MONASH University

VICTORIAN MARKET ASSESSMENT FOR **MICROGRID ELECTRICITY** MARKET OPERATORS

WHITE PAPER

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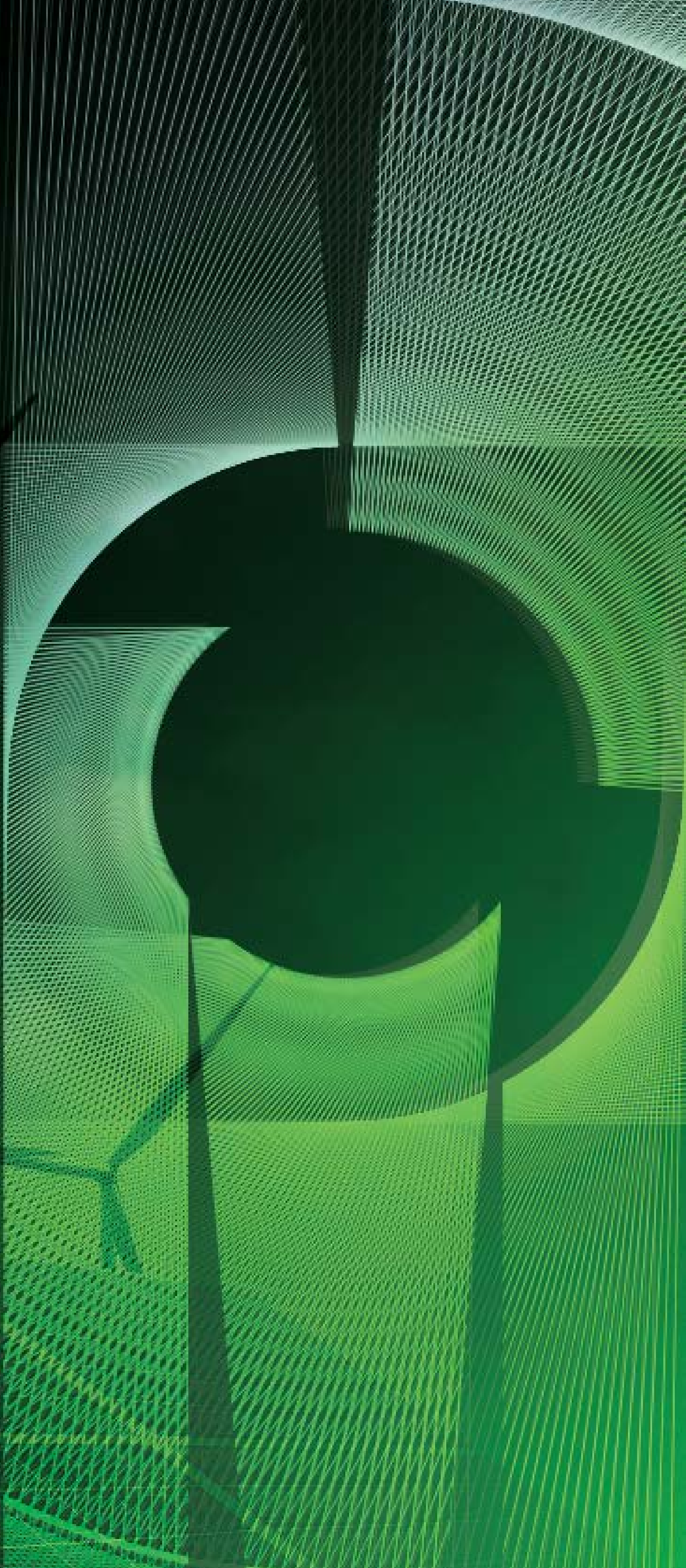

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Executive Summary

Increasing the deployment of microgrids could have substantial benefits for Victoria, with an estimated potential $22 to $36 million market in gross economic value per year, improved grid stability, lower energy bills for customers, and greater penetration of distributed renewable generation. Microgrids could represent an attractive financial proposition for residential, commercial and industrial customers and prospective microgrid operators. Through coordination of customers' distributed energy resources[1] by a dedicated microgrid operator, microgrids can improve the efficiency of energy use within the microgrid, provide valuable services to the broader electricity market and contribute to system reliability and security. This paper identifies a initial set of policy, market design, and regulatory enhancements which could be implemented to improve microgrid customers' and operators' capacity to access the economic value of controlling their distributed energy resources. This could enable greater uptake of microgrids and unlock the potential value for Victoria.

Distributed energy resources (DER) and decentralised power systems are fast becoming significant challenges to the traditional paradigm of Australia's electricity markets. In Victoria, and elsewhere in the Australian National Energy Market (NEM), DER are increasingly being deployed "behind the meter" at the customers' premises. An increasing number of prosumers are seeking to mitigate rising electricity prices and reduce their greenhouse gas emissions through deploying their own on-site renewable generation and storage.

The rise of DER presents both challenges and opportunities for the grid. Without a level of control and system integration, these decentralised solutions can create challenges for grid power quality and resilience. Conversely, coordinated and controlled use of customers' DER could provide substantial benefits for the stability of the network. However, the energy system is complex and customers are not currently able to access the value from their assets and investment.

A growing number of decentralised business models – including virtual power plants (VPPs), smart embedded networks and microgrids - are seeking to capture and provide new value streams to customers and other stakeholders. These new business models for managing two-way power flows also create new opportunities. In addition to securing higher penetration of renewables, the better coordinated deployment of DER can provide economic value to the market as a whole, and commercial value to consumers, market customers and distribution networks across the electricity sector. New business models could also help place consumer protection and interests at the core of their philosophy and commercial offering.

Microgrids include a number of participants. While some of these participants have well-established roles in the electricity market, others may represent new entities, which are evolving to provide services required in an increasingly distributed electricity system:

Microgrid end users are connected to the microgrid and may or may not own distributed energy resources. Microgrid end users rely on the microgrid to supply their electricity needs and optimise the use of these resources.

The microgrid network owner owns the infrastructure that makes up the internal microgrid electricity network.

The microgrid operator provides the hardware and software to monitor and operate the microgrid facilities and services.

The microgrid network owner and the microgrid operator may be the same entity.

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1. Distributed energy resources are small-scale load and generation facilities connected to the distribution system that could be controlled to the benefit of their owners. For example, rooftop solar, batteries and demand response.

Microgrids provide one avenue for sharing and monetising value from the increasing volume of DER. A microgrid is a small electricity network, composed of multiple co-located customers with their own electricity consumption needs and power generation. A microgrid has a single point of connection with the broader electricity market and a monitoring and control platform is used to coordinate the supply and demand of customers connected to the microgrid, and maintain grid stability. Through coordination, a microgrid can maximise the value of the connected DER for microgrid participants, the network and the broader market.

A microgrid operator provides the point of coordination for DER as well as the interface with the wholesale electricity market and the ancillary services market to manage system power quality (frequency and voltage control). Microgrid end users and the microgrid network owner benefit from the services of the microgrid operator, as the operator enables better coordination of DER within the microgrid, and the sale of energy services on the broader grid. In return for providing this service, a microgrid operator could charge a fee to participating end users or share the profits from managing electricity transactions with the broader electricity market. These sources of revenue would enable the microgrid operator to maintain its business operations to provide the service promised to its end users. A microgrid operator could represent a new class of participant in the electricity market, or the interface role could potentially be taken up by a wholesale market customer, retailer, a service aggregator or network service provider. This will depend on the business case for such an entity to operate independently or in partnership with existing actors.

A microgrid operator would provide expertise and a range of services to help end users make and save money. Savings are made by coordinating DER so that they are used efficiently within the microgrid. This could include shifting demand away from peak times, when energy is expensive, to off-peak times when energy is cheaper. It could also include managing storage on the microgrid to better respond to changes in customers' energy generation and energy demand, sharing renewable generation between DER owners, and, depending on regulatory changes, trading renewable generation and use of storage between end users.

Through interfacing with the broader electricity market, the microgrid operator could also help customers gain financial benefits for the services that their DER provide to the broader grid. Customers' energy resources could be coordinated to reduce demand on the network in response to high price and peak demand times. If this reduction in peak demand can delay the need for upgrades of the distribution or transmission network or improve reliability of supply, these network support services could represent a potential revenue stream for the microgrid operator and customers. In addition, customers' energy resources could also be coordinated to provide additional electricity supply into the wholesale market during peak demand times. Customers may also be aggregated to provide system control services for the ancillary services market.

The deployment of microgrids may also have broader benefits for grid stability and greenhouse gas emissions. In comparison to the current scenario where distributed renewable generation is connected to the network on a case-by-case basis with individual controls, microgrids enable better management of local voltage. This should increase the grid's capacity to host renewables and help reduce greenhouse gas emissions from the electricity sector. Microgrids may also be able to assist in maintaining grid stability through providing distributed frequency control under extreme system conditions, and through providing emergency generation under extreme conditions, including sudden outage of generation and transmission assets.

For microgrids to become an attractive investment opportunity for electricity market participants, and for microgrid end-users, a range of policy, market design and regulatory issues need to be addressed. Microgrid bring together a range of functions, such as supply of electricity to end-users, purchase and sale of electricity on the wholesale market and provision of ancillary services. With each of these functions regulated individually, microgrid regulation is currently a composite of the regulations that apply to each function. As a result, these regulations present a barrier to microgrids in three ways:

- Complexity;
- Uncertainty of interpretation - particularly the interaction of functions; and
- Prevention of access to value streams.

Some of these regulatory issues are not unique to microgrids. Because similar issues affect other distributed energy technologies a comprehensive review and reform of the regulatory framework may ultimately be required. However, in the meantime microgrids can be used as a test case for how regulatory frameworks should evolve to accommodate more sophisticated local electricity supply and services. Using microgrids as a regulatory test case will also create an important feedback mechanism, and provide important lessons for the wider transformation of the sector.

This White Paper makes five initial recommendations which could begin to address these issues and improve microgrid operators' and participants' capacity to access the value of their DER:

- **Recommendation 1 – Definition of a Microgrid:** Develop a non-exhaustive, non-prescriptive definition of a microgrid as a system that integrates local supply[2], network supply and electricity exported to the grid.

  There is no definition of a microgrid in either the Victorian regulatory regime or the National Electricity Rules. Existing definitions of 'embedded network' and 'embedded generation' provide an inadequate basis for authorising and regulating microgrids.

  A regulatory definition is needed to:

  - clearly distinguish microgrids from embedded networks;
  - enable microgrid activities and services to be authorised under the Victorian *Electricity Industry Act (2000)* and National Electricity Rules; and
  - facilitate best practice consumer protection.

- The development of a regulatory definition would complement the development of a model constitution for microgrid operators by the industry, which could provide an effective form of co-regulation ensuring that microgrid end users are afforded the same protections as other Victorian energy consumers.

- **Recommendation 2 – Guidelines for Microgrids:** Given the growth in decentralised energy systems, it is recommended that the Essential Services Commission be asked to develop guidelines on the application of:

  - the statutory licence/exemptions regime to microgrid activities and services;
  - the Energy Retail Code to microgrid operators and end users;
  - the Electricity Distribution Code to Distribution Network Service Providers (DNSPs) in their dealings with microgrid operators.

- **Recommendation 3 – Undertake Feasibility Study into Establishment of Independent Distribution System Operator (DSO)[3]:** That a comprehensive feasibility study into the establishment of an independent Distribution System Operator (DSO) be undertaken[3]. At present, there is limited transparency and independence in assessing the value of services that defer investment in the distribution network. These services are a potentially important and growing source of revenue for microgrids. Currently, the benefit of providing these services is calculated by the distributor, and service providers must engage in expensive contract negotiations with the distributor to access this revenue stream. The ad hoc nature of current arrangements for network support services also limits competition for the provision of these services. Establishing an independent DSO could help to overcome these issues. The role of the DSO could include the development of a transparent market for the provision of a defined network support service.

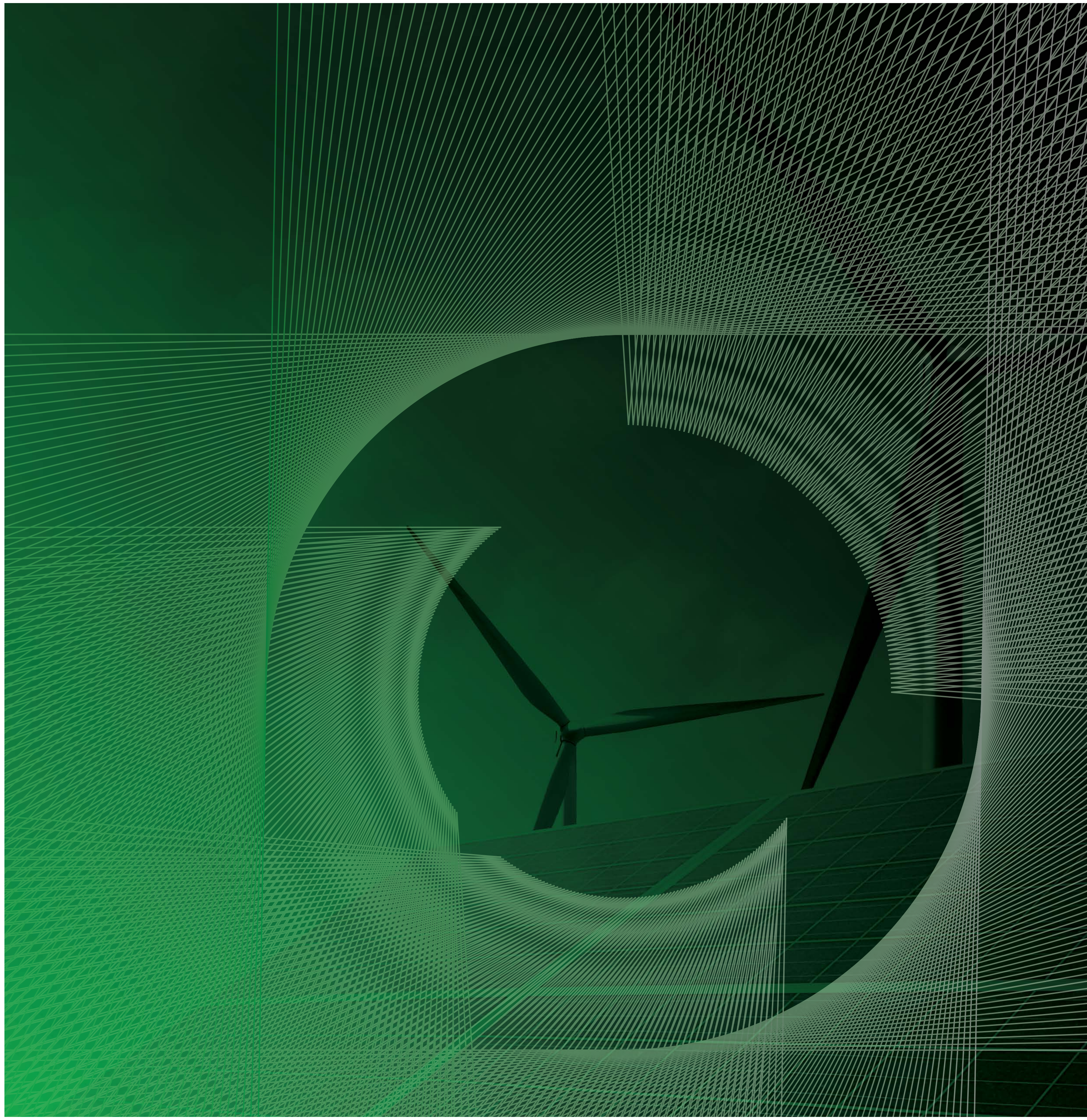
- **Recommendation 4 – Protect Local Supply in any New Regulatory Changes:** Victoria should ensure that any changes to the National Electricity Rules, especially as they relate to embedded networks and consumer protection, do not create new technical or financial barriers that will in practice prevent local supply in microgrids. Ensuring microgrid value streams can be accessed requires local supply to be enabled.

2. Local supply means electricity generated or stored within a microgrid and supplied to customers connected to the embedded network.
3. The feasibility study should take into account the findings of the Open Energy Networks process being delivered by the Energy Networks Association and Australian Energy Market Operator. In comparison to this process, the feasibility study should include a broader remit regarding the role of the Distribution System Operator.

- **Recommendation 5 – Investigate Market Design to Enable Access to Value from Reduced Loss Factors:** It is recommended that potential market design changes be investigated to enable microgrid participants to access a share of the value of reduced loss factors from shifting load from high load to low load periods. While a substantial regional benefit could arise from such activity, the economic benefit would be spread across all consumers and so microgrid operators and their customers could not be rewarded for providing this value. If microgrid operators and their customers could be rewarded, it would provide additional incentive for load shifting, battery storage and microgrid control.

