].

Table 2
Community-scale battery costs.

Battery location	Power and energy capacity (kW/kWh)	Estimated CapEx (AUD)	CapEX/kWh (AUD/kWh)	Year
Supplier quote 1	300/546	619,950	1135	2020
Supplier quote 2	68/142	309,930	2182	2020
Supplier quote 3	250/273	446,225	1634	2020
Beacon Hill, NSW	150/267	400,000	1498	2021
Fitzroy North, Victoria	110/284	800,000+	2817*	2022
Heyfield, Victoria	100/200	305,680	1528	2023

Software development represented more than half of the total funded work. The total battery system cost including installation, connection and artwork came in at about 1100 AUD/kWh. This number is much higher than expected due to the connection and artwork costs. For the hardware alone, including installation, the cost was well below 1000 AUD/kWh" ([53,54], page 50).
Source: Supplier quotes 1–3 are from ENEA [50] for the Macedon Ranges; Beacon Hill pricing from Vorrath [51]; Heyfield pricing from Mohseni et al. [52], *Fitzroy North reported cost per kWh from Wallin et al. [53,54]. Wallin et al. [53,54] data excludes software development (above table). Wallin et al. [53,54] note that: "the total cost including in-kind work and contributions by project partners was nearly $1.5M.

Table 3
Average battery installation prices, May 2024.

Battery energy capacity (kWh)	1–5	6–10	11–15	16–20	All
Installed AUD/kWh	1310	1200	1240	1320	1270

Source: Solar Choice [55].

sufficient charge, which increases up-front CapEx. To balance profitability and battery lifespan, the optimal daily cycling strategy depends on factors such as battery chemistry, degradation characteristics, and the specific application. Generally, limiting deep discharges and the frequency of such cycles can help extend battery life.

3.2. Observations on financial viability

Larger scale systems usually have lower CapEx costs per kWh than smaller scale systems (due to economies of scale). Accordingly, costs per kWh for residential and community-scale battery systems are considerably higher than those of their utility-scale counterparts. However, costs of residential-scale batteries are at par with community-scale batteries.

This may be because community-scale batteries are still bespoke, have variable cost of enclosures and may attract maintenance and management fees (Table 4).

The ARENA commissioned report by Shaw [9] on community-scale batteries concludes that under the current regulatory framework in Australia, only third-party owned community-scale batteries are financially viable and that a reduced network cost for local use of service is recommended to encourage the utilisation of local solar generation, as standard local network distribution charges render virtual storage unviable. Similarly, KPMG concluded that market and regulatory processes would need to change to facilitate the scaling of the models they examined.

The Yarra Community battery final report [53,54] also made several important conclusions relevant for all CSBs in the NEM. Firstly, current battery prices would need to *at least halve*, and additional revenue streams and lower running costs would be required for financial viability. Secondly, while arbitrage was the only predictably monetisable revenue stream, they foresaw it reducing with lower price volatility. Thirdly, it was essential to waive network tariffs. Finally, they noted that community-scale batteries may experience competition from residential-scale batteries, which can be more easily be aggregated, require simpler contracts, and have less registration complexity.

The MyTown Microgrid (Heyfield) project report concluded that, based on the analyses and findings presented, none of the battery case studies they analysed were economic without subsidy, with the potential exception of small batteries (10 kW/ 20 kWh) behind the meter at commercial premises [52].

An interesting insight from ENEA's business case analysis for a community-scale battery in the Macedon Ranges [50] was that a reliability value could be established from the benefit derived from avoiding outages. This was due to the battery being able to operate in islanding mode, and that this value could drive a positive business case. This suggests that community-scale batteries may be viable sooner in areas with unreliable power supplies.

The general conclusion from community-scale battery studies listed above is that while community-scale batteries have the potential to play an integral role in Australia's transition to a decentralised grid, at current cost levels and under the current regulatory environment they are at best marginally viable without subsidies. How regulatory changes could improve their viability is discussed in detail in Section 4, and an analysis of business models is presented in Section 5.

Table 4
CapEx ranges for different classes of battery based on selected projects.

Scale	Range cost (AUD/kWh)
Utility	698–1271
Community	1135–2817
Residential	1200–1320

Summary from Tables 1–3.

4. Community-scale battery services in Australia: current regulation and proposed reforms

In Australia, legal frameworks for the electricity system exist both on state (subnational) level and national level. The focus of this paper is on the national regulatory framework – applying across the NEM, covering the states of South Australia, Victoria, New South Wales, Queensland, and Tasmania.

As set out in Section 2, regulatory barriers have been identified as a central obstacle to in front of the meter battery deployment (e.g. Anuta, 2014; [57]). In light of recent reforms to facilitate battery storage deployment in Australia's NEM, a qualified view of these regulatory barriers needs to be provided. Reforms to the National Electricity Rules (NER) have enabled CSBs to deliver a range of services to networks, renewable generators, and the electricity system. Despite this, a range of unsolved issues impacting on the economic viability of smaller sized storage systems remain. These include the administrative costs associated with the running of CSBs, as well as the fact that a range of services by these batteries are not monetised.

This section first introduces the NEM regulatory frameworks and elaborates on the current status of community-scale battery deployment.

4.1. The regulatory frameworks of the Australian National Electricity Market

Community-scale and grid-scale batteries that are connected to the shared network must align their operations with the regulatory frameworks of the National Electricity Market. These frameworks rely on a uniform legislation, the *National Electricity Law (NEL)*, passed in all participating jurisdictions[6] as an appendix to state legislation.

Based on this legislation, an independent national market institution, the Australian Energy Market Commission (AEMC), passes the NER, which provide for a detailed regulatory framework covering participation in wholesale and retail market activities, as well as regulating both transmission and distribution network services [58]. Two further institutional bodies, the Australian Energy Market Operator (AEMO) and the Australian Energy Regulator (AER), are responsible for the operation and the economic regulation of the market respectively. The AER, in particular, is responsible for approving network tariff setting (under NER cl 6.12.1.) and enforcing unbundling requirements [59], both of which are of central importance to the operation and economic viability of community-scale batteries. Additional state-level legislative requirements around licencing may also apply but are outside the scope of this paper.