If these policy, market design, and regulatory issues are addressed, they could help enable deployment of microgrids which could create substantial economic value for Victoria. There may however, be further regulatory amendments required to enable the full potential of microgrids to be realised. This project will continue to investigate these and make further recommendations in its final report. It is estimated that $22 million per year levelised over the period from 2018-19 to 2022-23 in value could be created, assuming sufficient load could be aggregated by appropriately placed microgrids. This value arises in part from reduced loss factors on the distribution and transmission networks from load shifting from peak to off-peak periods ($3.5 million) as the microgrid flattens and shifts its external electricity consumption. Value also arises from earnings that accrue to the microgrid operator and customers from a number of sources, including participation in the ancillary services ($7.4 million), the energy market value of load shift to off-peak periods to provide network support services ($7.2 million), load reduction for network support to reduce expected unserved energy ($4.0 million) and distributed voltage control ($0.2 million). We calculate a potential upper estimate of value at $36 million per year, depending on the potential for microgrids to enable the deferral of network upgrades on a planned basis, and the level of contribution of microgrids to voltage and frequency control. These values are expected to increase beyond 2023 in real terms as the penetration of renewable energy increases in the electricity market and the value offered by distributed resources grows.

To enable greater deployment of microgrids, this White Paper strongly recommends that further work is carried out to identify opportunities to develop microgrid pilot sites where strong benefits are apparent, and address the policy, market design and regulatory issues identified in this paper. In the longer term, greater uptake of microgrids could unlock substantial economic value, improve grid stability, and reward customers for their investments in distributed renewable generation and storage.



Recommendations

1. Definition of a Microgrid

Develop a non-exhaustive, non-prescriptive definition of a microgrid, as a system that integrates local supply, network supply and electricity exported to the grid.

There is no definition of a microgrid in either the Victorian regulatory regime or the NER. Existing definitions of 'embedded network' and 'embedded generation' provide an inadequate basis for authorising and regulating microgrids.

A regulatory definition is needed to:

- clearly distinguish microgrids from embedded networks;
- enable microgrid activities and services to be authorised under the EIA and NER; and
- facilitate best practice consumer protection.

The development of a regulatory definition would complement the development of a model constitution for microgrid operators by the industry, which could provide an effective form of co-regulation ensuring that microgrid end users are afforded the same protections as other Victorian energy consumers.

Key elements of a definition should include:

Microgrid means a system for managing the electricity supply and demand of customers connected to an **embedded network**, in a way that integrates **local supply, network supply** and electricity exported to the grid.

Embedded network has the same meaning used by the AEMC in its draft report on the proposed regulatory framework for embedded networks.

Local supply means electricity generated or stored within a **microgrid** and supplied to customers connected to the **embedded network**.

Network supply means electricity supplied through the **connection point** to the embedded network.

Connection point has the same meaning as in Chapter 10 of the National Electricity Rules.

Consumer protections have the same meaning as in the existing Victorian energy regulatory regime.

2. Develop Guidelines for Microgrids: That the Essential Services Commission be asked to develop a guideline on the application of Section 16 of the *Electricity Industry Act 2000*, and the General Exemption Order 2017 to the key components of a microgrid, including:

- an embedded network;
- one or more sources of embedded generation;
- electricity storage;
- supply of electricity to multiple third-parties;
- a dynamic supply and demand control system;
- a single connection point to the distribution system; and
- a third party microgrid system operator.

It is also recommended that the Essential Services Commission be asked to provide guidance on the application of both the Victorian Codes to microgrids, in particular:

- the Energy Retail Code to microgrid operators and end users; and
- the Electricity Distribution Code to DNSPs in their dealings with microgrid operators.

3. Undertake Feasibility Study into Establishment of Independent Distribution System Operator (DSO): That a comprehensive feasibility study into the establishment of an independent Distribution System Operator be undertaken. Using the network surrounding the Monash Microgrid as the study area could help identify how a DSO would facilitate the operation of microgrids, and quantify the value of the network service it could provide.

4. Protect Local Supply in any New Regulatory Changes: That Victoria ensure that any proposed changes to the National Electricity Rules as they relate to embedded networks, do not create new technical or financial barriers that will in practice prevent local supply and sale in microgrids. It is also essential that any proposed changes to the national laws and rules do not weaken Victoria's existing consumer protections.

5. Investigate Market Design to Enable Access to Value from Reduced Loss Factors: That Victoria investigate the feasibility of market design changes to enable access to microgrid operators and their customers of the value from loss savings that arise from load shifting and optimised battery operations. This may also be applicable to utility scale investments in storage that reduce the energy losses associated with peak demands in load centres and peak generation in renewable energy zones. The market design changes would seek to improve the efficiency of the electricity market by providing incentives for distributed storage and load control to reduce energy losses and improve the efficiency of the use of the distribution and transmission system.

White Paper **Scope**

To understand and quantify the value proposition presented by microgrids to Victoria in the context of the current Victorian regulations and constraints; and provide initial regulatory, policy, and market reform recommendations.

About

Monash's Microgrid

Monash University has committed to transitioning to Net Zero Emissions by 2030. As a part of this, Monash is building a Microgrid on its Clayton campus over the next two years, to demonstrate how a 100% renewable electricity system can operate reliably, and the value it can provide to customers and the broader energy network.

As a model of a small city, Monash's Microgrid provides a realistic and useful platform for research into technological, business and customer behavioural features of the deployment of distributed resources and their coordination through microgrid operations. The microgrid system being implemented on Monash's Clayton campus is intended to be a fully functioning local electricity network and trading market with dynamic optimisation of resources interacting with an external energy market.

Monash is investigating a prototype of a microgrid as a service platform that allows market participants and customers to access value streams within a distributed renewable power energy system and market.

Funded by the Victorian Government, the Microgrid Electricity Market Operator (MEMO) project seeks to address a gap in the current energy market, investigate the business case for the creation of these new entities and provide regulatory recommendations to address potential barriers preventing their establishment in Victoria.

Scope of this White Paper's Regulatory Discussion

Ascertaining the parameters of the relevant regulatory paradigm is circumstantially dependent. Given the highly variable nature and scope of microgrids, detailed advice on regulatory challenges requires examination of the particular microgrid system and/or services individually, on a case by case basis.

As microgrid systems develop, the nature and number of participants and stakeholders changes, so do the range of microgrid services provided into, within, and from, the microgrid system. A further layer of complexity is added by reference to the different relationships between the microgrid and other markets and stakeholders external to it. Accordingly, as microgrid systems and microgrid services become more sophisticated and multifaceted, the extent to which policy, market design, and regulatory concerns arise also becomes more complex. It is important to note here that beyond the analysis of regulatory matters, both policy and market design questions are also raised in this White Paper.

This white paper invites the reader to consider key questions throughout the report and also brings forward a set of unanswered questions on the valuation, policy, market design, and regulation in appendix 6.5.

As such, the preliminary regulatory discussion in this paper is predicated upon the following:

- What are the services to be provided through the microgrid system discussed in this White Paper? Do the current regulations adequately provide for these?
- To what extent do the current regulations adequately provide for the recognition of a new entity?
- To what extent does the capture of the value streams identified in this paper depend on matters of policy, market design, and/or the existing regulatory framework?

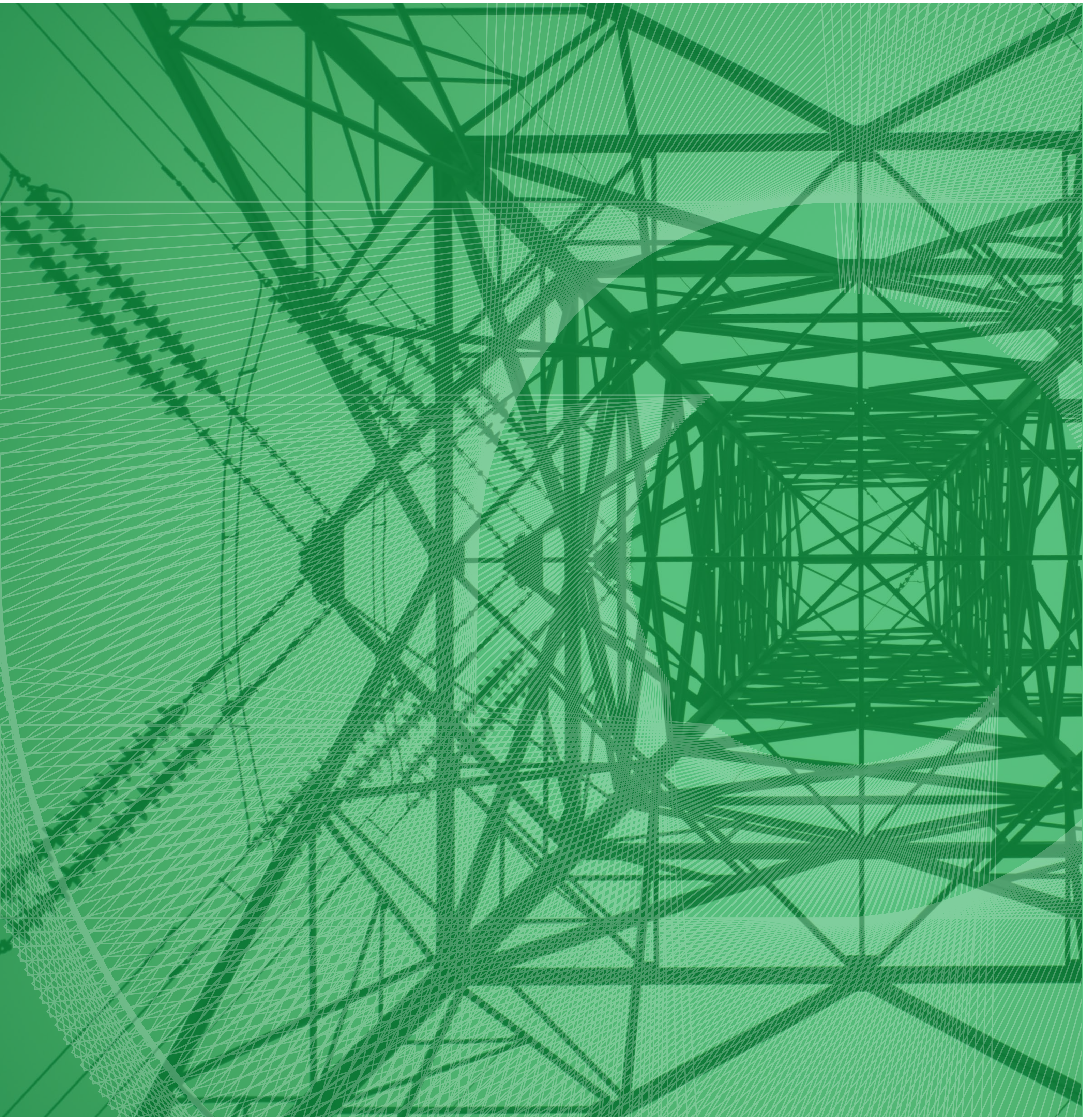
In this White Paper, Chapter 3 sets out an overview of the regulatory framework governing the generation, supply, sale, and end-use of electricity in the national and Victorian settings Chapter 4's discussion turns to the applicability and adequacy of the existing regime to emergent microgrid systems and services, and the role of a dedicated microgrid operator.

Many of the points raised in this paper remain open questions to be addressed through the future work associated with the MEMO project. This report presents initial recommendations, however there may be further regulatory amendments required to enable the full potential of microgrids to be realised. This project will continue to investigate these and make further recommendations in its final report.

The Monash Net Zero team welcome feedback from stakeholders on this White Paper. Feedback can be provided to netzero@monash.edu

Abbreviations and Definitions

Abbreviation or Term	Meaning
AEM	Australian Energy Market including wholesale gas and electricity and retailing of these services.
AEMO	Australian Energy Market Operator which operates wholesale gas and electricity markets in Australia in all states but excluding the Northern Territory.
DAPR	Distribution Annual Planning Review which describes the network constraints, the consumer energy at risk and the planned projects for the next 5 years.
Capex	Abbreviation for capital expenditure which is an up-front expenditure to provide long lifetime investment assets.
DER	Distributed energy resources are small scale load and generation facilities connected to the distribution system that could be controlled to the benefit of their owners.
DLF	Distribution loss factor influences the price which retailers pay to deliver electricity to a customer. The Regional Reference Spot Price is multiplied by the DLF (and MLF) to determine the price for the consumer. The DLF is specific to location and voltage level of connection.
DSM	Demand side management refers to the control of customers' energy resources in response to external market prices and contingencies that may affect supply reliability.
DSO	Distribution System Operator is the concept of a local operator focused on optimisation of power flows within and resources connected to a distribution system.
ENA	Energy Networks Association, an organisation representing the network service providers and asset owners in Australia.
MEMO	Microgrid Electricity Market Operator is Monash University's concept for a local operator of distributed energy resources – a microgrid operator.
MLF	Marginal (transmission) loss factor influences the price which retailers pay to deliver electricity to a consumer through a transmission connection point. The Reference Spot Price is multiplied by the MLF (and DLF) to determine the price for the consumer. The MLF is specific to the transmission connection point for each distribution network.
NEM	National Electricity Market operated by the Australian Energy Market Operator.
NSP	Network service provider is a generic term for an organisation which provides distribution or transmission services to the electricity market. This includes connection services for customers which are negotiated and electricity transfer services which are regulated.
NZI	Monash University's Net Zero Initiative which seeks to decarbonise its Australian campuses by 2030 through maximising the benefits from solar power, energy efficiency, energy storage, building control systems and purchase and integration of off-site renewable energy.
Opex	Abbreviation for operating expenditure for maintenance, staffing and on-going services needed to support a project or business.
prosumers	A word original coined by Alvin Toffler (1980) but recently applied to electricity consumers who adopt distributed generation and become producers as well as consumers, hence "pro-sumers".
Reserve and Emergency Reserve Trader role of AEMO	The Reliability and Emergency Reserve Trader (RERT) is a function conferred on AEMO to maintain power system reliability and system security using reserve contracts.
VPP	Virtual Power Plant is the concept that an aggregation of small distributed resources can be coordinated through bidding and dispatch control to behave as if it were a dispatchable power plant in the wholesale market. This may include using emergency generators or demand side response to be equivalent to dispatchable power. The aggregated resources do not have to be at the same distribution connection point to be effective.
ENO	Embedded network owner/operator.



1. The Microgrid and Need for Microgrid Services

1.1 Context

Australia's electricity grid is being challenged by a dramatic change in operating conditions, shifting from centralised generation, served by transmission and distribution networks, to one with embedded distributed energy resources. Australia currently has more than 1.6 million mini-generators[4], penetration of rooftop solar PV of nearly 20% and a local penetration in some areas of over 30% of all customer premises[5]. In Victoria, fifteen percent of dwellings have a solar PV system.

The challenge is for the clean energy transition to take place in an integrated and coordinated manner that guarantees grid stability while avoiding unfair impacts on consumers. While decarbonisation and decentralisation trends come with opportunities, regulatory changes will be needed to enable the value to be passed onto to customers.

The increasing penetration of variable energy resources and distributed deployment of storage is expected to increase the value of local management of distributed resources. The increase in the local value results from the potential contribution of distributed resources to preventing or relieving localised network performance issues where the network is at risk of breaching its performance obligations[6].

The Energy Networks Association (ENA) and CSIRO's Network Transformation Roadmap/CSIRO Roadmap envisaged that by 2027[7]:

> "An expanding range of new energy technologies and services are supported while continuing to efficiently provide a range of traditional electricity services. Advanced network planning, operation and intelligence systems ensure the safe and efficient integration of large-scale renewable generation, hundreds of microgrids and millions of customer distributed energy resources. Market based mechanisms reward customers with distributed energy resources for providing network support services, orchestrated either directly or through other market actors".

This view of the future conceives of optimisation of the operation and investment in distribution system connected resources including connected microgrids that self-organise their own operations to optimise participation in up-stream markets. The role of a *Microgrid Electricity Market Operator* or *microgrid operator* discussed in this white paper is a key component of this projected transformation.

Similarly, the Essential Services Commission (ESC) of Victoria investigated the energy and network value of embedded generation[8] with a focus on solar PV systems to identify evidence that network costs were materially influenced by solar PV generation. The ESC identified a prospective need for a "Distribution System Operator" (DSO) to optimise local distributed energy resources where they had a material effect on network costs and services. The energy value was assessed primarily as a foundation for updating the feed-in tariff for exported power to the distribution system. The network value of solar PV installations to that time was assessed as no more than $3 million/year and varied considerably by network connection point.

4. ENA, Electricity Network Transformation Roadmap - Key Findings Report, 2016.
5. Clean Energy Council, Clean Energy Australia Report, 2016.
6. Note: The increase in local value created is likely to be restricted by the very broad basis used for the calculation of network performance requirements under network licences, the absence of diversity in local load profiles, and capped by the cost of the available alternatives.
7. ENA Roadmap Reports at *https://www.energynetworks.com.au/electricity-network-transformation-roadmap*
8. Essential Services Commission, The Network Value of Distributed Generation, February 2017, found at *https://www.esc.vic.gov.au/sites/default/files/documents/distributed-generation-inquiry-stage-2-final-report-network-value.pdf*

1.2 A Microgrid

A microgrid has become a generic term that describes many different types of aggregated energy systems. For the purposes of this paper, a working definition of a microgrid will be taken to be:

> A system for managing the electricity supply and demand of customers, in a way that efficiently integrates local sources of generation and storage of electricity ('local supply') with electricity supplied from or exported to the grid ('network supply').