The NEM is a liberalised *energy only market*, without any form of capacity market or mechanism. The system currently has 10 ancillary markets for frequency raising and lowering. The rules of participation in both the wholesale and in the ancillary markets are clearly set forth and discussed in the context of community-scale battery participation in Table 5.

4.2. Service provision and regulatory requirements

The NER require participants in the NEM to register with AEMO under specific participation categories, depending on their function and activity in the market. Detailed requirements for each of these participant categories are set out in Chapter 2 of the NER. A battery operator seeking to monetise the full functionality of a battery currently must register across a number of participant categories to provide these

[6] These include New South Wales, Queensland, Tasmania, South Australia, Victoria and the Australian Capital Territory. The State of Western Australia (WA) and the Northern Territory (NT) are not connected, but the NT does apply locally adapted version of the rules. WA has its own electricity system regulatory framework.

Table 5
Battery services and regulation in Australia's National Electricity Market.

Service	Sub-service	Service status	Revenue streams or value generated	Reforms
Integration of renewable generators (reducing curtailment, solar soaking).	Wholesale market participation.	Enabled. Currently the CSB has to be classified as market load or market generating unit. The CSB operator has to be registered for market participation. Most likely category is a Market Small Generation Aggregator (MGSA). From 3 June 2024 registration will be required as Integrated Resource Provider (IRP) instead, a new single registration category, which replaces the MSGA registration. A CSB is exempt from registration as generator for nameplate rating of <5 MW. From 3 June 2024 these will be classified as non-scheduled bidirectional units.	Monetised. Arbitrage in wholesale markets. The price difference between feed-in and discharge price must be high enough for profitable operations. Batteries are not eligible to create and sell Australian Carbon Credit Units under the Australian Carbon Credit Unit (ACCU) scheme or certificates under the Renewable Energy Target Scheme	Introduction of new Integrated Resource Provider (IRP) category, see above.
Services for system operations such as frequency and voltage regulation.	System ancillary services.	Enabled, if bigger than 1 MW. From 31 March 2023, Market Small Generation Aggregators can provide ancillary services. From 3 June 2024, Integrated Resource Providers (IRP) can provide ancillary services.	Monetised services: bidding on various ancillary markets for both lowering and raising frequency. Influencing ancillary market prices and volatility.	Note – the ancillary market is considered to be limited, so this income source may be curtailed in the near future [62].
Services to local communities.	Improving local network hosting capacity to facilitate higher local DER deployment.	This is currently not a monetised and recognised service, but a side-effect of local battery operations.	Not monetised. A CSB could provide this service to the local DNSP as network support service on a contractual basis.	In case of "services to the community", the gap between the local benefit of a CSB and the reality of implementing these solutions is particularly apparent. This is the most promising area of potential reforms.
	Providing storage solutions for a group of local DER, i.e., shared-battery-as-a-service (virtual storage and peer-to-peer trading).	Enabled. Could in theory be contracted directly with each local consumer (residential rooftop solar) requiring local storage solutions for their generated electricity, but not financially viable.	Benefit to consumers to allow energy use on site and avoid investment into home battery where not feasible.	From 2025, networks can apply export tariffs to consumers exporting to the grid. [63], but are also tasked with seeking solutions to actively integrating DER. Localised storage will become more viable after this change.
Network support services.	Replacing or postponing network investment/congestion relief (through demand response), voltage management.	Enabled for CSBs not owned by the DNSPs as non-network contracted service. Network-owned CSBs can provide regulated services (network support/installation/maintenance).	Monetised. Revenue model: DNSP-owned: Services as regulated network assets (note the application of ring-fencing rules) Non-DNSP owned: services for networks as a 3rd party provider.	Networks will only contract network support services from non-network owned CSBs if it is more efficient for them to do so, than providing these services themselves. Area of future reforms.

services to the market, or alternatively, contract with a registered participant who is allowed to provide the relevant service. Any generating unit connected to the shared network needs to be registered as a generator (NER cl. 2.2.1), unless exempt. In addition, a battery must register as a market participant in order to participate in the wholesale and ancillary markets as required. This means that a CSB provider must either manage the registration requirements of a number of different categories, or otherwise be operated for each of these functions by separate registered entities. At the time of writing, the regulator has addressed this overlap by creating a new, bi-directional market participant category. This new integrated service provider category will be available from 3 June 2024. It will allow for one registration to provide both market and ancillary services [60].

Beyond participation in electricity markets, batteries can also provide network services. However, unbundling of competitive (generation and retail) from non-competitive (network) services is an underlying principle of the regulatory frameworks in liberalised electricity markets, such as the NEM [61]. This meant that until recently, a battery operator had to outsource the provision of network services to a third party. The new ring-fencing guideline for electricity distribution [59], clarifies that CSBs that are not owned by a network are allowed to be contracted to provide network services without a waiver, even if the CSB also provides contestable services (such as ancillary services) or participates in the market. Network-owned and operated batteries do still require a ring-fencing waiver if they also want to offer contestable services. Thus, CSBs can now deliver a range of services without the need to contract third-party providers for individual services. In the following we show that despite progress, these regulatory reforms have not addressed all barriers to the economically viable deployment of CSBs in Australia's NEM.

4.3. Current status and regulatory challenges to community-scale battery deployment in Australia

As of March 2024, CSBs can already provide a number of services (see Table 5), and as explained above, registration requirements are being simplified by the regulator. Nevertheless, unlike for grid-scale and residential batteries, we have not seen widespread adoption of CSBs beyond bespoke pilot projects.

Table 5 summarises the key services and subservices CSBs are technically capable of delivering. Not all these services are monetised. Understanding the range of services and support that CSBs provide to the electricity system (as well as the communities) is critical in informing policy makers. As introduced in part 2.1, we classify CSB services into four main categories in the vein of Csereklyei et al. [5], with slight additions to the framework. The key categories include (i) services for variable renewable generators; (ii) services for overall energy system operations; (iii) services for allowing deferral of network investment, and (iv) services to local communities.

The status of these services (whether they are enabled or not), the resulting revenue streams, and current enabling reforms are provided in each of the columns. It should be noted that some of the sub-services CSBs provide are by definition overlapping. For example, the provision of FCAS services simultaneously delivers value to the system and supports the integration of renewable generation.

We note that a number of other non-energy services have been discussed recently in the Australian energy policy landscape (e.g. [5,10,64]), including synthetic inertia and system strength, resource adequacy requirements, emissions reduction, and resilience. Currently, insufficient detail is available on whether markets for these services will be created in the future and whether (and how) CSBs can participate.

Mountain et al. [65], recommended the introduction of a national renewable storage target model that would provide additional income streams for battery availability, based on a certificate scheme (similar to renewable energy certificate schemes). Mountain et al. [65] expressly see this scheme designed to capture all storage – in front or behind the meter, in the distribution or the transmission system – thereby providing an interesting proposal for future CSB support.

The promise of CSBs is one of local benefit and impact. While often touted as one of the key advantages of batteries in the local network, providing battery services to a specific set of (local) consumers – for example as a solar soak during the day – has so far not been viable. The regulatory framework does not currently enable or monetise these solutions – which have to be implemented through a contractual model. A regulatory reform in this space could provide substantial benefit.

Additionally, network tariffs and retailer fees further hamper the implementation of CBA business models, directly benefitting local rooftop solar generating prosumers. Currently, network tariffs as well as retailer fees and margins both apply when a community-scale battery is charged (from local consumers to a battery) and discharged (from a battery to local consumers) [10,12].[7] Residential behind the meter batteries do not have these charges. Pilot projects undertaken so far rely on trial tariffs to avoid being charged twice for network costs. Therefore, tariff reforms should be a priority among policies aiming to enable the deployment of CSBs.

To summarise, community-scale batteries can now provide a stack of services for networks and wholesale markets in the Australian NEM. In practice however, stringent operating requirements, network tariffs, and associated high operating expenditures impact the viability of these solutions (e.g. [10,64]). The next section will explore the different business models that community-scale battery solutions in Australia have adopted to navigate this regulatory background.

5. Case studies of current Australian community-scale battery projects

A business model can be defined as the manner by which value is created by an organisation, which is subsequently shared with a customer [37,66,67]. New business models within the energy sector are developing in tandem with a shifting regulatory landscape of the energy transition (see Section 4); one which is being driven by concerns over climate change, more empowered consumers, new technology, digitalisation, and energy market liberalisation [68].

Australia also has some of the most abundant renewable energy resources in the world, with an estimated 5 TW of wind [69] and 179 GW of rooftop solar potential [70]. The country's energy market operator is forecasting that this can be exploited to enable 125 GW of additional VRE[8], and 46 GW/640 GWh of storage by 2050 [4].

As mentioned before, the market for CSBs is still in its infancy and deployment to date has been mainly as funded trials in Australia. This is despite a recent increase in interest due to concerns over energy affordability, reliability, and resiliency; the falling cost of solar PV, storage, and enabling technologies [71]. This has given rise to supportive policies and programs from state and federal governments to fund feasibility studies and pilots into community-scale batteries, many of which are still ongoing (see Table 6). Notably, the Victorian Government has committed to storage targets, which are slated to be legislated in the future. Due to this immaturity, there is no consensus in the market yet on the most suitable business models for these applications.

The following section describes the business model choices for community-scale batteries and presents three examples of those being deployed in a leading global energy storage market, Australia. The purpose of this is to highlight how the business model and proposition for CSBs are being shaped by the legal and regulatory frameworks that exist for community-scale energy storage.

5.1. Business model characteristics and design

The position of the CSB on the grid, who owns it, and where its located, are some of the very first design choices that shape and differentiate a community-scale battery project. These characteristics influence greatly the business model possibilities and how value is created and for whom. These can also be used to help analyse community-scale battery business models. Fig. 1 below illustrates these design considerations and options.

For grid position, *behind the meter* refers to those CSBs that are on the customer's side of the utility meter, where the value typically being sought is to reduce energy costs, for example, by peak shaving to reduce demand charges, or increasing the amount of self-consumption of onsite solar PV generated electricity. *Front of the meter* refers to those CSBs on the utility's side of the meter, where the value sought is related to the energy system. For example, to provide network support or ancillary services. Front of the meter batteries are connected directly to the distribution or transmission network [19]. For the scope of this paper, we have focussed only on front-of-meter community batteries as examples.

In terms of ownership, these have been broadly classified as three types based on the traditional energy supply model but with the addition of a *community-owned* category:

- *An energy utility who generates, sells, or distributes electricity. This can be further divided into DNSP-owned or energy retailer-owned.*
- *A third party who is involved as an entity in addition to the community and energy utility.*
- *A community who may or may not be a customer but are mooted to benefit in some way.*

The location of the CSB can be either on public or private land. Once these basic design choices are broadly known, more detailed exploration of the business model characteristics and design possibilities can be undertaken.

The business model canvas developed by Osterwalder and Pigneur [37] provides a compact summary of the key characteristics of a business model. We populated a business model canvas for three different CSB projects selected based on an initial screening against the *grid position*, *ownership*, and *location*. This ensured three quite distinct business model approaches would be analysed.

Following a scan of different CSB projects in Australia, the three different business case studies selected are shown as follows in Table 7.

[7] In addition, as the Australian Government [12] points out, technical capabilities for CSBs are likely to include advanced metering, integration, telemetry, and control capabilities', all of which can add considerably to the operating costs of a community-scale battery.

[8] From AEMO's [4] Step Change Scenario.

Table 6
Funding programs for community-scale batteries in Australia.