A microgrid could have the following characteristics:

- a site within a private distribution network ('embedded network') or a public distribution network ('microgrid zone');
- one or more sources of electricity generation connected to the embedded network ('embedded generation');
- On-site electricity storage ('battery storage');
- Supply of electricity to multiple third-parties ('supply');
- A dynamic supply and demand control system ('control system');
- A single connection point to the distribution system ('connection point');
- A third party microgrid system operator ('microgrid operator'); and
- Grid connected, but capable of islanding ('islandable').

The microgrid system considered here will be a fully functioned local electricity network and trading market with dynamic optimisation of resources interacting with an external energy market. Broad deployment of microgrids across Victoria may also reduce network losses. The benefits of reduced network losses accrue to all electricity consumers (referred to as "public" benefits in Section 1.3).

The microgrid would provide customers with services that are not available from the distribution network to which they are connected. Specifically, microgrids enable customers to:

- Share and maximise the value of local supply; and
- Minimise the cost of network supply.

Microgrids can also provide a range of network services including:

- Demand response;
- Voltage control; and
- Frequency control.

These services may be efficient substitutes for services provided from the external electricity market.

Figure 1 shows the components of microgrids, their characteristics and the services provided. In this paper, the focus is on "smart embedded networks" and "microgrid" types of systems shown in Figure 1.

FIGURE 1: **MICROGRID COMPONENTS, CHARACTERISTICS AND SERVICES**

MICROGRID COMPONENTS, CHARACTERISTICS AND SERVICES PROVIDED TO THE GRID

GRID-CONNECTED

	Components				Electric Boundaries	Islanding	Main Grid Interaction		
	Generation	Storage	Load	Controller & EMS			Ancillary Services	Local Services to DNSP	Market Participation
Simple Embedded Network	Not Included	Not Included	Included	Not Included	Included	Not Included	Not Included	Not Included	Not Included
Virtual Power Plant	Included	May be Included	May be Included	Included	May be Included	Not Included	May be Included	May be Included	Included
Prosumers Clustering	Included	May be Included	Included	Included	May be Included	Not Included	Not Included	Not Included	Included
Smart Embedded Network	Included	Included	Included	Included	Included	Not Included	Included	Included	Included
Microgrid	Included	Included	Included	Included	Included	Included	Included	Included	Included
Off-grid Microgrid	Included	Included	Included	Included	Not Included	Included	Not Included	Not Included	Not Included

Included | May be Included | Not Included

1. What are the implications of microgrid control applied to a public network?

2. How does control affect retailing, network service, system operations?

3. Can microgrid control be applied by existing entities or does a new market entity need to be defined?

How does this differ from a **Virtual Power Plant?**

Participation in a microgrid operation is potentially more productive than participation in a Virtual Power Plant (VPP) arrangement because the focus of a VPP is different. A VPP business focuses on aggregating distributed resources over a region for wholesale market participation. It will need to ensure that network constraints do not block the acquisition of resources into the wholesale market, but it may not provide services to the prosumer to assist cost minimisation, other than the revenue available from selling energy and ancillary services.

A microgrid has a focus on local resource optimisation at the low and medium voltage level. It may not operate at wholesale scale and therefore may contract resources through a VPP to serve wholesale market needs more efficiently than being a wholesale market participant itself. If the microgrid can operate at wholesale market scale (say 5 MW), it may present itself as a VPP to the market, depending on its business model and broader ambitions.

The value proposition is focused on earning an income from optimisation of resources behind a market connection point, rather than a regional focus of resource aggregation.

1.3 The Value Streams

The important service provided by a microgrid is the smart management of the local network and its connected distributed energy resources so as to maximise the value to its customers through maximising its value in the external electricity market. These benefits are private benefits; the microgrid also offers social and public benefits and, by bringing multiple resources and customers together, may have an enhanced opportunity to participate in energy and network markets.

Table 1 summarises the types of value streams which have been identified and the ways in which economic and commercial value is delivered. There are potential benefits from:

- **Private Benefits:**
  - Management of the site's load profile to flatten demand (load shifting), shift load from peak network periods (peak demand reduction), and export production at periods of high wholesale prices, reducing total costs at the connection point, and reducing system costs, for example, by reducing energy losses in the network.
- **Public Benefits:**
  - Local voltage and network power flow control raising the local hosting capacity for renewables;
  - Efficient management of customers' distributed battery energy storage to contribute to the management of the site's load profile, and also to better manage external network constraints;
  - Providing for disconnection of loads and connection of emergency generation under extreme system conditions, including sudden outage of generation and transmission assets; and
  - Providing distributed frequency control under extreme system conditions including system restoration.
- **Revenues from Market Participation**
  - Providing distributed frequency control under normal system conditions through ancillary service markets participation;
  - Network support markets to reduce expected unserved energy and defer network investments; and
  - Network ancillary service markets for local voltage control.

TABLE 1: **MICROGRID MARKET IMPACT AND VALUE**

Type of Value Stream	Market Impact	Source of Economic Value	Source of Commercial Value
Private Benefits:			
Lower electricity purchase costs from the shifting of load from high price to lower priced periods.	Depending on scale of microgrid, may see some shift in peak prices or peak pricing periods. Lower distribution network congestion.	Ability to shift load from higher to lower energy price periods. Ability to shift load from higher to lower price network tariffs. Some consequential reduction in loss factors.	Relative to alternative, unmanaged consumption profile, lower electricity purchase and network costs. Depending on the distribution tariff characteristics, network savings may be short term. Commercial value of loss factor reduction spills-over to market customers generally (Refer below in Table).
Efficient management of distributed storage, other connected assets.	Batteries are: - more efficiently operated over the diverse customer base and more fully utilised; and - enabled to absorb surplus renewable energy that otherwise would be curtailed.	Better asset utilisation than alternative (individual ownership and dispatch). Reduced cost of network services through more appropriate control of storage. Enables some load shifting away from periods when high cost generation is required. Extra renewable energy captured.	Battery owners: - reduce the cost of energy purchase for the microgrid as a whole. May receive a fee from the microgrid operator for allowing remote control of storage devices; - able to capture low cost energy from the wholesale market that would otherwise not be viable for the individual consumer to capture without a third party providing dispatch services. NSP: Reduced investment risk due to more stable network loading.
Public Benefits:			
Local voltage control from distributed resources	Improves local voltage control and allows more variable generation to be connected without violating quality of supply requirements. May also reduce utility scale investment in voltage control equipment.	Additional local generation is connected which increases potential penetration, reduces energy losses and defers network investment. NSP: The saving in network investment. Social: the benefit of reduced carbon emissions.	Risk of high and low voltages is reduced, so electrical equipment lasts longer. However, no commercial benefit unless a payment mechanism is created for the provision of local voltage control. It is possible that local voltage control provision could be a condition of connection to achieve higher penetration of renewables in some areas.
Demand side response for network load control following contingencies or under extreme load conditions.	Additional control of downstream peak demand allows NSP to avoid severe network constraints and the maintain reliability without network augmentation.	NSP: The saving in capital cost from network investment avoided or deferred, plus associated operating and maintenance costs, offset by the cost of the control service.	Customer: reduced energy costs in return for providing load control. NSP: may earn a higher profit by deferring capital investment and purchasing load control instead.
Reduced energy losses due to lower distances for power flow in the network.	Reduced energy loss factors.	Lower cost for thermal generation because less is needed to make up network losses.	All consumers in the relevant area: Reduced purchase cost of electricity due to reduced loss factors.
Under-frequency load shedding (UFLS) scheme to be integrated with MO.	Instead of shedding whole feeders for the purposes of under-frequency load shedding, MO could provide load control for this purpose which does not shed the distributed generation as well.	Reduced risk of load shedding in response to non-credible power system disturbances. Solar power generation is maintained and may respond to the frequency disturbance to help rebalance the power system.	Reduced risk of load shedding in response to non-credible power system disturbances. MO and its customers may receive a fee for providing UFLS services to the networks.
Connection and utilisation of emergency generation capacity.	Existing emergency generation capacity is enabled for fast response grid support by synchronising to the grid when extreme loading conditions occur in the network.	Deferred network investment and increase in local supply reliability under extreme loading conditions Value offset by cost of retrofitting control and synchronisation with grid. Consumers: Increases reliability of supply under extreme conditions.	Prosumers: fee for provision of emergency generation to the grid. Note that conversion of existing emergency generation for synchronous grid operation is often difficult or expensive relative to the commercial value available.
Local distribution of renewable energy surplus to microgrid participants' instantaneous requirements.	Local surplus renewable energy is provided to a local customer. Does not change wholesale market energy flow if sourced from zero marginal cost renewable energy.	Depends on whether such flows increase penetration of renewable energy. If so, network, generation and emission costs may be reduced. Potential reduced network, generation and emission costs to associated asset owners.	Lower losses and lower loss factors overall. Depending on the trading arrangements (e.g. Transactive Energy Market), prosumers and their customers may reduce their retail energy purchases and exposure to the retail margin.
Lower carbon emissions from additional renewable energy.	Additional renewable energy accelerates the transition to low carbon future.	Network, generation and emission costs may be reduced.	Commercial value of reduced carbon emissions would be realised if carbon pricing were restored in the energy market.
Revenues from Market Participation:			
Demand side response for network load control.	Additional control of downstream peak demand allows NSP to avoid network constraints and maintain reliability without network augmentation.	NSP: The saving in capital cost from network investment avoided or deferred, plus associated operating and maintenance costs, offset by the cost of the control service.	Customer: reduced energy costs in return for providing load control. NSP: may earn a higher profit by deferring capital investment and purchasing load control instead.
Peak demand management in the network (transmission and distribution).	Reduce peak demand, peak power flow in the network.	NSP: The saving in capital cost from network investment avoided or deferred, plus associated operating and maintenance costs. Assumes quality of supply is not degraded by deferment.	Consumer: Reduced network charges from lower peak demand, and/ or energy imports during peak periods.
Provision of frequency control services to the power system AS (ancillary services).	Distributed provision of frequency control services provides more competition, lower ancillary service costs and more security in frequency control.	Generator: Reduced costs and revenues for providing frequency control. Thermal and hydro power plant does not need to provide as much frequency control and can operate at a more efficient loading level.	Prosumer: may receive a fee for providing frequency control which more than offsets the lost value from reduced power production from solar power or battery.
Sale of electricity into wholesale, retail markets.	Depending on scale, time of day, may alter wholesale price.	Increased market efficiency.	Pool revenues.
Sale of voltage control services to the local network as a network ancillary service.	Distributed voltage control defers centralised voltage control from reactors and capacitor banks, and improves voltage stability of weak networks.	Deferred investment in centralised voltage control equipment. Improved quality of service in weak networks.	Revenues for network ancillary services for voltage control.

1.4 The Economic Value of Microgrids in Victoria

The estimated annual value of microgrid operations is between $34 and $51 million/year levelised over five years from 2018/19 to 2022/23 depending on the influence on network project deferral and the ancillary services markets.

Table 2 summarises the value that was assessed assuming microgrid operation fully exploits the opportunities for control of demand-side resources and is present in the appropriate locations at the required scale. Data sources, valuation methodology and analysis are described in Appendix 6.3 and 6.4.

TABLE 2: **SUMMARY OF THE VALUE OF LOAD CONTROL**

Source of Economic Value	Levelised Value per year 2018/19 to 2022/23 $m/year		Qualifications
	Conservative	Maximum Potential	
Private Benefit			
Two-hour load shift for the controllable load that can serve network support services	$7.2	$8.3	Assume contracted transfer from peak to off-peak pricing using the forward price for peak and flat profile contracts. Two-hour storage based on typical thermal characteristics of buildings and electricity battery storage. Higher value based on half the rate of value decline of base case.
Market Participation			
Network support to reduce expected unserved energy where it is cheaper than network augmentation	$4.0	$7.3	Assumes network projects proceed and that transfers occur before microgrid resources are called upon.
Ancillary services in Victoria for generation raise and lower, contingency and regulation services	$7.4	$15.4	Up to 260 MW of service available in Victoria allocated to the most profitable locations for microgrid services. Assume 130 MW for conservative case.
Voltage control to defer capacity banks	$0.2	$0.3	Where the microgrid capacity is large enough to defer some capacitor banks, either for replacement or new assets. Higher value based on doubling the value.
Mix of Private & Public Benefit			
Cost savings due to load shifting from peak to off-peak periods	$3.5	$4.5	Indicative only based on a load shift of 373 MW from 84.3% to 90% percentile load to 44.3% to 50% load for two hours on every work-day using electricity contract prices. Higher value using half the contract price decline from 2018/19.
Total value $m/year	$22.3	$35.8	
Conflict between services $m/year	$1.3	$3.8	Conflict between network support and ancillary services reduces the total value by the amount shown.

The levelised value of $22 m/year in 2018 dollar terms was assessed as a conservative estimate of the gross economic value that is available in this period. It assumes that sufficient load could be aggregated by appropriately placed microgrids with sophisticated controls at the magnitude needed to supply the range of services canvassed. The value requires 373 MW or load control which suggests that about 1 GW of load or about 11 % of Victorian distribution peak demand would need to be covered to achieve this gross value. The calculation does not have regard to costs or the minimum feasible scale for microgrid services, which has not been assessed.

The share of the value available to microgrids depends on a favourable combination of the necessary control set to achieve the benefits, the minimum required scale to access the opportunity, and the location of the microgrid. It is worth noting that:

- Not all services are required at all locations or equally valued at all locations (Appendix 6.4, Table 13 and Table 14).
- Some of the local values dependent on providing network support are not sustained for long periods as efficient network projects are imminent.
- Not all locations are likely to be able to support a microgrid of the scale and sophistication required. Appendix 6.4 discusses some of the aggregate service scale assumptions underlying the calculation of the total achievable value.
- There has been no attempt to eliminate sites where the quantum of service may be too small to viably deliver through microgrid technology.
- The revenue streams are broadly proportional to the amount of load control that the microgrid can offer. Some revenue streams such as reducing expected unserved energy rise more exponentially with the amount of load control. Ancillary services would be roughly proportional to load control capacity.

The following sources of economic value of microgrid control were not quantified:

- Any public benefits, including the extra emission abatement achieved because enhanced control reduces barriers to connection of solar PV resources. This would require analysis of hosting limits for connection of solar PV and the impact of distributed voltage control.
- The scope to synchronise emergency power plants that currently only run in island mode. It is considered that existing plants are costly to connect and do not offer net economic value.
- Potential markets for under-frequency and emergency load shedding schemes
- The value of resiliency if microgrids can island and continue to provide essential services when the local power system is blacked out under extreme conditions or multiple outages[9].

The value could be higher if:

- The items above that were not included could be quantified and added;
- Network projects were deferred due to strong offerings from providers of demand side services, or due to lower growth extending the period when network projects cost more than the value of expected unserved energy without them proceeding. Deferral of network projects could add $3.3 m/year over the assessment period which is included in the higher estimate;
- More detailed assessment showed higher value in loss savings from load control in more remote locations;
- Closure of synchronous power plant reduced the availability and increased the value of ancillary services;
- Constraints on hosting of solar PV power in distribution networks start to be realised, requiring additional distributed voltage control; and
- Alternative assumptions are made about the market conditions are considered as discussed in Appendix 6.4.

The levelised value could be lower if two hours of load shifting of 373 MVA could not be realised in practice. The other value components have minimal downside uncertainty. In most of the favourable locations, the ancillary services value is the main source of value as shown in Appendix 6.4, Table 13 and Table 14.

This analysis of the value of microgrid operations was limited by the five year outlook in the Distribution Annual Planning Reviews (DAPR). This outlook period is not long enough to assess the value of investment in microgrid technology which has a 5 to 15 year life cycle. To support microgrid investment, the DAPRs will need to be enhanced to provide a longer-term view of the value of control of distributed energy resources to reduce energy at risk and defer network investment, up to 10 years to match the corresponding review of transmission planning.

4. How can the investor be sure of the long-term value of microgrid control when network planning at distribution level is based on a five year outlook?
5. How can the distributors be required or incentivised to provide a longer term view of the value of distributed energy resources to support investment planning?

9. Islanding remote grids to reduce bushfire risk from power lines could create an economic benefit. It is however very difficult to quantify and would be site specific. It does not represent a commercial value stream under current market rules, unless NSP provides a revenue source to match its reduced risk. Permanent islanding could enable lines to be decommissioned.

2. The Role of Microgrids and Microgrid Operators

2.1 The Microgrid Operator

A *microgrid electricity market operator* or *microgrid operator* as a new participant in the electricity market provides an important opportunity to lay the groundwork for well thought through approaches to the evaluation of specific opportunities, as well as the merits/benefits and costs of the required policy and rule changes.