Funding program	Summary	Funding value	Funding source	Period	Projects funded
Community Batteries for Household Solar Program	Funding to help deploy 400 community batteries across Australia.	AUD 200 million to deliver 58 batteries (with AUD 171 million allocated to ARENA to deliver at least 342 batteries).	Federal Government (Australia-wide)	From 2023	Funded fifty-three projects in Stream 1, two in Stream 2.
ARENA	Matches up to 50 % of industry funding on innovation projects.	AUD 1.96 billion invested in total (AUD 14.7 m on community batteries with an extra AUD 171 million from the Federal Government received in 2022).	ARENA	First community battery project started in 2014	Funded three projects to date.
Neighbourhood Battery Initiative	Grants for pilots, trials, and demos for ownership and operational models.	AUD 10.92 million	State Government (Victoria)	2021 (Round 1) 2022 (Round 2) 2023 (Round 3)	Funded sixteen projects in Round 1 and two projects in Round 2, nine projects in Round 3.
Regional Community Energy Fund	Grants to community energy projects that supports dispatchable renewable energy and benefits the local community.	AUD 15.4 million on 7 projects.	State Government (New South Wales)	2021 Round 1 (No decision on a round 2)	One project funded in 2021 (Enova's The Beehive Project).
RACE for 2030 Cooperative Research Centre	Cooperative Research Centre that matches federal funding with that from industry.	AUD 68.5 million	Federal Government (Australia-wide)	2020–2030	One project funded (the UTS/Curtin University led SEVI Project).

Table up-to-date as of May 2024.
Sources: ARENA [72], Victoria State Government [73], NSW Government [74], Australian Government [75], RACE for 2030 [76].

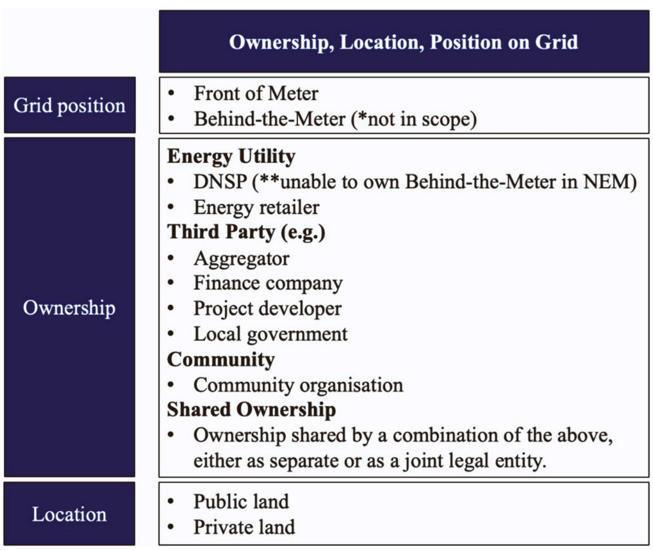

Fig. 1. Initial business model design considerations for CSBs.

It should be noted that we included the Molonglo Battery, which is bigger than 5 MW.However, as this battery is connected to the distribution network, it falls under our wider definition set out in 2.1.1.

While the conventional business model canvas features nine key sections, for the purposes of this study the authors modified the canvas with the addition of extra value proposition cells in order to capture the intended benefit to both the *community* and the *owner* – not just to the *customer* (see Fig. 2). Where the community and customer are the same entity, these value proposition cells are merged. CSBs can be classified as one type of BESS.[9]

Table 7
Summary of three CSB case studies for business model analysis.

	Community Battery Business models		
	Case study 1	Case study 2	Case study 3
Name of project	Yarra Energy Storage Service (YESS) Trial Fitzroy North	Ausgrid Community Battery Trial	Molonglo Battery – Grid-Scale Battery Trial
Battery size	0.11 MW/0.284 MWh	0.15 MW/0.267 MWh	10 MW/20 MWh
Grid position	Front of meter	Front of meter	Front of meter
Ownership type	Community organisation	Energy utility (DNSP)	Investor
Owner	Yarra Energy Foundation	Ausgrid	Finance company (Undisclosed)
Land ownership (public/private)	Public land	Public land	Public land
Community location	Fitzroy North, Victoria (3068)	Beacon Hill, NSW (2100)	Molonglo Valley, ACT (2611)
solar PV installations (<100 kW since 2007)	5 MW (1133 installations)	14 MW (1967 installations)	40 MW (5701 installations)
Renewable share of electricity generation from May 2023–May 2024 by state [1]	Victoria: Solar 12.5 % Wind: 20.7 % Hydro 4.8 % Battery (Discharging): 0.3 %	NSW: Solar 21.2 % Wind: 8.6 % Hydro 4.4 % Battery (Discharging): 0.1 % Bioenergy: 0.2 %	ACT: The ACT has no electricity generation of its own and is connected to NSW through the transmission grid.

5.2. Business model analysis

The following section focusses on the business model analysis of the three case studies described and previously selected.

5.2.1. Fitzroy North Community Battery

The Yarra Energy Foundation (YEF) is a not-for-profit community organisation established by the Yarra City Council local government in 2010. It states its role as supporting the uptake of renewable energy and energy efficiency within all sections of its community, while reducing carbon emissions through offering energy-related advice and services [77]. In 2022 it launched the Yarra Community Battery, a front of the meter, community-owned CSB in a metropolitan suburb of Melbourne, Victoria. It was funded by the Victoria State Government through the Neighbourhood Battery Initiative. YEF has a major role across the full project lifecycle, from initial community engagement to the final knowledge sharing activities. It was supported by the local DNSP in the development of a pre-feasibility study which was used to support a subsequent grant application to the state government.

YEF procured the system from the BESS vendor, with an additional integrator and infrastructure service provider involved in the sales

[9] The canvas in Fig. 3 can be used for all types of batteries, not only CSB.

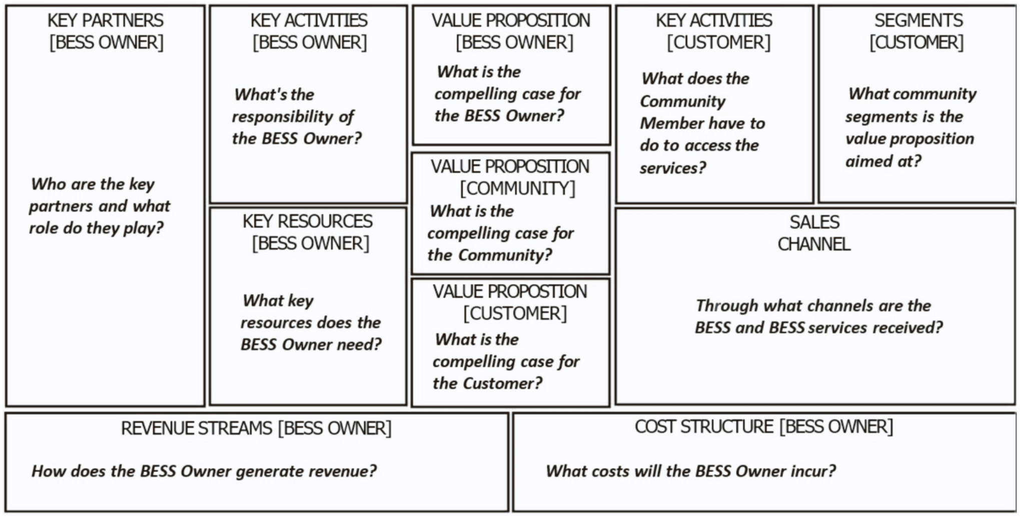

Fig. 2. Business model canvas for community-scale batteries.
(Adapted from the business model canvas by Strategyzer.com and. Licensed under the Creative Commons Attribution-ShareAlike 3.0 Unported License, see [37].)

channel. It also has a direct relationship with an energy retailer who is also an *aggregator* from whom it procures services. There is a long list of key partners which the BESS owner must work with to realise the trial. These are drawn from industry, academia, government, advisory firms, as well as product and service suppliers (see Fig. 3).

The revenue streams of the battery include FCAS income and energy arbitrage. The battery is charged during the day when solar generation is high and demand is low and discharged at night when solar generation is low and demand is high. The arbitrage decisions are set as a function of the FCAS prices, with bids made into the various FCAS markets.

YEF was seeking a way to support the Fitzroy North community reduce its carbon emissions by increasing the amount of solar capacity that could be installed locally. It initially sought a virtual solar storage business model that would also help its community members access locally generated renewable energy, including non-solar households and renters. However, the legacy solar PV subsidy in the state and the high number of people in the community on this feed-in tariff meant that the economics were not deemed compelling enough for this business model. This is expected to change as the solar PV feed-in-tariff ends in 2024. The community benefit was therefore not derived from the sum of individual reward but rather linked to the greater good. This comprised of the tangible and calculable (i.e. carbon emission savings of the community) to the intangible (i.e. support for the local grid, place making and civic pride). To date, the community reaction has been captured by a community survey undertaken by YEF, which found that over 96 % of respondents were "supportive" of a CSB being installed in their

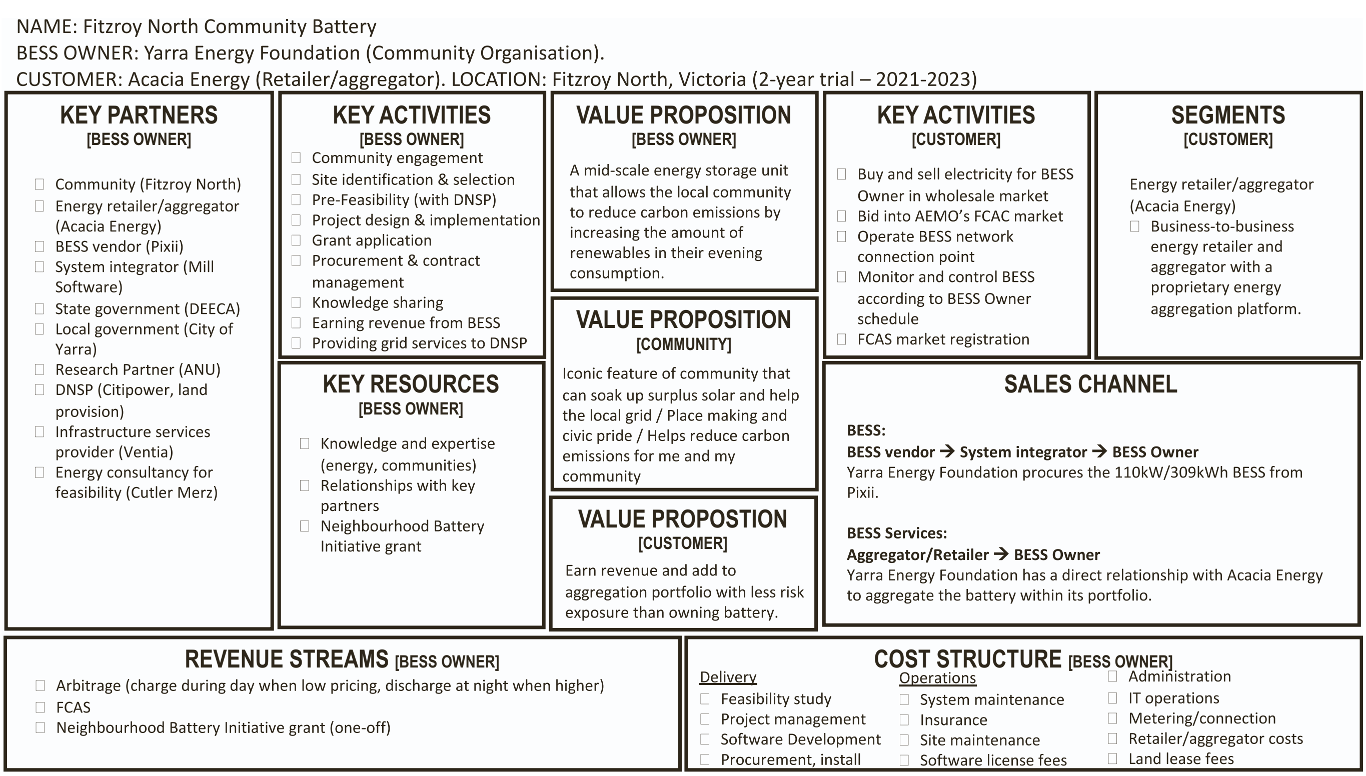

Fig. 3. Business model canvas for the Yarra Community Battery.

neighbourhood [78]. Over the next 2 years, YEF will also look to explore the option to raise capital for the community to take over the title as owners of the battery.