The microgrid operator:

- provides a customer centric, single interface to the broader wholesale energy market. It allows the local internal energy resources to interact to reduce total energy costs at the local level and successfully compete with external alternative sources of energy and ancillary services to lower costs in wholesale markets.
- is intended to access the value streams available in wholesale markets for actions resulting from control of local generation and energy storage capacity and the control and shifting of load from high price to low price periods. Value streams are also available from controlling voltage and power flows in the local distribution network and at the transmission connection point.

The range of services a microgrid operator could provide includes:

- Operating the microgrid control system (installation, operation, analytics, maintenance), managing supply and demand of electricity
- Managing the embedded network power quality and resilience
- Billing, electricity procurement and customer services
- Accessing revenue streams on the customer's behalf through participation in demand response and ancillary services markets

The microgrid operator may participate directly or indirectly (i.e. through third parties) with the energy markets operated by the Australian Energy Market Operator (AEMO).

2.2 The Microgrid Ecosystem

FIGURE 2. **PARTICIPANTS AND RELATIONSHIPS IN MICROGRID OPERATIONS**

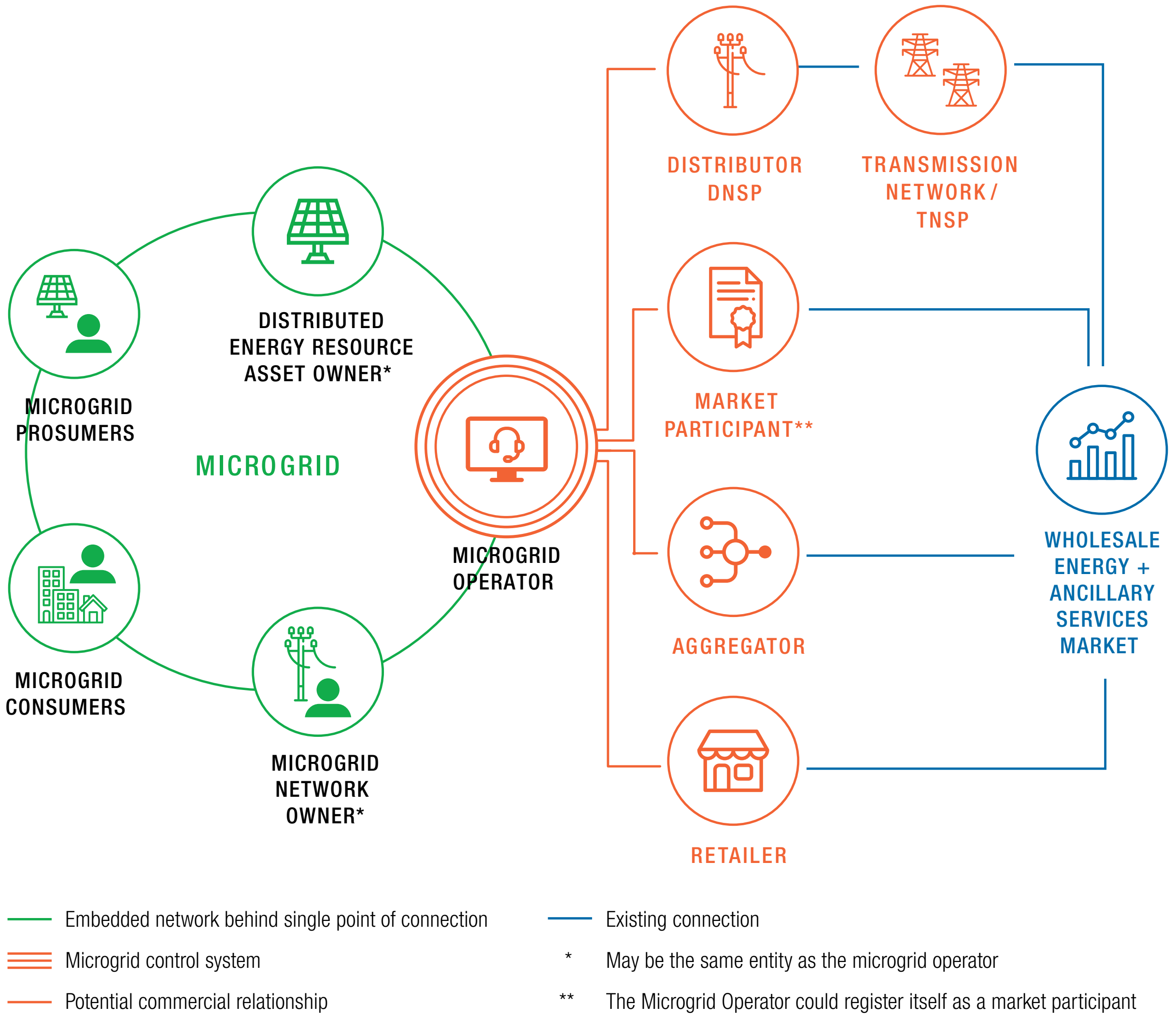


Figure 2 shows a diagram of the participants and relationships anticipated in microgrid operations.

Microgrid participants and stakeholders include:

- **Consumers** – may or may not participate in service provision through demand side management (DSM)
- **Prosumers** (generate some electricity) – will seek to maximise advantage of their distributed energy resource including storage and DSM
- **Microgrid asset owner** (DER and Internal network owner) – will seek to maximise return on assets and manage any internal constraints
- **External network owner** (connection points) – will seek to optimise utilisation of the external network and may seek network support services to manage peak power flows and voltage variation
- **Wholesale energy/ancillary services market** – energy and ancillary service trading, currently restricted to retailers (energy) and Market Participants
- **Wholesale traders** (hedging energy price) – sale of hedge products to manage spot price risk that cannot be limited by control of local load and generation
- **Retailers** – sale of electricity to customers (billing, customer service)
- **Regulators**
  - AEMC (wholesale market rules influence the role of prosumers in the market)
  - AER (network revenue regulation – influences the investment incentives for networks and the allowed revenues and hence network service prices)
  - Essential Services Commission (State jurisdiction for licencing and regulation of retailing)

6. Is the microgrid operator the retailer for the connected customers?
7. Are microgrid operator and retailer completely separate roles?
8. Can the microgrid operator and network owner be entirely distinct?
9. Can the microgrid operator and microgrid asset owner be entirely distinct?
10. Can a connected customer be a non-participant in microgrid operations? Will they be worse off if they don't participate?
11. How will regulations for microgrids be established and how will performance be monitored?

2.3 Value Proposition

The Microgrid Operator
• The Microgrid Operator intends to facilitate the transition to 100% renewable power, by providing value to network, market and customers, across multiple sites. • Its principal objective is to empower its customers to reduce energy costs, increase the efficiency of on-site DER, reduce emissions whilst maintaining a service standard equivalent to or better than that offered by the main grid. • The positive flow on effect to the microgrid customers, network and market will depend on the ability of the microgrid operator to access and stack the benefits of the value streams outlined in this paper.

Customers/Consumers/Prosumers	Network	Market

The microgrid operator would enable its 'Customers' to:
• **Have better control** and visibility over their distributed energy resources thanks the microgrid smart control technology.
• **Optimise the use of their renewable energy** assets to benefit from the transition to the low-carbon economy
• Participate in the energy market and gain financial benefits through the provision of progressive retail services, peak demand management and ancillary market participation.
In particular, the microgrid operator will enable its customers to:
• **Make electricity cost savings** thanks to:
  • the ability to shift load from higher to lower energy price periods;
  • the efficient management and optimisation of distributed storage and connected assets;
• **Access new revenue streams** through participation in ancillary markets not accessible by individual customers.
	Microgrid operators would benefit the networks and NSPs in providing:
	• **Visibility** over low the voltage networks and controllable loads
	• **Power quality** and **resilience** to the electricity grid
	• Help with network system **planning**.
	In particular, this would be achieved through:
	• Voltage control
	• Frequency control
	• Reduced energy losses through localised DERs
	• Capacity management through peak demand management and demand response, leading to deferred network investment.
		Value that Microgrid operators could bring to the Market could include:
		• Becoming a specialised Market Participant. Thanks to the aggregation of assets, market analytics and expertise, a microgrid operator would be able to participate in the energy market and bid into ancillary market services.
		• Addressing competition in providing demand response services. Monopolistic DER providers could get higher profits at the expense of customers and networks due to insufficient competition in tendering to provide network support. Promoting microgrid technology and an operator model would enhance demand response competition, likely leading to more efficient network support costs.

2.4 Key Considerations and Challenges to Accessing Value

A number of key features will be important in enabling the efficient integration of microgrids with the broader electricity system.

Microgrids will be most capable of contributing to electricity system stability and function if they are able to buy and sell energy on the wholesale market, rather than relying on a standard contract with a retailer. A number of factors contribute to this:

- Under current retail arrangements, the temporal value of providing energy and ancillary services to the market at a given time is invisible to customers, as it is packaged into a single bill with time averaged prices with other savings and costs. As a result, prosumers cannot access or see the full value of coordinating their distributed resources with the external electricity market. Linking microgrids with the wholesale market will enable customers to access this value.
- Microgrid access to the wholesale market may help to lower energy prices for all customers if sufficient scale can be reached. If the microgrid operator's controllable resources are able to be scheduled in the wholesale market either directly or through an aggregator, then it may contribute to influencing regional prices for energy and ancillary services. Because microgrids can efficiently provide energy and services, this may result in lower energy prices.
- Access to the wholesale market will also enable more efficient coordination of the microgrid resources in the energy market. Efficiency is greater with all material resources bid into the market because it enables more accurate pre-dispatch forecasting and results in a more secure operational plan.

Aggregation is another important feature required to enable microgrids to access value from the market and network. As distributed energy resources continue to increase in volume, the need for coordination of these resources on the wholesale market will increase. However, the National Energy Market Dispatch Engine will not practically be able to handle potentially millions of small bids. As a result, aggregation will be necessary for microgrid energy resources to participate in the wholesale market.

Aggregation also has a number of additional benefits for market function:

- Aggregation will assist in maintaining system stability. If a large amount of distributed resources (for example, batteries) respond in exactly the same way to spot electricity price changes without orchestration, this will result in problematic changes in the network power flow conditions. This will become more important in the future as user equipment is internet enabled and distributed control systems are rolled out for microgrid operation.
- Aggregation will coordinate microgrids' distributed energy resources, grouping sufficient capacity to respond to market contingencies and help defer network development. In isolation, single microgrids are unlikely to provide enough capacity to support these functions. Aggregation would enable microgrids to access these value streams.

Changes to the function and governance of distribution networks may also be required for the integration of microgrids in the electricity market. The role of the DSO may need to be created to integrate the contribution of distributed energy resources to managing localised network conditions. This would also enable greater transparency about the value of services that can help to defer network asset investment.

Determining the value of these services is an important element for a prospective microgrid operator in deciding whether to undertake new ventures, however, this value is currently difficult to calculate, and requires extensive contract negotiations with distributors. One option for addressing this issue would be to establish a DSO to provide greater transparency about the value of network services. Alternatively (or in addition), a system could be established whereby microgrid operators could apply for a contracted service for network support, or receive revenue on a spot basis at the Value of Customer Reliability[10] for the network support they provide through load and local generation control to the extent that it reduces emergency load shedding. Whatever system is set up to enable greater transparency would also need to promote competition in providing network services, to ensure that these services are provided at an efficient cost. In addition, distributors may need to upgrade their operations to enable the assessment of bids for network support at 5 minute intervals at the medium voltage feeder if network support were to be provided on a spot trading basis.

Since the provision of network support for network contingencies is rarely utilised because of the generally high reliability of network assets[11] and infrequency of extreme peak demand, a contracted form of network support would be preferred to support confidence in service provision and stability of benefit cashflows to microgrids in return for their investment in providing control services.

10. The Value of Customer Reliability is assessed by AEMO for various classes of customers (residential, industrial, commercial, agricultural) and is weighted by the customer mix at various network locations for the purposes of valuing energy at risk and assessing the value of network upgrades. This index could be used to directly value controlled load changes which avert or reduce emergency load shedding after a network contingency without requiring a formal network support agreement.

11. For example, substation transformers are regarded as about 99.8% reliable when in serviceable condition.

12. How will microgrid operations be linked to distribution, transmission and energy market operations in a seamless efficient manner?
13. How will AEMO get the visibility it needs of all the downstream resources and control actions, those coordinated by aggregation and bidding and those that only response to perceptions of current and future prices?

14. As more and more distributed energy resources potentially become internet enabled and responsive to wholesale market conditions in order to minimise consumer costs, there is greater potential for system instability with rapid changes in wholesale demand that cannot be forecast. Can microgrid operations be the solution to managing this risk and securing small consumers’ access to the value stack?

15. Is there any evidence that the cost of network support is provided at a price that is closely matched to the avoided network expansion cost and value of expected unserved energy? Does this indicate lack of competition in the provision of demand side services or merely that the industry is immature and that costs are inherently high with existing industry development? Could promotion of microgrid operations help the industry down the cost learning curve and deliver lower DER control service costs and prices through increased competition?

16. If microgrid operations lead to a more efficient dispatch of distributed resources, how can the microgrid operator and its customers access that value if the wholesale market responsibility remains with the retailer?
17. Do retailers, microgrid operators and customers need to make some agreement to make this work?
18. Do any regulations prevent such contracting?
19. Are there any implications for vulnerable consumer protection?

3. Policy and Regulatory Context

3.1 Definition

Microgrids are an emerging technology that provide services to customers that are not generally available from existing industry participants. As a result, there is a high degree of uncertainty about the policy and regulatory context in which microgrids are developing. In order to frame later discussion of the policy and regulatory contexts for microgrids (sections 3.2 and 3.3), this section sets out a proposed definition of a microgrid 'base case' and its core components.

There is no definition of a microgrid and its key components in Victorian legislation or regulation (including the National Electricity Rules). This is in itself a barrier to the development of microgrids, due to a lack of clarity about how electricity sector laws and regulations apply. For the purposes of this paper, a working definition of a microgrid is given in Section 1.2.

A microgrid will also be taken to have the following core components ('base case'):

- a site with a private distribution network ('embedded network');
- one or more sources of electricity generation connected to the embedded network ('embedded generation');
- On-site electricity storage ('battery storage');
- Supply of electricity to multiple third-parties ('supply');
- A dynamic supply and demand control system ('control system');
- A single connection point to the distribution system ('connection point'); and
- A third party microgrid system operator ('microgrid operator').

3.2 Policy Context

The ways in which microgrids are expected to interact with the existing electricity supply system will influence whether there is a need for change to existing policies. There are currently few, if any, specific policies that apply to microgrids.

Because the need for policy reform is still emerging, how microgrids are enabled and developed needs to be considered in the context of electricity policy more broadly. Electricity policy is currently driven by four main issues:

- the fact that electricity is an essential service (access);
- the performance of the electricity market (choice, affordability and reliability);
- the transformation of the electricity supply network (connection & network service); and
- carbon pollution reduction.

Consumers are impacted by all of these issues to varying degrees. Consumer protections have a strong presence in Victorian energy policy and laws. How these issues may frame the development of policy on microgrids is discussed below.

3.2.1 An Essential Service

Electricity supply has long been regarded as an essential service. However, technology development means that access to electricity is becoming even more important for social and economic participation. Today, electricity is essential for people to access information, communicate, work, study and carry out a wide range of everyday transactions.

Being essential implies indispensability, and the delivery of benefits to wider society beyond the value of the service to individual customers. Policy therefore recognises that there are consequences or harm that can arise from disruption to supply. Disruption may have social and economic impacts on individuals, businesses and communities.

Electricity supply is essential, whether it is provided through local or network supply. In Victoria, it is expected that all electricity customers, including microgrid customers, will have equal access to consumer protections to maintain access to supply.

In Victoria, there are particularly strong protections around disconnection for non-payment of electricity bills, with disconnection being a measure of last resort. The ability for a customer to choose who supplies them with electricity is also seen as an important consumer protection. Any policy on microgrids could be expected to require microgrid owners and operators to meet minimum standards of consumer protection.

3.2.2 Electricity Market Performance

Most electricity customers choose where they obtain their electricity from. Domestic and small business customers can choose their electricity supplier by participating in the electricity retail market. However, recent inquiries have highlighted major issues in the performance of this market[12]. These issues include:

- the failure of competition to constrain market power;
- the proliferation of largely undifferentiated offers and opaque pricing;
- inadequate or overly complex customer information;
- excess profits generated from high margin products;
- consumer penalties for not meeting conditions on discounts; and
- conflicts of interest of intermediaries.

These issues are shaping current policy development and can be expected to strongly influence policy on microgrids. There is increasing recognition that at a fundamental level when a service is indispensable, market discipline is weakened because consumers generally cannot exit the market if they are dissatisfied with the service.

Policy on microgrids can therefore be expected to focus on the degree to which microgrid services to its customers are transparent, ensure access to consumer protections and facilitate or limit competition.

12. See, e.g., Australian Competition and Consumer Commission, *Restoring electricity affordability & Australia's competitive advantage*, (2018); Patricia Faulkner, Terry Mulder and John Thwaites, Independent Review into the Electricity and Gas Retail Markets in Victoria (2017).

To the extent that microgrid supply is cheaper than the alternative (100% network supply without the benefit of the microgrid's control services) consumers will benefit. However, this may not be the case if customers cannot opt out of microgrid supply (without penalty) and access the alternative of network supply. Key policy issues for the design and operation of microgrids therefore include:

- whether microgrids should be required to facilitate customer choice
- whether microgrids should be required to provide third party access to embedded networks, and if so at what cost?
- whether microgrids should be subject to price regulation.

In order to deliver cheaper and cleaner electricity, microgrids combine local and network electricity supply with demand response, and potentially access to revenues from wholesale and network services markets. Value is therefore created through shared enterprise involving the microgrid owner, operator and customer.

Key policy issues for the authorisation and governance of microgrids may include:

- the status and authorisation of the microgrid system owner or operator

- the appropriate form of legal and contractual relationships between the parties

- the rights of microgrid customers

3.2.3 Network Transformation

It is increasingly recognised that the electricity supply network must evolve to accommodate different and more distributed forms of electricity supply.[13]

The development of microgrids presents a number of policy issues related to network transformation, including:

- a right to connect;
- the value of network services; and
- capturing the value of reductions in network losses and wholesale electricity prices.

A Right to Connect

Distribution network service providers ('DNSPs') have obligations to maintain supply within particular technical parameters. Connecting distributed electricity resources to the network can impact on network performance.

Current policy enables DNSPs to charge individual connection applicants for a range of connection costs. DNSP's are also able to place significant conditions on the connection. These costs and conditions vary according to the capacity of the network at the particular connection point.

Conditions on connection may include prohibition of the export of electricity, or restrictions on export of electricity at particular times. Such conditions may have a significant impact on the financial viability of a microgrid.

The benefits of distributed electricity resources in general and microgrids in particular are currently constrained by policies that place significant technical and financial constraints on the development of microgrids. There may be a need to consider whether microgrids should have a right to connect on more standard terms and conditions.

13. Energy Networks Australia, CSIRO, *Electricity Network Transformation Roadmap: Final Report* April 2017.

The Value of Network Services

Microgrids can provide a range of network services to assist with the control of frequency, voltage and current at both a local and system wide-level.

However, existing policies that promote non-network solutions for managing network performance are not well suited to most microgrid proponents. This is due to a number of factors including:

- the scale of operation of a microgrid;
- different investment timeframes for microgrids and network planning;
- the absence of information on the value of local voltage control; and
- a lack of transparency in the evaluation of non-network solutions by DNSPs.

One proposal that has been examined to address these issues is the establishment of an independent Distribution System Operator ('DSO') that manages distribution network performance in real time (See Section 1.1). A DSO could act as the external customer for the network support services offered by microgrids. A commitment to the establishment of a DSO would be a major policy reform.

However, absent such a reform, it is highly uncertain how microgrid proponents will be able to capture a fair share of the value of microgrids to the operation of the network. Currently the only accepted mechanism is a network support contract with the Network Service Provider (NSP) which commits the support provider to control distributed energy resources as the request of the NSP usually in anticipation of or after a network contingency.

The Value of Reduced Network Losses and Wholesale Prices

Microgrids can create a range of positive externalities. Two of the most significant are:

- reductions in network losses, which results in lower electricity costs for all consumers (refer to 6.1.3); and
- downward pressure on wholesale prices (refer to 6.1.4).

There is currently no mechanism by which investors in microgrids can capture a share of this public value. This may provide an economic barrier to efficient microgrid development. Accordingly, it is recommended that the scope for change in market design to provide suitable incentives to capture the benefits of loss reduction be investigated.

Victoria has strong policies that promote investment in local supply largely through the Victorian Government's renewable energy target and related programs. These programs may be funded in part on the basis of the benefits that flow to all Victorian consumers from various forms of distributed energy resource through reduced electricity costs.

3.2.4 Carbon Pollution Reduction

The development of microgrids may accelerate investments that reduce carbon pollution. This may occur in two ways:

- facilitating energy efficiency;
- promoting more efficient investment in renewable energy.

Facilitating Energy Efficiency

It is likely that the control systems used by microgrids will provide access to data that will assist customers to identify ways to reduce their total electricity consumption.

Microgrids will also provide incentives for demand response. Although this may result in load shifting, it may also incentivise investment in energy efficiency measures. Customers may be incentivised to make investments to improve the thermal performance of their homes to reduce dependency on electricity at times of peak demand and high prices due to low solar and wind power production.

Victoria has strong policies and programs that promote energy efficiency that take into account the value of carbon pollution reduction. These programs would be available to customers of microgrids.

Efficient Investment in Renewable Energy

One of the unique selling points for microgrids is the fact that customers of the microgrid can share in local supply. A significant proportion of this local supply will come from renewable electricity in particular solar PV.

Microgrids can therefore facilitate more efficient investment in renewable electricity through economies of scale and location. In other words, it may be possible to locate generation at particular sites within the microgrid more efficiently than for example deploying PV on individual customer premises.

Victoria has also strong policies and programs that promote renewable electricity generation that take into account the value of carbon pollution reduction. These programs would also be available to customers of microgrids, and may significantly reduce the capital cost of establishing local supply within the microgrid.

3.3 Regulatory Context

There is no specific laws or regulation that apply to microgrids as a whole in Victoria. Rather, the separate activities that are involved in microgrid operation are individually regulated.

The base case outlined in 3.1, shows that the operation of a microgrid, as contemplated in this White Paper, involves the generation, storage, distribution, supply and sale of electricity. These activities are prohibited in Victoria under the *Electricity Industry Act 2000* (EIA) unless the person undertaking the activities is licensed or exempt from the requirement to hold a licence.

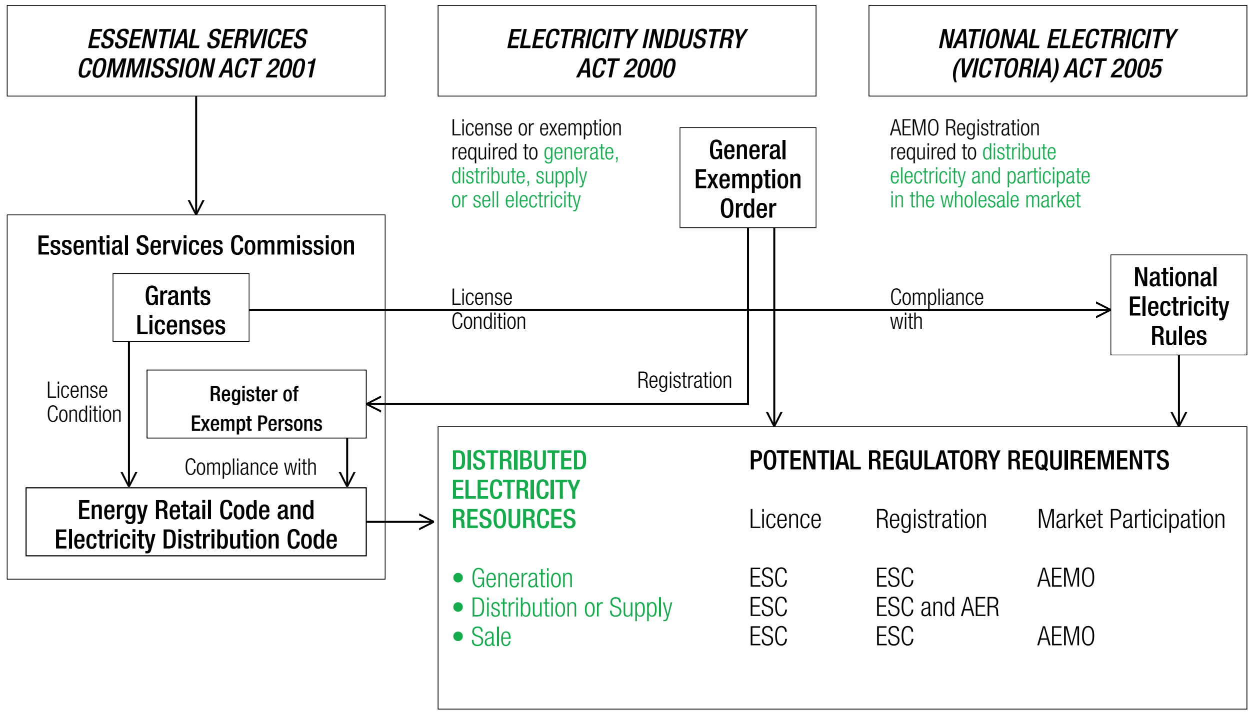
Because microgrids are connected to the distribution network, and may participate in the wholesale electricity market, microgrids also need to comply with the *National Electricity Victoria Act 2005* (NEVA) as a condition of their licence(s) or exemption(s). Compliance with the NEVA, requires compliance with relevant National Electricity Rules (NER). Guidelines on how these rules apply are issued by the Australian Energy Market Operator (AEMO) and the Australian Energy Regulator (AER).

This section provides an overview of the current law and regulation as it applies to microgrid operation in Victoria. It aims to provide context for the discussion in Chapter 4 about how these laws and regulations impact on the different value streams.

3.3.1 Current Law in Victoria

Figure 3 below illustrates broadly how the current law in Victoria authorises and regulates electricity supply activities, including local supply in Victoria. Three main pieces of legislation are involved, the *Essential Services Commission Act 2000* ('ESCA'), the EIA and the NEVA.[14] It also illustrates some of the key interactions between these laws.

FIGURE 3: **OVERVIEW OF THE AUTHORISATION AND REGULATION OF DISTRIBUTED ELECTRICITY SUPPLY IN VICTORIA**



Essential Services Commission Act 2001

In broad terms, the ESCA establishes the Essential Services Commission ('ESC') as both the rule maker and regulator of the energy sector in Victoria.[15] The objective of the ESC in regulating the electricity industry is to promote the long-term interests of Victorian consumers having regard to the price, quality and reliability of electricity supply.[16] The ESC's functions include those conferred on it by the EIA.[17]

Of particular relevance to microgrids is the power to issue licenses,[18] and the obligation to maintain a register of people who are exempt from the requirement to hold a licence.[19] Other relevant powers and functions conferred on the ESC by the EIA are discussed below.

As part of Victoria's commitment to participation in the National Electricity Market ('NEM') a range of the ESCs powers, particularly those relating to the economic regulation of the network are exercised by the AER, under the NEVA.

Electricity Industry Act 2000

The EIA establishes the prohibition on electricity supply in Victoria without a licence or exemption.[20] It places a range of obligations on licence holders through deemed licence conditions, and empowers the Governor in Council to make Orders in Council exempting a person from the requirement to hold a licence.

14. Note: the Energy Safe Victoria Act 2005 also applies to the operation of micro-grids.
15. Importantly the ESC's powers and functions are wider than those of the AER which does not have a rule making function.
16.Section 8 ESCA.
17. Section 10(a) ESCA
18. Section 19(1) EIA
19. Division 3A EIA.
20. Section 16(1) EIA.

3.3.2 Licensing

The EIA empowers the ESC to grant licences on a range of conditions. There are two types of licence condition – those that are deemed by the EIA itself ('deemed conditions'), and others that are determined by the ESC.[21]

Deemed licence conditions of particular relevance to microgrids, include:

- the obligation to participate in a customer dispute resolution scheme approved by the ESC;[22]
- the obligation on electricity retailers to set and offer feed in tariffs ('FiT'), on prices, terms and conditions set by the ESC.[23]

Victoria has not adopted the National Energy Consumer Framework ('NECF'). Instead, licence conditions set by the ESC regulate the supply and sale of electricity to customers. Of particular importance are the licence conditions that require compliance with the Energy Retail Code ('ERC') and the Electricity Distribution Code ('EDC').

The ERC has been harmonised with the NECF, however it also includes a range of additional consumer protections and obligations on licensees, in particular protections relating to wrongful disconnections and payment difficulties.

The ERC and EDC are made by the ESC and are amended from time to time. Breaches of provisions of these codes by a licence holder are subject to the ESC's enforcement powers.[24]

Relevant provisions of the ERC and EDC also apply to exempt persons.

Exemptions

General exemptions from the requirement to hold a licence are set out in a General Exemption Order ('GEO')[25] The GEO defines two types of exemption; deemed, and registerable. A registerable exemption is subject to the person being registered in the Register of Exempt Persons under the Act.

Exemptions are available from the need to hold a licence to generate, distribute and sell electricity subject to a range of conditions. Of particular importance are general conditions that:

- require compliance with relevant provisions of the ERC and EDC as specified by the ESC; and
- require participation in an approved dispute resolution scheme.

Each activity for which an exemption is granted is also subject to a range of particular conditions. Some of the more important conditions are discussed further in 3.3.3.

National Electricity Victoria Act 2005

The NEVA sets out the law, regulations and rules that relate to the operation of the national electricity market and electricity supply network in Victoria.[26]

The owner or operator of a generator connected to the distribution system must be registered with the AEMO, or be exempt from the requirement to do so.[27] Similarly, a person involved in the distribution of electricity to third parties must be registered with AEMO or be exempt from the requirement to do so.[28] A person who wants to participate in the wholesale electricity market, either as a buyer[29] or seller[30] of electricity must be registered as a market participant with AEMO.

21. Section 20(2) EIA: a licence is subject to such conditions as are decided by the Commission
22. The ESC has approved the Energy and Water Ombudsman Victoria ('EWOV') as a dispute resolution scheme under Section 28 EIA.
23. Part 2, Division 5A EIA.
24. The ESC's enforcement powers are set out in Divisions 1 and 2 of Part 7 of the ESCA.
25. General Exemption Order 2017, made under section 17 EIA, published in the Victorian Government Gazette No. S 390 on 15 November 2017.
26. Part 2 NEVA.
27. Clause 2.2.1 National Electricity Rules ('NER').
28. Clause 2.5.1 NER.
29. Clause 2.3.1 NER
30. Clause 2.2.4 NER

3.3.3 Application of the Law and Regulations to Microgrids

Within the regulatory framework outlined above, the extent to which regulatory issues arise will vary according to the type of aggregated electricity systems sought to be introduced. As such, regulatory challenges may be of little concern, as is the case with simple embedded networks. On the other hand, as the proposed system becomes more complex in its characteristics and involving a broader number of participants, regulatory complexity can also increase.

Whilst this needs to be analysed on a case-by-case basis, several common issues arise in respect of the regulation of distributed electricity in Victoria depending on:

- the location and scale of activity;
- who is being supplied;
- whether electricity is exported; and
- if electricity is to be bought and sold in the wholesale market.

Location and Scale of Activity

Generally, exemptions are granted for smaller scale electricity supply activities that occur with a single site. For example, a standing exemption from registration with AEMO is provided for a generation unit under 5MW.[31] A deemed exemption from the requirement to hold a retail licence in Victoria is granted to anyone re-selling electricity to less than 10 customers on a single site.[32] However, as the scale and complexity of distributed electricity supply increases, the availability of exemptions reduces and/or the conditions on the exemptions increase.

When a microgrid includes distributed electricity assets that are located at a number of different sites, a retail licence would be required to trade electricity between the sites. Whilst the grant of such a licence will always be subject to the decision maker, and therefore cannot be automatically assumed, it is worth noting that the ESC has previously granted a limited retail licence for a Virtual Power Plant ('VPP') with 20 customers across different sites.[33]

Who is Using the Electricity

Conditions on exemptions are particularly linked to who is using the electricity, and the perceived need for consumer protections. Electricity generated, distributed and used by the same person in a location may be exempt from most if not all licence and registration requirements. For example, unless electricity is being distributed or supplied to a third party, there is no need to hold a distribution licence or to be registered or exempt by AEMO. Another example is the deemed exemption from holding a retail licence available if a person is supplying to a related company.[34] However, because electricity is an essential service, once electricity is being supplied to third parties and particularly small business and domestic customers, regulatory requirements increase. For example, compliance with particular requirements of the Energy Retail Code is a condition on a registered retail exemption,[35] and there is a maximum price that a person holding the exemption can charge its customers.[36] The policy drivers behind these obligations are to ensure all domestic customers can choose their retailer, have access to dispute resolution through the Energy and Water Ombudsman Victoria (EWOV), and protections such as payments for wrongful disconnection and assistance in the event of payment difficulties.

31. Section 2.3a) AEMO Guide to Generator Exemptions and Classification of Generating Units.
32. Section 4(2), GEO.
33. *https://www.esc.vic.gov.au/sites/default/files/documents/Onsite%20Energy%20Solutions%20-%20Licence%20Variation%20-%2023%20January%202019_0.pdf*
34. Clause 4 Electricity Industry Act 2000, General Exemption Order 2017 Order in Council ('GEO').
35. Clause 8 GEO.
36. Clause 8 GEO.

Exporting Electricity

What regulation applies also depends on whether electricity is exported and to whom the electricity is sold.

Electricity generation behind the meter at a connection point will typically be used to offset demand at that connection point. However, if electricity generated exceeds demand within the site and is exported, a condition of the generation exemption is that the total exported output must be sold to a licensed retailer.[37] Different regulations apply if the distributed generator or microgrid wants to buy and sell electricity in the wholesale market.