5.2.2. Ausgrid Community Battery Trial

Ausgrid is a DNSP with 1.7 million customers across three highly populated areas of East New South Wales (NSW). Its role is to build, operate, and maintain the electricity distribution network. It states its current priorities as supporting the delivery of affordable, clean, and sustainable energy. In 2021 it launched the Beacon Hill Community Battery, a front of the meter, utility-owned CSB in a suburb of Sydney. It was internally funded via the Ausgrid Network Innovation Program, with the CapEx added to its regulated asset base (RAB). The RAB is the sum of all the accumulated investments that a DNSP makes in its network. The battery is considered a network asset and it was installed during Version 2 of the electricity distribution ring-fencing guideline, which at the time did not contemplate the leasing of capacity from the battery. The AER did allow the battery innovation trial to be undertaken as planned, however future CSBs deployed by Ausgrid will be done under a ring-fencing class waiver.

Ausgrid employed a utility-owned, front of the meter virtual solar storage subscription business model for mid-scale BESS. Ausgrid had a major role across the full project lifecycle, from initial community engagement to the final knowledge sharing activities. It commissioned a feasibility study from a professional advisory firm that was subsequently published on its website. Ausgrid procured the system from the BESS system integrator/installer. It also has a direct relationship with an energy retailer/aggregator who, in return for lease payments, is allowed by Ausgrid to control the battery in order to access electricity market value. These lease payments are then deducted from Ausgrid's RAB (see Fig. 4).

Compared with a community-owned BESS example, key differences are that there are more key partners who hold multiple roles, potentially reducing the margins and overall costs. In NSW, where the trial is being undertaken, the solar feed-in-tariff ended in 2016. This means that there had been a more compelling proposition for community members in NSW to seek to maximise the self-consumption of their solar, compared with those in Victoria. However, an initially offered option for community members to access virtual storage against a nominal fee will be discontinued beyond the trial period.

In terms of revenue streams, the BESS owner (Ausgrid) receives lease payments from the energy retailer/aggregator for use of its battery for accessing electricity market value (such as FCAS and energy arbitrage). It also gets compensated by the Network Innovation Program, an AER-approved network innovation trial scheme.

Ausgrid was seeking a flexible alternative to augmenting existing network infrastructure while helping to reduce peak and minimum demand periods in neighbourhoods with high solar PV penetration. Accessing new value streams while helping to support a new industry was also viewed as an attractive proposition, which was de-risked through accessing available innovation funding. For members of the community, the value proposition was intended as an easier, lower cost alternative to purchasing and managing a residential BESS for their own home. The wider community benefit being that the battery helps increase the capacity of the neighbourhood's network to connect and export locally generated electricity from solar. A 2022 survey of the trial participants conducted on behalf of Ausgrid, found general support and that "environment" was the most common motivation for enrolling in the trial, albeit it more strongly linked in conjunction with other financial and social motivators [79].

5.3. Evoenergy's Molonglo Grid-Scale Battery Trial

Evoenergy is the main DNSP in the Australian Capital Territory (ACT) where it is responsible for the distribution of electricity to 200000 residential and business customers, including Australia's capital city of Canberra. In 2020, Evoenergy identified the need to address a constraint in the network to ensure the continued reliable supply of electricity to the Molonglo area. This greenfield development area is located approximately 10 km west of the capital's central business district. Over the next 30 years, the area is expected to see considerable development

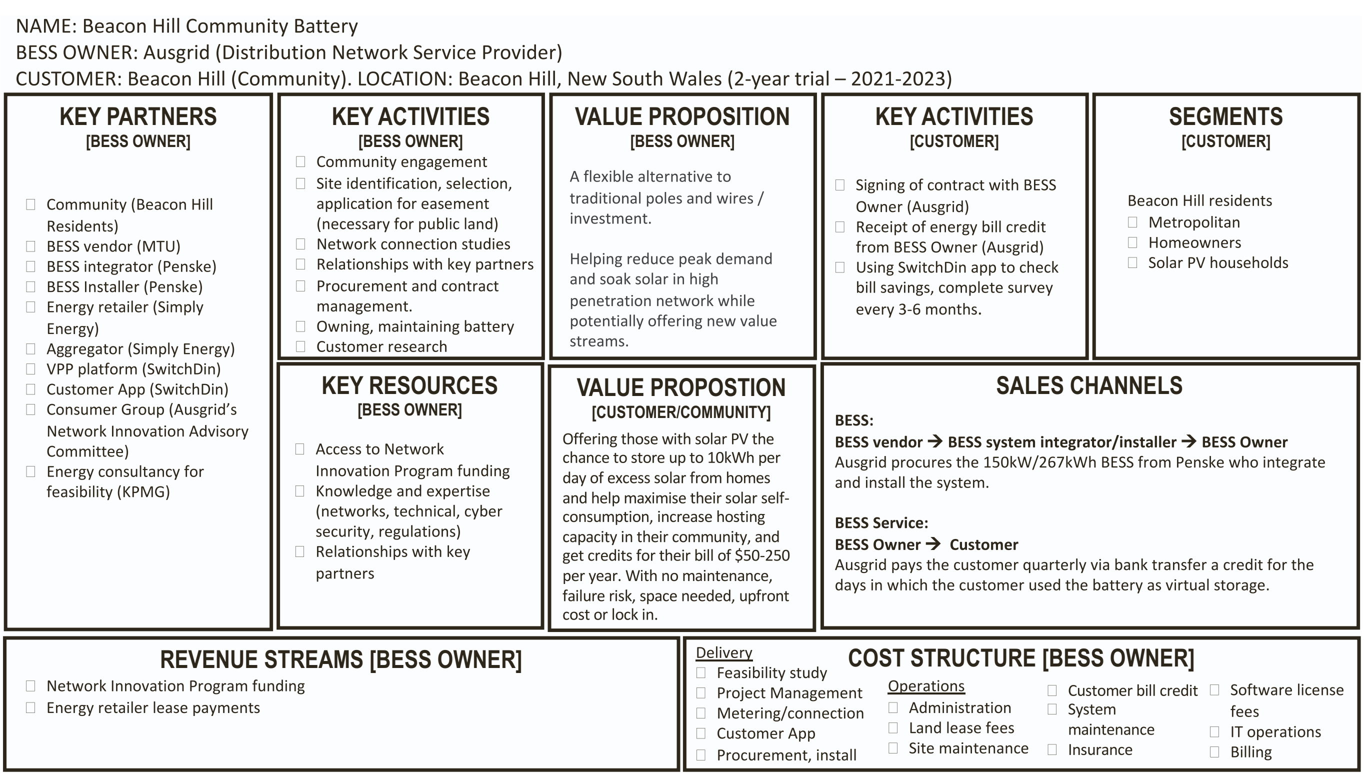

Fig. 4. Business model canvas for the Ausgrid Community Battery Trial.

with new suburbs being established.