Buying and Selling Electricity in the Wholesale Market

If the owners or operators of distributed electricity resources want to buy and sell electricity in the wholesale market, there are a range of ways this can be achieved. As an example, distributed generation can be sold through small generation aggregator ('SGA') who can register with AEMO provided each individual generation unit is not more than 30MW, has its own connection point and is exempt from registration.[38] An SGA can be deemed to be an agent of a retailer,[39] meeting the condition for an exemption from holding a generation licence, that the total export is sold to a retailer. Most owners or operators of distributed electricity resources will meet the balance of their demand for electricity through a standard retail contact. However, a microgrid operator may want to be the single interface with the electricity market, in which case it would need to become a Market Customer and potentially hold a retail licence.

37. Clause 14 GEO.
38. Clause 2.3A.1 NER
39. Clause 5.A.A.3 NER

4. Regulatory Challenges: Value Streams, Microgrid Participants, and the Microgrid Operator

Against the regulatory context set out in Chapter 3, this part of the discussion turns to the applicability and adequacy of the existing regime to emergent microgrid systems and services, and the role of a dedicated *Microgrid Electricity Market Operator (MEMO) or microgrid operator.* Regulatory issues and value streams are also considered. This preliminary regulatory discussion in this White Paper is predicated upon the following matters:

- Do the current regulations adequately provide for microgrid services to be delivered?
- To what extent do the current regulations adequately provide for the recognition of new entities – a dedicated microgrid operator?
- To what extent does the capture of the value streams identified in this paper turn on matters of policy, market design, and/or the existing regulatory framework?

4.1 Regulatory Challenges and Reforms: Overview

4.1.1 Distinguishing Between Microgrids, Other Supply and/or Sale Models and Emergent Technologies

At the outset, it is important to draw attention to the character and functionality of microgrids. As explained earlier in Section 1.2, the type of microgrid considered in this White Paper – and the subject of the MEMO project - is indicative of emergent sophisticated, complex DER models of electricity supply and sale that include local demand and supply. These are not the same as existing, readily recognised and relatively simple, types of embedded networks and distributed generation. Microgrids are not, for example, generation aggregators across the distribution network such as a VPP, or an enhanced form of an embedded network that merely incorporates PV rooftop solar and/or battery storage.

The challenges presented by these new forms of electricity supply and sale are no longer just a question of regulating one directional flow of electricity with linear transactions from generation – through the wholesale and retail markets - to end-user. Microgrids and other new technologies being deployed across the AEM are changing this in two key ways. Firstly, as rooftop solar PV installation continues to rise, local generation embedded behind the meter is increasingly flowing back into the national grid and the markets. Secondly, as more sophisticated technologies are developed and introduce into the existing system, localised transactional markets can develop, which entail a multi-directional form of electricity supply and sale outside the currently recognised two-way flow noted above.

In the regulatory context, the distinction between microgrids and other supply and/or sale models is critical. It reveals several key regulatory challenges, to both the Victorian and national regulatory regimes. Importantly, this distinction highlights that existing electricity laws, regulations and rules are not fit for purpose. Current regulatory regimes - both nationally and in Victoria - are not designed for complex DER and local demand and supply and present challenges across a range of other technologies. For example, in Victoria, there is no specific licence/exemption regime that is directly applicable to microgrids of the kind contemplated in this White Paper. Rather, seeking to regulate complex DER models of electricity supply and sale – such as microgrids - in Victoria requires detailed consideration of a composite set of regulatory obligations on an ad hoc, case by case basis. Matters are further complicated at the national level. For instance, the complex supply and sale of the kind that characterise the microgrids examined in this White Paper are not contemplated by the current consideration of embedded networks' regulations.

4.1.2 Where to from Here: Future Regulatory Reforms

It is becoming increasingly apparent that emergent technologies and complex DER models of supply and sale - such as those which characterise microgrids of the kind discussed in this paper - present a considerable challenge to the current regulatory framework. Generally, these emergent "behind the meter" complexities raise questions about the adequacy of existing regulations, and the problematic approach of simply seeking to make the regulatory regime "fit" situations that were not envisaged at the time of their making. More specifically current regulations for both the wholesale and retail markets – Victorian and national - are no longer fit for purpose in the current climate of rapid technological change and development of more sophisticated systems of electricity supply and sale. Addressing this increasingly problematic situation involve two distinct, yet related, reform pathways:

1 Long term, comprehensive regulatory reform at national and individual jurisdictional levels; and

2 Short term reforms involving a restricted form of regulatory development that focuses specifically on microgrids of the kind under consideration in this paper.

Long Term, Wholesale Regulatory Reform

Undoubtedly, at some point, regulatory reform will be required across-the-board, to ensure the future sustainability of the electricity sector, not only in terms of ensuing a safe, reliable and secure system/network, but also in providing the supply of affordable, reliable and secure electricity to consumers. At the broadest level, this would entail a wholesale review of the current regulations. This may well be the best outcome in the long run – especially as it will avoid the poorly or unregulated proliferation of uncoordinated small scale changes across the entire Australian electricity sector. However, such a major undertaking will require extensive research, analysis, negotiation, and consultation with all stakeholders across all of the AEM's participatory jurisdictions. By its very nature, this will be a lengthy and time-consuming process, in which agreed regulatory solutions will not be forthcoming immediately.

In the meantime new technologies and DER models of electricity supply and sale – including microgrids - will continue to be developed and adopted, especially in circumstances where there are strong values streams that maybe captured by interested parties. In consequence, the potential for ad hoc, poorly regulated developments to occur across the entire sector is considerable. This raises questions as to what, if anything, can be done in the meantime to minimise the emergent regulatory chaos surrounding the growth in emergent technologies and DER models for electricity supply and/or sale.

Short Term Reform: Specific Microgrid Regulation

In addressing this issue, it is suggested that the approach to ensuring these new developments are adequately regulated – for the overriding purpose of securing affordable, safe, and reliable electricity supply to energy consumers – might take a different pathway in the short term.

This would involve specific attention being given to the regulatory challenges presented by microgrids of the kind considered in this paper, e.g., emergent complex DER models for electricity supply and/or sale. Specifically, microgrids could be used as a "test case" with regards to suitable regulation of innovative DER models of supply and sale. Once the regulatory framework is settled for complex supply and sale systems and networks such as microgrids, it could then be applied – with or without minimal adaption/modification depending on the final regulatory form and scope - to the various individual components/technologies that form part of a microgrid, e.g., a VPP that is aggregating generation for supply into the NEM, or an enhanced embedded network that comprises, for instance, a singularly owned, large embedded network with sizeable battery storage and no retail function.

The benefits of pursuing such an approach in the immediate future include:

- Focusing on one new approach to supply and sale is immediately manageable;
- Providing provide greater clarity and certainty to market participants, regulators, investors, prosumers, and consumers engaged in microgrid activities; and
- Delivering an important feedback mechanism on regulatory successes and failures within a constrained context, which provides important lessons for the wider transformation of the sector and guidance for future comprehensive regulatory reform.

This report presents initial recommendations, however there may be further regulatory amendments required to enable the full potential of microgrids to be realised. This project will continue to investigate these and make further recommendations in its final report.

4.1.3 A Suitable Starting Point: Defining a Microgrid for Short and Long Term Reform

Section 4.2 below focuses on the creation of a statutory definition for a microgrid and the benefits of creating regulatory terminology consistency and clarity. Before turning to that discussion, it is important to point out that taking this kind of action will most likely reduce, rather than increase, regulatory complexity.

It is, at first instance, tempting to assume that creating a statutory definition for a microgrid would be simply complicating the existing regulatory framework by adding yet another layer of regulatory decision making and compliance. However, this paper recommends that defining microgrids will not only provide greater clarity and certainty to policy makers, regulators, market participants, prosumers, and consumers, but will also act as a regulatory "test case" for ascertaining the extent to which a wholesale reform of the sector's regulatory framework is both required and what its nature and scope ought to be.

As suggested in this paper, it is clear that, when it comes to emergent complex supply and sale systems/networks - such as those which characterise sophisticated microgrids of the kind considered in this paper - the existing regulations are not fit for purpose. At best, what can be said is that the existing regulatory framework – which was created for an entirely different type of supply and sale – can be applied sector wide, in a piecemeal, inconsistent manner. Such an outcome will only lead to greater confusion, uncertainty, and potentially unreliability across the entire system.

Consumer protections have already been the subject of ongoing review and development in Victoria, and more recently at the national level. Victoria's advanced consumer protections must be safeguarded in any future regulatory framework. As such, it is critical that any proposed developments at the national level, such rule change proposals under consideration by the AEMC, do not hamper the full operative protections afforded to Victorian electricity consumers. Focusing on microgrid regulation in the short term can help focus on addressing consumer protection specific issues as they arise, and also ensure than any beneficial regulatory changes identified are transferred to other situations.

4.2 Regulatory Terminology Clarification

4.2.1 Definition of the Purpose and Functions of a Microgrid

Unlike readily recognised situations, such as simple embedded networks or small scale residential roof top solar PV systems, a microgrid of the kind envisaged in the MEMO project, and discussed in this White Paper, brings together a range of functions: electricity generation and storage, distribution (into, out of, and within the microgrid), and sale (between microgrid prosumers and consumers, the microgrid and another Victorian entity (licenced/registered retailer or VPPA), and/or the microgrid and the wholesale market).

As the discussion in this White Paper demonstrates, microgrid regulation in Victoria is a composite of the regulations that apply to each of the various individual functions. Accordingly, in combination the existing regulatory framework presents barriers for the successful advancement of microgrids in three key ways:

(i) Complexity;

(ii) Uncertainty of interpretation - particularly the interaction of functions; and

(iii) Prohibition/restriction of value creation.

Defining the functions of a microgrid is possible, but will not overcome these barriers unless the regulations for individual functions are modified. As such, rather than adding an additional layer of regulatory compliance complexity, the utility of a regulatory definition - in respect of overcoming barriers to microgrids present in the existing Victorian regulatory framework for electricity supply and sale - warrants further consideration. In general, establishing a regulatory definition, setting out the purpose and functions of a microgrid, would facilitate and streamline the regulatory requirements of authorisation and/or exemption. It would also provide greater clarity for the industry and regulators, and safeguard existing consumer protections.

Victorian law – and laws elsewhere in Australia – is replete with statutory definitions that are neither strictly prescriptive nor exhaustive in nature and scope. Thus, at a minimum, a regulatory definition of a microgrid must be flexible enough to respond to ongoing changes and developments. It must also ensure that Victoria's existing consumer protections are supported. Accordingly, in respect of the regulatory requirements of authorisation and/or exemption, a non-exhaustive, non-prescriptive definition of a microgrid could be developed, which defines a system for managing the electricity supply and demand of customers connected to a smart embedded network, in a way that integrates local supply, network supply and electricity exported to the grid. It should also ensure that microgrid consumers are extended the same protections afforded to Victorian energy consumers.

Consequently, in addition to recognising existing Victorian consumer protections, such a definition should include, for example, the following elements:

> **Microgrid** means a system for managing the electricity supply and demand of customers connected to an embedded network, in a way that integrates local supply, network supply and electricity exported to the grid.
>
> **Embedded network** has the same meaning used by the AEMC in its draft report on the proposed regulatory framework for embedded networks.
>
> **Local supply** means electricity generated or stored within a microgrid and supplied to customers connected to the embedded network.
>
> **Network supply** means electricity supplied through the connection point to the embedded network.
>
> **Connection point** has the same meaning as in Chapter 10 of the National Electricity Rules.
>
> **Consumer protections** have the same meaning as in the existing Victorian energy regulatory regime.

4.2.2 Co-regulation of Microgrids

Victoria needs to ensure that proposed rule changes (see 4.3 below) that aim to promote the potential for retail competition within embedded networks, do not prevent the value of microgrids being realised.

Light touch regulation of embedded networks has clearly failed. Potentially hundreds of thousands of customers have not been afforded adequate consumer protections and are paying an excessive cost for their electricity. Victoria has taken steps to address these problems as outlined in 4.3 below.

By contrast, microgrids are by design providing end users with services not available from existing market participants. This value provides a policy basis for recognising microgrids specifically within the regulatory framework. However, the development of microgrids must proceed on the basis that end users are not disadvantaged. An opportunity therefore exists for a model of co-regulation.

If a MEMO is established as a corporation (Pty Ltd or Ltd by Guarantee), it will operate according to its constitution in compliance with relevant laws, rules and regulations.

A model constitution for MEMO could be developed in consultation with regulators and stakeholders, setting out its purpose, membership and governance, including the rights and entitlements of end users

The GEO and the NER could then be amended so that a MEMO operating in accordance with the model constitution, would be deemed to be exempt from:

a) holding a licence (ESC);

b) registration with AEMO; and

c) meeting particular conditions of exemption that are a barrier to microgrid operation/viability.

4.3 Regulating Microgrid Participants: Prosumers and the Microgrid Operator

There may be merit in considering a specific scheme of regulation for microgrids that recognises the full range of value that microgrids deliver. This could be in the form of specific exemptions or a specific licence. However, as outlined in section 3.2, there are policy reasons for customers of microgrids being afforded the same or similar protections and opportunities to participate in the retail market.

These policy drivers are reflected in the AEMC recent report *Updating the regulatory frameworks for embedded networks* (31 January 2019). The report proposes significant changes to the regulatory approach to embedded networks which may add to the regulatory complexity and the associated costs, as well as potentially ruling out the sale of local supply to other participants in the microgrid. (See AEMC rule changes section p52-53 for more information).

While we would not foresee regulation of supply behind the connection point to be expected within AEMO jurisdiction, there is a need to ensure these rule changes do not hinder the development of microgrids in Victoria.

The application of regulation to microgrid value streams has been considered in relation to four activities:

- Supply and/or sale *into* the microgrid – Retail energy market and microgrid interactions;
- Supply and/or sale of electricity *from* the microgrid:
    a. to another entity, e.g., VPP aggregator; or
    b. *into* the NEM
- Supply and/or sale *within* the microgrid – intra-microgrid participants' interactions; and
- Introduction and role/activities of a new participant – dedicated microgrid operator.

General regulatory matters arising in these identified contexts are set out in the following Tables under the heading of Table 3, and further developed in Section 4.2.

AEMC Rule Changes

The AEMC has been active in considering a range of potential rule changes that aim to balance the need to facilitate innovation in the electricity sector, with the need to protect consumers. Three areas of work are of particular relevance:

- Wholesale demand response mechanisms
- Embedded network regulation
- Stand-alone power systems

The potential relevance of each of these work streams to microgrids is summarised below.

Wholesale Demand Response

The AEMC has received a number of rule change proposals that aim to facilitate wholesale demand response. The AEMC is consulting on a range of potential mechanisms that 'facilitate wholesale demand response, at least cost, without undermining the market'.[40]

As outlined in this paper, demand response delivers a range of potential benefits to a number of different parties. The design of a wholesale demand response mechanism will have a significant effect on who captures the value from wholesale demand response.

The development of an efficient and accessible wholesale demand response mechanism could be an important source of revenue for microgrids. It will therefore be important that the design expressly includes microgrid operators as one of the likely participants. This white paper envisages microgrids and microgrid operators to be designed to ensure that end users are fairly compensated for the services they provide. Ensuring that access to any mechanism adopted is independently facilitated, will be critical to overcome the information asymmetries and imbalance of negotiating power currently faced by microgrids when negotiating with a DNSP.

40. AEMC Slides from Wholesale Demand Response Workshop – Melbourne 5 March 2019.

Embedded Network Regulation

The AEMC has proposed a series of rule changes to both the National Electricity Law (NEL) and the National Electricity Retail Law (NERL) regarding embedded networks. These rule changes are driven primarily by concerns about barriers to customers in embedded networks accessing retail market competition, including additional costs faced by retailers in supplying these customers.

Because a microgrid can be based on an embedded network, and embedded networks must be registered with AEMO (or exempt from the requirement to do so), some of these proposed rule changes will apply to microgrids in Victoria. A number of the proposed rule changes will undermine the viability of microgrids.

The effect of the proposed embedded network rule changes is to make an embedded network customer effectively the same as a standard customer connected to the grid. This will impose significant additional costs on embedded networks, and therefore microgrid operators.

The AEMC's rule change proposal is based on its finding that the existing regulatory framework in the NEL and NERL is no longer fit for purpose. However, Victoria has its own regulatory framework which was comprehensively reviewed, and recently amended. The new regulations ensure that important consumer protections, including access to the Energy and Water Ombudsman of Victoria (EWOV) and key provisions of the Energy Retail Code (ERC) are extended to embedded network customers (and therefore microgrid end users).

Victoria is also proposing to introduce a Victorian Default Offer, to replace the current Standing Offer. The VDO will set a regulated limit on the price embedded network customers can be charged for their electricity. This will provide strong protections for embedded network customers.

The AEMC has concluded that consumer protections should be driven by the needs of consumers. Importantly, microgrids provide services to end users that are not provided by standard embedded networks. In particular, microgrids enable end users to obtain additional value from DER and demand management is not being offered by existing market participants. It is therefore critical that the distinction between an 'embedded network' and a 'microgrid' is recognised in any rule changes, to ensure that the viability of microgrids is not undermined.

Standalone Power Systems

The AEMC is currently looking to develop a national framework for the supply of electricity from stand-alone power systems, including third parties.

Two aspects of this work are relevant, at least in principle, to the development of microgrids as contemplated by this paper.[41] The first is that it is considering the basic standard of consumer protections that should apply to all consumers of electricity as an essential service. The second relates to whether stand-alone power system operators should be required to provide third party access to their network.

The stand-alone market is not the primary target for the development of microgrids as outlined in this paper. However, it will be important to ensure that any regulation that emerges from this work, do not flow on to microgrids in a way that weaken existing Victorian protections or undermine their viability.

41. It should be noted that the AEMC has adopted a significantly different definition of a microgrid to the concept outlined in this paper. The AEMC considers a microgrid to be a stand-alone system, while the concept of a microgrid contemplated in this paper is assumed to be captured by its definition of an embedded network.

TABLE 3: **ANALYSIS OF REGULATORY ISSUES AND QUESTIONS**

SUPPLY AND/OR SALE OF ELECTRICITY INTO THE MICROGRID		
Activity/Services		**Regulatory Issue/s**
Distribution	• Supply of electricity though the microgrid's privately owned embedded network to the microgrid's end-users; and • Facilitated by the embedded network owner/operator (ENO) through single parent connection point (connection agreement with DNSP).	**Does the microgrid's ENO have a licence to engage in distribution activities or fall within recognised exemption class (size, number end-users etc dependent)?** Electricity Industry Act 2000, ss 16 & 17; Victorian General Exemption Order 2017 (GEO 17): Distribution: Part 2, Div 2, ss 6 & 7, Tables 3 & 4; Subject to 'exemption conditions': Part 2, Div 3, which include Vic Distribution Code.
Retail	Sale of electricity – on-selling - by the ENO to the microgrid's end-users. NOTE: end-users can now – theoretically – buy electricity from any licenced (authorised) Retailer. Problem for end-user – need energy only contract with Retailer to avoid paying network charges twice. **Potential regulatory problem:** if relevant value stream depends on end-users *only* buying electricity from the microgrid's ENO (on-seller) then current regulations do not permit this constraint on consumers' retail decisions. **Recommendation:** Seek qualification on exemption to the effect that microgrid end-users obliged to buy from microgrid ENO?	**Does the microgrid's ENO have a licence or fall within recognised exemption class relevant to on-sellers (size, number end-users etc dependent)?** Electricity Industry Act 2000, ss 16 & 17; Victorian General Exemption Order 2017 (GEO 17): Part 1 (gen); Retail: Part 2, Div 1, ss 4 & 5, Table 1 & 2; Subject to 'exemption conditions': Part 2, Div 3 – which include Vic Energy Retail Code. NOTE: required now to: • be registered with EWOV; and • provide standard consumer protections to all end-users within the embedded network etc.
SUPPLY AND/OR SALE WITHIN THE MICROGRID		
Activity/Services		**Regulatory Issue/s**
Intra-microgrid activities –	Trading between microgrid participants; • Distribution; • Selling; and • Generation (small scale embedded and/or storage) for supply and sale (generators not required under NER for central dispatch).	**Only Distribution and/or sale:** Same as above – licence or exemption - activity/service dependent. **Embedded Generation (small scale) and/or Storage:** • Licence/exemption (Vic) – El Act 2000 as above; GEO 17, Part 3 – Generation: s 13, Table 5 (common connection point and less than 30MW); and • If neither of these – no common connection point or more than 30MW, then no exemption. If all three activities, then must satisfy the requirements of Multiple Activities exemption: GEO 17, Part 4. If unable to do so, then required to obtain a licence.
SUPPLY AND/OR SALE FROM THE MICROGRID		
Activity/Services		**Regulatory Issue/s**
To the NEM	Supply and sale of embedded distribution (generation and storage) to the NEM through the microgrid operator: • Via an external party – a VPPA in Victoria; or • Into the wholesale market.	Microgrid operator (or individual prosumers) require: • Licence or exemption (Victoria); AND/OR • Registration, authorisation or exemption (NEM).
DEDICATED MICROGRID OPERATOR		
Activity/Services		**Regulatory Issue/s**
Supply, Sale, Generation	From outside into the microgrid network through to end-users and/or from microgrid to the external markets (aggregator, VPP, DSO?) • peak demand reductions; • efficient management of distributed battery energy storage; and • enabling local electricity markets for disposition of local surplus generation.	In: ENO – licence or exemption - as per above; Prosumers Agent – generation licence or exemption - as per above Out: Licenced/Exempt (Vic Retail) and/or authorised or exempt (NEM) Policy question: If microgrid operator does not qualify for exemption – what action – new class or licence?
Other Activities	Other activities that the microgrid operator might engage in on behalf of the microgrid and its participants/stakeholders, e.g., providing local voltage control, distributed frequency control under extreme system conditions; disconnection of loads and connection of emergency generation under extreme system conditions; lower carbon emissions (secondary benefit).	Case by case basis depending on activity – system or service, internal or external to the microgrid.

4.4 Regulating Value Streams

The potential value streams from distributed electricity resources are outlined in Section 1.4 of this paper. This section examines how these value streams are regulated. All economic, social and environmental value in electricity supply is ultimately created by regulation.

Entry to the industry is controlled by regulation. Economic regulation of monopoly assets such as transmission and distribution aims to ensure that network asset owners do not make excess profits. Electricity retailers are required by regulation to invest in energy efficiency and renewable regulation to achieve social and environmental outcomes. Regulation sets the rules for the operation of wholesale markets and defines the consumer protections necessary for the supply of an essential service.

How value streams are regulated is therefore examined by looking at three primary sources of value:

- the value of distributed electricity supply behind the meter (connection point);
- the value of exported electricity in the wholesale market; and
- the value of exported electricity for the operation and management of the network.

There is a particular focus on how regulation determines who creates and who captures the value and how that applies to the Monash Microgrid as a test-case.

4.4.1 Regulation of Electricity Supply Behind the Meter

This sub-section examines the regulation of electricity supply behind the meter.

Regulation of behind the meter supply depends on two main factors. Firstly, whether electricity is being supplied by one party to another, and secondly whether electricity is being distributed across site boundaries.

4.4.2 Supplying Third Parties

As outlined above, self-supply behind a meter is largely unregulated. Self-supply involves the consumer of the electricity owning the electricity assets, including small scale generation units, electricity management and control systems and the wiring to buildings and other facilities.

If the Monash Microgrid is owned by the University and only supplies electricity to university departments, then it does not need to be licensed or registered provided there are no individual electricity generation units (including batteries) with a name plate capacity of greater than 5MW.

However, if the Monash Microgrid is intended to supply third parties with electricity, such as food and other services providers on campus, Monash University will need to register with both the ESC and AER to obtain exemptions from holding a licence and AEMO registration.

Monash University as the holder of exemptions would need to ensure that in operating its microgrid it complies with the relevant provisions of the Electricity Distribution Code (EDC), Energy Retail Code (ERC) and National Electricity Rules (NER).

Importantly, the Monash Microgrid can be operated by a third party, provided that third party does not own the electricity supply assets that make up the microgrid and operates them as the agent of the University. This is a common way in which embedded networks are currently managed in shopping centres, industrial parks and some apartment complexes.

However, if the microgrid is operated by a third party, such as MEMO and the electricity supply assets are owned by or leased to the operator, then the operator will need to seek the relevant exemptions from the ESC and AER. This is because the operator will be deemed to be supplying a third party (Monash University).

4.4.3 Supply Across Site Boundaries

The exemptions from holding a distribution licence in Victoria are limited to supply within a site owned, occupied or operated by the person distributing the electricity. In the case of the Monash Microgrid, Monash University would be able to claim the exemption. However, a MEMO would not.

If Monash University wanted to connect or extend the Monash Microgrid to another Monash University site that was not directly adjacent (by any means other than using the regulated distribution system), it would require a distribution licence. However, neither AEMO registration nor an exemption from registration would be required provided the supply was intended solely for Monash University's own use.

However, a microgrid generating and supplying electricity between sites in different ownerships, would not be entitled to an exemption from the requirement to hold a distribution (and retail) licence. This is because under the current exemption the sale of electricity generated on a site is restricted to the owner/occupier of the site or a licensed retailer. In other words, the exemption does not allow exported electricity from one site to be sold to another microgrid participant on another site.

4.5 Regulation of the Wholesale Market Value of Electricity

It is unnecessary for the purpose of this paper to describe the extensive regulation that applies to the operation of the wholesale electricity market. It is taken as a given that a participant in the wholesale market will be paid the spot price for any electricity that it supplies and will pay the spot price for any electricity purchased in the market.

The focus of this sub-section is on how participation in the market is regulated, and how that regulation applies to distributed energy resources in general and the Monash Microgrid in particular.

4.5.1 Sale of Exported Electricity

Any exports from un-licensed electricity generation must be sold to either a licensed retailer or a Small Generation Aggregator (SGA).

For electricity exported from premises with a photo-voltaic system (PV), retailers must pay the customer either a flat or time-varying minimum feed in tariff ('FiT') as determined by the ESC. Some retailers offer higher rates to some customers.

SGA's contract with owners of small generation units for exported electricity. An SGA may sell the electricity that it aggregates to a licensed retailer, or become a Market Participant in its own right and sell the electricity directly in the wholesale market.

Monash University could enter into a contract to sell any export of electricity from the Monash Microgrid to an existing SGA. However, SGA's are intermediaries and would not pay the full wholesale market price for the exports. Alternatively, Monash University could register itself as an SGA for any connection points where electricity is expected to be exported.

4.5.2 Purchase of Electricity

As outlined in above, owners of distributed electricity resources usually meet any demand that they cannot obtain from their own resources from a licensed retailer. However, microgrid owners may be able to manage their distributed electricity resources to minimise the risk of purchasing any net demand from the wholesale market.

Purchasing electricity in the wholesale market requires registration as a Market Customer with AEMO, and classification of some or all of its connection points as 'market loads'. A Market Customer must purchase all of its electricity demand at these connection points from the spot market.[42]

Direct participation in the wholesale market as a Market Customer may or may not require a retail license or exemption. If the Market Customer is participating in the market solely to meet their own needs, they can register with AEMO without a licence. However, if some of the electricity supply is to be sold to a third party, retail and distribution licences and/or exemptions will be required.

42. Clause 2.3.4(c) NER.

4.6 Regulation of the Network Value of Electricity

This sub-section looks how the value of distributed electricity resources in providing network services is regulated. It looks in particular at the regulation of value creation and how that value is shared between a microgrid owner and the network.

4.6.1 Value Creation

There are a range of costs and benefits of connecting DER to the network. These costs and benefits are highly dependent on location. In some areas of the network, connection of DER may require substantial investment in the network. In other areas connection may be possible with little or no need for a network upgrade. Connecting DER may also enable distribution service providers to defer capital expenditure and reduce network operating costs.

The potential network benefits of DER were the subject of an inquiry carried out by the ESC in 2017.[43] The inquiry found that the network value of DER varied by location, time and whether the output of the DER could be controlled. However, the inquiry also found that the value of network service was difficult to quantify, particularly below the sub-station level due to the lack of published information on network capacity and performance. Refer to *Appendix 6.4.3* for discussion of the missing data.

The inquiry noted the potential for an independent Distribution System Operator (DSO) who understands the needs of the network in real time and purchases the network services was needed to efficiently manage the system.

4.6.2 Regulation of Value – Network Level

At a network level, distribution businesses are required to apportion their expenditure between investment in traditional network upgrade projects and non-network solutions such as purchasing network services from third parties. It has been recognised that incentives for non-network solutions are inadequate and new incentives are expected to be introduced in 2021, along with market testing through a tender process.

However, decisions about non-network solutions will be made by the distribution service providers through the traditional network planning and procurement processes. These are not well suited to smaller scale distributed electricity resources that can deliver dynamic value to the network in real time.

In the absence of an independent DSO, the costs and benefits of a particular distributed electricity resource is determined by the distribution business. The capacity of a microgrid to obtain an on-going revenue stream from such a source is therefore highly uncertain and dependent on contract negotiations for a network support service which can be expensive to complete satisfactorily to all parties.

4.6.3 Regulation of Value – Microgrid Level

There is no specific regulation of how value created by a microgrid is shared between the owners/investors, the microgrid operator and customers.

It could be assumed that a customer of a microgrid receives the benefits of participation through lower electricity costs and potentially payments (or offsets) for demand side participation. However, depending on the ownership and objectives of the microgrid operator, the majority of value created by the microgrid may be captured by the owner and/or operator.

As outlined in section 3.3 these issues may be relevant to the status and authorisation of the microgrid system owner or operator. Microgrid customers are likely to be in a weak negotiating position relative to the microgrid operator. This may be overcome by information and disclosure obligations. It would also be overcome if microgrid customers were shareholders of the microgrid owner/operator.

The business model, including the ownership structure(s) for the microgrid operator are the subject of later stages in this project.

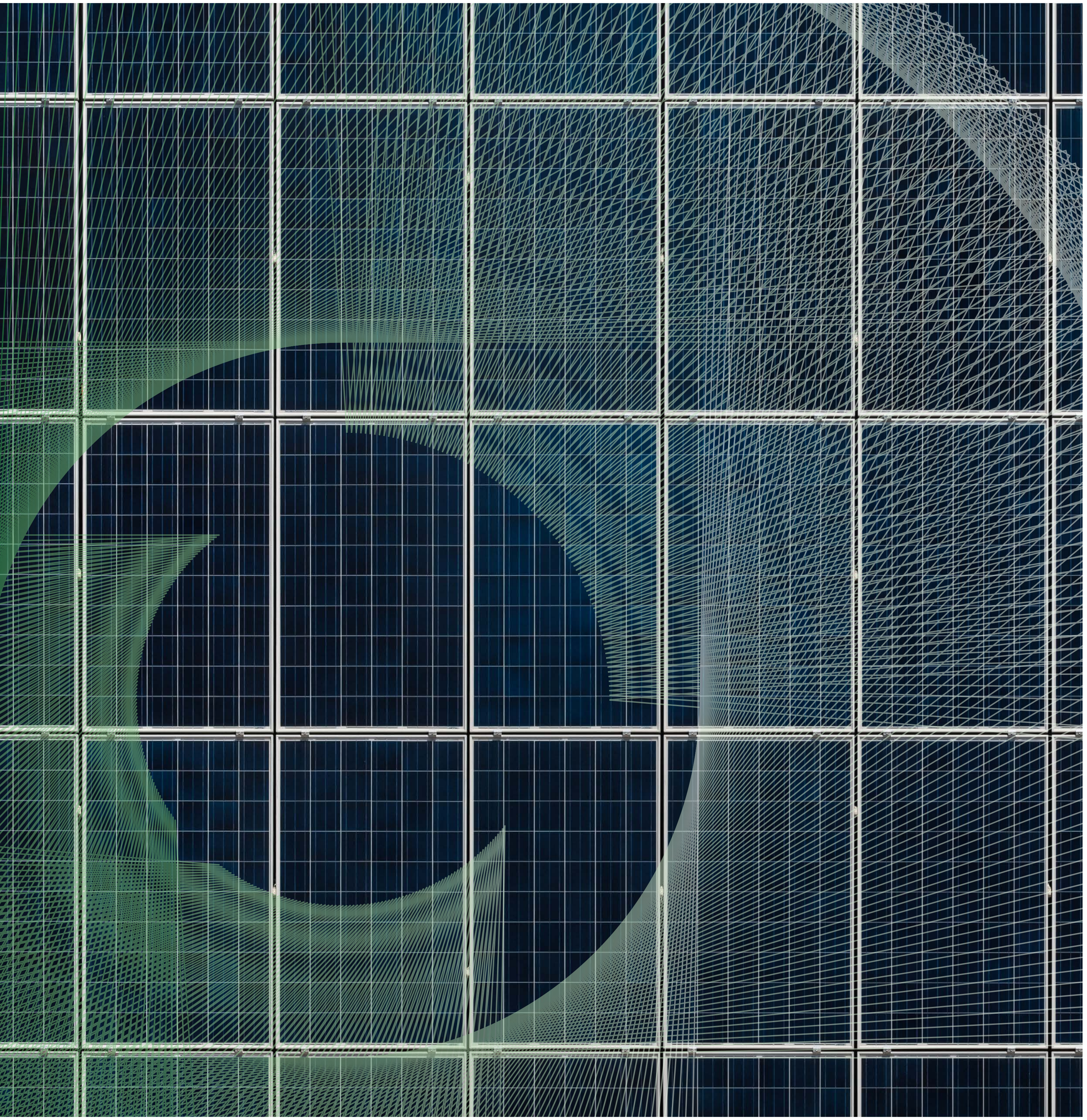
43. Essential Services Commission 2017, *The Network Value of Distributed Generation: Distributed Generation Inquiry Stage 2 Final Report, February 2017.*

4.7 Ensuring Value Streams: Regulatory and Related Issues

The establishment of a microgrid system and microgrid services gives rise to a range of questions that address the immediate indeterminate nature of such matters: policy, market design, and regulatory. This is shown in the following Table 4.