Australia's National Electricity Rules (NER) required a Regulatory Investment Test – Distribution (RIT-D) be undertaken where augmentation projects with a value greater than AUD 6 million are needed. Evoenergy identified a BESS at Molonglo as the preferred option to defer investment in upgrading the local zone substation by 2 years.

Evoenergy had a major role in initiating the project via the regulatory investment test, which identified a technical need for the BESS. The project developer (ITP Renewables) responded to Evoenergy's RIT-D and then were subsequently contracted by them to deliver the project. It was initially intended that the project developer would also finance, own, and operate the BESS. It would then earn revenue from FCAS and energy arbitrage while providing grid support services to Evoenergy. However, it was subsequently decided that the BESS would be sold to a finance company who would instead own and operate it.

The Molonglo battery is considerably larger than the CSBs featured in the other case studies (multi-MW as opposed to hundreds of kW). While no direct benefits flow to the community, there are indirect ones for all energy consumers through the deferral of a network investment option. No survey of the community and its perception of the benefit was known to have been undertaken and made publicly available.

The Molonglo battery thus is a 3rd party-owned (non-network owned) network asset. In terms of revenue streams, the BESS owner will access electricity market value through energy arbitrage and FCAS (see Fig. 5). It will also receive payments from Evoenergy for providing grid services, such as voltage control and peak shaving. In the presence of the new ringfencing rules, the battery can be contracted to provide network services without a waiver, even if it also provides contestable services.

6. Discussion

6.1. Future business models for CSBs

While the presented CSB business models have been developed for the specific local characteristics relevant for each case study, a comparison between the business model canvasses reveals which arrangements were perceived as successful, and what their relevance might be for applying similar propositions in different jurisdictions. It should be noted that innovative business models encompassing immature technologies and markets often undergo rapid evolution and the canvasses are only a snapshot in time. Those planning on implementing similar propositions should be prepared to "fail fast" and adapt their business models according to the prevailing local context and market environment.

The analysis of the YEF business model showed a large number of stakeholders involved, arguably adding to the complexity (and cost) of managing such an initiative and achieving the necessary buy-in. As the BESS owner, the community organisation does accept a larger amount of the risk in exchange for a greater control over its business model and how it manages the sharing of the benefit with the community. Interesting to note was the shift in the business model from a "virtual storage asset for individuals" to that of a "valued community asset".

While YEF had to abandon an initially planned business model relying on individual community member buy-in (due to a lack of compelling economic case as potential consumers still received legacy feed-in-tariffs, see Section 5.2.1), a subscription-based model was pursued in the Ausgrid case study. Clearly the subscription-based, virtual storage model lends itself more to those markets with stronger drivers for maximising self-consumption. A community where environmental motivations for participation are high was also a common factor between these two business models.

In the third case study, the business model for Evoenergy was based around a network constraint and regulatory investment test. However, its attractiveness to an international renewable energy investor shows that these assets may soon feature more in other renewable energy investment portfolios. This business model may be transferable to those markets where sufficient electricity market value (such as arbitrage or ancillary services) can be captured.

One factor all the case studies had in common was the access to public grants or private innovation funding to reduce the initial CapEx

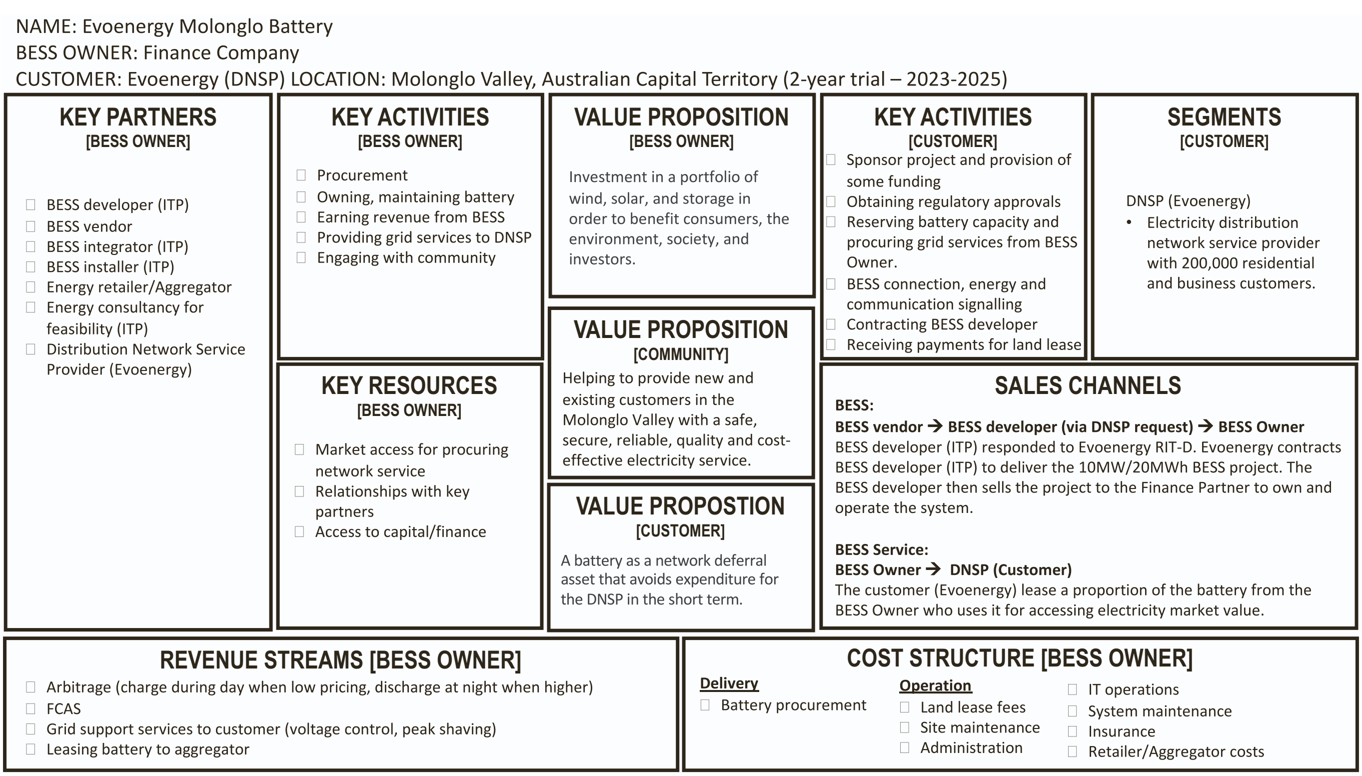

Fig. 5. Business model canvas for the Evoenergy Molonglo Battery Trial.

and improve the business case. Until the costs of CSBs sufficiently decrease, such funding schemes are likely to be another prerequisite for the transfer of these business models to other markets.

6.2. CSBs and community benefit

CSBs offer substantial additionality over other forms of storage in the form of community benefits, such as local energy management, decarbonisation, and equity [80]. YEF participants noted that despite a lack of direct economic benefit, support for the CSB being installed was found to be extremely high. The Ausgrid example found general support from participants and while environmental drivers were a strong motivation, they were most likely coupled with other financial and social motivations. Ausgrid's value proposition differs from the YEF example in that more direct economic benefit was offered to individual households, in the form of virtual storage with credits applied to energy bills as a reward. While no similar community feedback was received on the Molonglo case study, it remains to be seen whether community members and households would be indifferent; or whether electricity distribution networks could find latent community support and enthusiasm for network-owned batteries, if they applied the same community engagement techniques and publicised the indirect community benefit.

6.3. Relevance and future research

The experience in Australia mirrors those described by Parra and Mauger [32] and De Juan-Vela et al. [31] in the European context. The front of the meter position of CSBs lead to exposure to regulatory requirements mirroring those of bigger batteries. It is also notable that the successful storage models described by Kumar and Shrimali [35,81] in the US context, are all comparatively large-scale, and these studies too, are cautious about the effort required to develop viable front of the meter markets for storage. Our study shows that even where multiple CSB value streams are enabled (a key recommendation made for example by [25], for the Finnish market), the administrative effort associated with accessing these value streams may be underestimated or not fully appreciated by policy makers or other proponents and provide a barrier to deployment. This is a function of an unbundled market which does not readily enable one entity to access value streams across the different functions of an electricity system, such as retail, generation, and networks. As a result, this necessitates the involvement of multiple partners and exposure to multiple administrative requirements for each of these functions.

The need for network tariff reform to ensure that charges are not applied twice – when charging and when discharging – has been confirmed for the Australian example and echoes reform suggestions in many of the case studies from other jurisdictions (e.g., [28,35,81]). More research exploring whether and how new and innovative business models can be enabled to overcome these barriers is urgently required. With the expansion and implementation of requirements for energy communities in the EU, initiatives that specifically integrate local battery storage as part of a community effort may provide an opportunity for fruitful cross-pollination. Particularly when it comes to exploring new business models and engendering the regulatory changes needed to enable these.

Future research should also elaborate on the viability of behind the meter solutions for community-scale batteries, for example within the context of microgrids. Finally, this research also identified a high level of ambiguity surrounding the realised (and realisable) revenues and operating costs of community-scale batteries (per installed capacity). This is due to the pilot nature of these innovator case studies. As more projects continue to be deployed, it will be important to establish and benchmark these costs and revenues to better understand the viability and prospects of this type of battery class.

7. Conclusions

Australia is undergoing a major energy system transition that will result in a predominantly renewable powered electricity system meeting increased electricity loads [4]. Storage will play a significant role in ensuring the provision of reliable, sustainable energy. While energy storage solutions can come in several class sizes, in this paper we particularly focused at the more nascent CSB type that is smaller than their utility-scale front of the meter counterparts but larger than behind the meter residential-scale systems.

Deployment of both utility-scale and residential batteries has been more successful in Australia to date, although interest in and funding for CSBs has been increasing markedly in recent years. The CSB market is still nascent and is reliant on funding from either government support programs or DNSP innovation funds. This paper shows that a lack of transparency on the business model and business case for CSBs, uncertainty over future energy market value, whether falling battery costs can keep up with any future removal or decline in funding, continued community appetite for and acceptance of CSBs, and policy and regulatory uncertainty, can all pose risks to whether CSBs can achieve scalability. Different stakeholders, including communities, DNSPs, energy retailers, aggregators, government, and finance companies, may all gain from an increase in CSB capacities, catching up with residential- and utility-scale deployments.

CSBs can deliver a range of monetised and unmonetised services. In terms of monetised services, FCAS and energy market arbitrage are currently their key sources of revenue in Australia's NEM. Other predominantly localised services that CSBs deliver, such as place-making for communities, local network support, and local DER integration support, are not monetised but are potentially of high interest to communities as the case studies in this paper show. While the regulatory landscape is already changing towards the enablement of whole-of-system services, capturing and monetising local benefit and services delivered such as (i) local DER integration, (ii) local network support (iii) community empowerment and support of energy justice, is currently outstanding. Network tariff reform and regulatory reform acknowledging the benefits for system stabilisation and network support, which batteries provide in a predominantly zero marginal cost intermittent generation system of the future, should become a focus for policy makers.

CRediT authorship contribution statement

Zsuzsanna Csereklyei: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Scott Dwyer:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Anne Kallies:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Dean Economou:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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