TABLE 4: **POLICY, MARKET DESIGN OR REGULATORY IMPACT?**

VALUE STREAM	ISSUE			COMMENT ON KEY ISSUE
	Policy	Market Design	Regulatory	
Peak demand management in the network (transmission and distribution)	?	✓	?	Information asymmetry limits adoption of load control for network support
Reduced energy losses due to lower power flow in the network	?	✓	?	There is no way for loss benefits to be captured under the current market design
Demand side response for network loading control following contingencies or under extreme load conditions	?	✓	?	Information asymmetry limits adoption of load control for network support
Local voltage control from distributed resources	?	✓	?	Need is an emerging issue for high DER penetration
Provision of frequency control services to the power system AS (ancillary services)	?	✓	✓	Distributed frequency control is yet to be developed as a service
Efficient management of distributed storage	?	✓	✓	Requires local control to maximise value
Under-frequency load shedding (UFLS) scheme to be integrated with MO and DSO.	✓	✓	?	Exposure to load shedding requires policy assessment
Connection and utilisation of emergency generation capacity	?	✓	?	Cost barriers for brownfield sites
Local disposition of surplus renewable energy (peer trading by displacement of retail volumes)	✓	✓	✓	Structure for local retailing would need to be adopted
Local disposition of surplus renewable energy (peer trading with a local electricity market)	✓	✓	?	Local market would need to be developed for MGO and DSO implementation
Lower carbon emissions from additional renewable energy	?	✓	?	Only requires voltage and power control to lift hosting capacity



5. The Development Opportunity for Victoria

If Victoria takes a pro-active role in facilitating the establishment of microgrid and distribution system operators, then the State will be better prepared for the decarbonisation of its electricity supply and the increasing penetration of renewable and distributed resources

Victoria can:

- Lead the nation in establishing the regulatory frameworks for establishing microgrid operation;
- Support research and development in the commercial mechanisms and information systems needed to support microgrid markets;
- Stimulate microgrid industry development and competition in demand side services that will ensure network support services can be expanded and delivered at an efficient price.

The efficient development of microgrid facilities could potentially lead to the following commercial/economic benefits:

- Lower power bills for microgrid consumers arising from more efficient asset utilisation and lower network service charges;
- Lower ancillary service charges due to greater participation in provision of voltage and frequency control by small customers who, in the absence of a microgrid would be unable to participate in the market;
- Improve network utilisation resulting in lower network service costs, as well as improved network performance and control offering wider community benefits;
- Lower wholesale energy prices because peak demand is minimised;
- Reduce incidence of negative spot prices and provide a more secure investment risk profile for renewable energy by diverting surplus renewable energy to thermal and electrical storage capacity; and
- Increase competitive pressure on retail margins because microgrid operators reduce risk for retailers in managing peak demands in their portfolios, and the control facilities reduce wholesale price volatility through stronger demand side participation in wholesale energy market.

6. Appendices

6.1 Appendix: Sources of Value

Microgrids provide multi-faceted value to a range of participants. The value of local control and trading of resources and the integration of variable renewable energy resources and storage is reflected in social, commercial and economic benefits which, although they may overlap, are distinct sources of value to be evaluated separately. The concept of a "benefit stack" has been applied to recognising that distributed resources can provide benefits for their owners either through use of distributed resources for their own needs or for selling services to the external electricity market such as exporting power or controlling local voltage and system frequency. Sometimes these opportunities are in conflict as discussed in this chapter.

6.1.1 Social, Commercial and Economic Benefits

Control of distributed energy resources provides social, commercial and economic values to participating consumers and asset owners. The following discussion of economic, commercial and social benefits is framed in the context of microgrid developments where investments yield more efficient use of energy resources deployed in the microgrid and may give rise to public benefits to other consumers outside the microgrid, as well as revenues to the microgrid for services provided to networks and the energy market.

Economic Benefit

The economic value generated or destroyed from a policy change, regulatory change or an investment decision is the sum of the impacts across all affected individuals or entities. The economic value is measured as the "economic surplus" of benefits over costs taken over the projected life of the invested assets.[44] It is a useful concept for measuring whether the decision is worth pursuing for the community as a whole and particularly relevant for guiding government policy that encourages efficient participation in commercial activities.

Calculating the expected impact on economic value can be challenging. For example, it is often difficult to estimate a future monetary benefit across multiple entities because it requires a quantitative representation of how those parties will interact and how it will affect their monetary position. Also, it might not be obvious how to quantify non-monetary benefits from a policy, and further, policy makers may value the benefits to one party more than another. All assessments of economic value for investment purposes are subject to forecast uncertainty, and therefore the risks need to be understood in each case. This section discusses the key concepts behind economic value and the prerequisites for commercialisation; that is the creation of a perceived commercial benefit.

44. Note: The fact that future payments are worth less than current payments is considered in the quantitative analysis of value based on a time discount rate equivalent to the cost of funding capital investment.

Commercial Benefit

The commercial benefit from a policy or investment decision is that which accrues to affected stakeholders. Commercial benefit is useful to measure to indicate whether affected stakeholders will support (or not oppose) a decision having economic value. In some cases, commercial benefit can arise without economic benefit if one party can convince another into a transaction that is favourable to the seller of services or where, for example, one party's competitive entry into a market displaces others or reduces prices for all participants.

The commercial benefit to the new entrants is in part a transfer from previous suppliers, some of whom may withdraw from the market and all of whom earn lower revenues. The addition of new providers to ancillary service markets, for example, in the absence of any growth in the demand for ancillary services is likely to result in falling payments for all providers of ancillary services to the benefit of customers as a whole. Customers' benefits, in this case, could exceed the commercial benefits accruing to the new entrant.

Not all commercial benefits can be measured with reference to the revenue accruing to affected stakeholders. Some benefits or additional costs may accrue to non-participants; for example, where the addition of a further party causes network constraints that adversely affect energy supply to other customers, the benefit to the newly connected party overstates the total economic benefit.

Finally, some potential commercial benefits may not result in payments to the provider because of regulation or convention. Some potential benefits to the network and energy markets that a microgrid could provide – services required only in the event of an emergency, for example – may not be remunerated because conventionally in the event of an emergency control of the electricity system passes from a market to the operator acting under its emergency powers. Markets, however, could provide some or all of the necessary services.

Social and Public Benefit

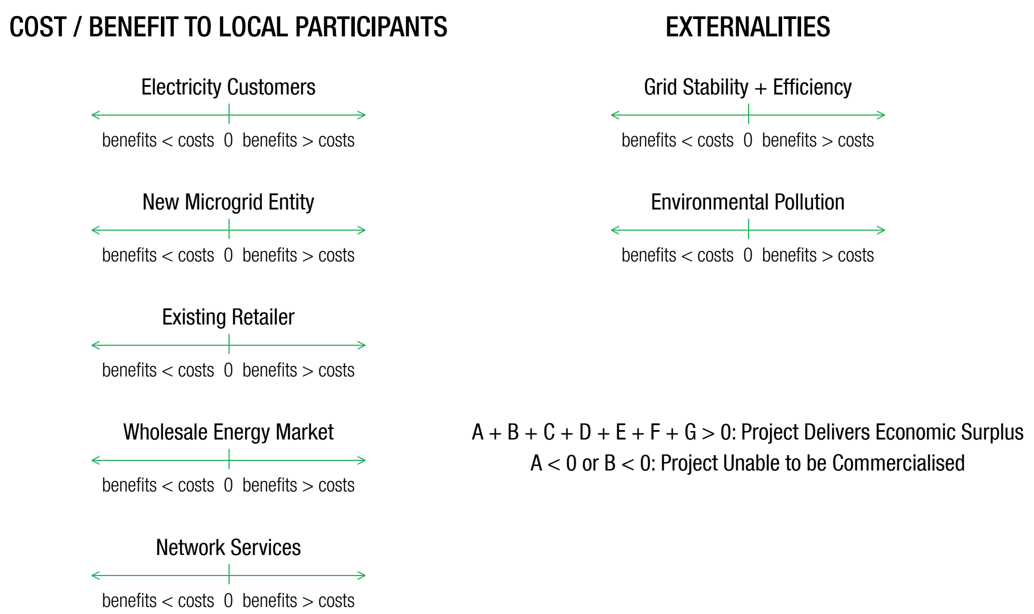
Social benefit refers to the wider benefits of a decision that accrue to non-participants; the benefits that may be understood conceptually but not be reflected in payments to the party providing the benefit. For example, greater confidence in the reliability of electricity supply may not be quantifiable but could influence other lifestyle and commercial activities that have economic value to the community. Reduction in carbon pollution has a social value that has been estimated (as discussed below in section 6.1.2.) but it may not be reflected in commercial benefits unless some form of pricing or constraint is applied to carbon pollution.

Public benefits is that class of benefits which result from the interaction of the technical characteristics of the microgrid and the connected networks. In bringing customers and assets together and managing their collective performance, a microgrid offers benefits for local networks and system operation relative to the status quo, where each of the connections and assets is managed individually. The benefits offered include better voltage control, better co-ordinated and controlled responses by the microgrid operator in response to energy and network emergencies, and a more predictable response by a larger integrated entity to market and system changes. These public benefits flow to energy market participants who are not involved in the microgrid either because they are connected but do not offer to contribute controlled load or they are connected outside the microgrid. Changes in network loss factors affecting microgrid non-participants are classified as public benefits.

Realising Economic Benefits as Commercial Benefits

Ideally, the commercial value to parties from a project arises from the changes in payments that arise between parties as investors seek to recover the costs of a beneficial decision from those who will benefit from the decision. For example, Figure 4 disaggregates the value generated from a potential microgrid development into the parts affecting local participants and non-participants. There will be some costs and benefits arising from changes in grid stability and efficiency that may not be fully reflected in prices to market participants; these are shown as Externalities in the diagram.

FIGURE 4: **COMPONENTS OF ECONOMIC BENEFIT**



First, consider the costs and benefits to electricity customers. It may be that they only care about their energy bills for a given consumption pattern, in which case measuring the costs and benefits would be determined by the net impact on their energy bill. However, they may also value less visible and quantifiable features such as the new lower probability of local blackouts or the changes in the timing of their consumption facilitated by the microgrid. Therefore, their total benefit (cost) is their willingness to pay to have the new microgrid installed (not installed). Similarly, the microgrid entity and the existing retailer will benefit by the amount their profits change from the new microgrid development. Further, non-participants may also be impacted by the broader effects on the wholesale markets. For example, to the extent that the microgrid results in a more efficient use of resources that others can benefit from (and any associated pollution consequences), outsiders may receive public benefits also and support the development.

However, a total economic surplus is neither necessary, nor sufficient for a project to take place. For a microgrid project to proceed, the decision-making entities must be convinced that there is a commercial benefit to the investing participants. If there is an economic surplus, transfer payments between the impacted entities could in principle be designed such that the project goes ahead because it makes all participating stakeholders better off financially.[45] For example, suppose only the local electricity customers and the new microgrid entity need to come to an agreement for a project to proceed. If the prices for microgrid services are too low, the microgrid operator will not enter the contract to provide services, and if too high, the electricity customers will reject the deal. Further, even if regulations allow the two groups to reach an agreement, then the customers' retailers may seek some share of the economic benefit. If the retailer has veto control over the microgrid transaction arrangements, then the economic benefit may be appropriated by the retailer or a favourable development inhibited through abuse of market power.

This paper considers all value streams a microgrid can potentially deliver, under the assumption that if an economic surplus can be generated, local participants can then negotiate contracts such that each party is better off and the project proceeds. It will further examine the regulatory environment and changes required such that projects that could deliver an economic surplus can more easily be made commercially viable.

45. A common way for pollution and other grid costs and benefits to aligned with decision maker incentives are to have market prices reflect the externalities (for example through carbon pricing or scarcity pricing).

In summary:

- Economic costs and benefits arise from the sum of all monetary transactions in a (microgrid) development
- A net economic benefit arises if benefits exceed costs over the lifetime of an investment assessed allowing for the cost of capital funding
- The distribution of commercial benefits among stakeholders depends on how transfer payments between parties are affected by the agreed energy service transaction arrangements
- The broader social and public benefits of microgrid development may be identified conceptually but are more difficult to quantify and are not normally captured by commercial arrangements.

6.1.2 Value of Carbon Reduction

A strong drive of Monash's Net Zero Initiative and Microgrid project is addressing the challenge of global warming. Ideally this would be easier if the harmful effects of carbon emission could be quantified and price per tonne of emission, but Australia's Labor Government initiative on carbon pricing did not achieve sustained political acceptance and was terminated by the Abbott Government in 2014.

Reducing carbon emissions by businesses and consumers provides:

- Social and economic value through the reduced exposure to the damage from severe weather, wild fires, sea level rise and other adverse effects of global warming too numerous to list here; and
- Commercial value from reduced exposure to insurance costs, climate related business risks, reduced carbon emission costs if carbon is priced or otherwise constrained.

The social value of reduction in carbon emissions ("the social cost of carbon") has been assessed by international organisations and recently discussed as shown in Table 5. Values range from US$10 to US$200/tCO2 with typical expected average and marginal values in the range $US40 to $US100/tCO2. These are high enough to warrant substantial reductions in CO2 emissions and to make it economic to do so if emissions were priced at these levels, particularly in electricity systems where the cost of abatement is already zero in some settings where oil and gas are the primary energy source. The prospect that eventually carbon emissions will be priced at these levels represents substantial "carbon risk" for most businesses and provides a strong incentive to decarbonise as soon and as much as is practical and affordable.

Accordingly, Monash University has seen fit to do its part to reduce its carbon emissions to zero by 2030 as both a social contribution and an academic pursuit to bring long-term benefits to society.

The commercial value of reduced carbon emissions through deployment of distributed renewable energy comes from reduced grid energy purchases if a carbon constraint is applied to inhibit fossil fuel consumption. If a carbon constraint is applied in the future, this may also increase delivered electricity price and enhance the value of controlling distributed energy resources. If there is no carbon pricing or constraint applied in energy markets, then the value of carbon emission reduction would remain an externality that could not yield direct commercial value. It could provide indirect commercial value from the reputational advantage of the microgrid participants contributing to reduced carbon emissions.

If microgrid operation increases the value of distributed energy resources based on storage and renewable solar/wind energy, then this can be expected to increase the rate of growth of decarbonisation due to consumer response. Control services may have an indirect leveraging effect on reducing carbon emissions by increasing the value of solar PV and battery storage to microgrid connected prosumers, thereby increasing global social benefits and commercial benefits to those prosumers. This can be regarded as a secondary behavioural effect of microgrid operations though accelerated investment in decarbonisation.

TABLE 5: **REFERENCES ON THE SOCIAL COST OF CARBON**

Source	Date	Basis	Value	Reference
National Bureau of Economic Research Robert S Pindyck	Nov 2016	Ratio of the average present value of damages from an extreme outcome to the total emission reduction needed to avert such an outcome. Probabilistic basis from a survey of expert opinions for the World.	US$80 - $100/t up to $200/t CO2 Value dominated by high impact low probability consequences	*http://web.mit.edu/rpindyck/www/Papers/SCCRevisitedNov2016.pdf*
Yale University William D Nordhaus	Nov 2016	Using DICE (Dynamic Integrated model of Climate and the Economy) for 2015 using 2016 data in US$2010 dollar prices to create a marginal value for the World	US$31/t CO2 up to US$200/t for low discount rate A marginal value at 2.5% discount rate	*https://www.pnas.org/content/pnas/114/7/1518.full.pdf*
Harward University Martin L Weitzman	Nov 2016	Discusses the concept of a World Climate Assembly voting to establish a world-wide minimum price for carbon	Discusses values from $10 to $100/t CO2 with typical values of $US40 and US$51/t CO2.	*https://www.belfercenter.org/sites/default/files/legacy/files/dp86_weitzman.pdf*

6.1.3 Value in the Electricity Network

The control of distributed resources has commercial and economic value in enabling power flows in the distribution and transmission network supplying a microgrid to be more closely operated to the capacity of the network having regard to the inherently variability of demand, and distributed renewable energy power sources and the consumer operated battery storage. If networks can be operated so that peak power flows are controlled within network capacity more precisely, then asset utilisation increases and investment in new assets may be deferred or avoided indefinitely. Reducing peak power flows also has the benefit of reducing total network energy losses in most situations which reduces the cost of delivered power.[46]

Variable renewable energy in low voltage networks at high penetration without suitable dynamic controls may result in degradation of power quality due to adverse voltage variation as power production varies. Reverse power flow back into medium voltage networks can cause excessive voltage if the network is not specifically designed for such power flow. This is a risk to the life of consumers' equipment; penetration of renewable energy connections may need to be limited until appropriate voltage controls are provided. Microgrid control contemplates the scope to coordinate inverters attached to prosumers' solar PV and battery facilities so that they contribute to local voltage control which enables the network to accommodate higher levels of renewable energy penetration into low and medium voltage networks.

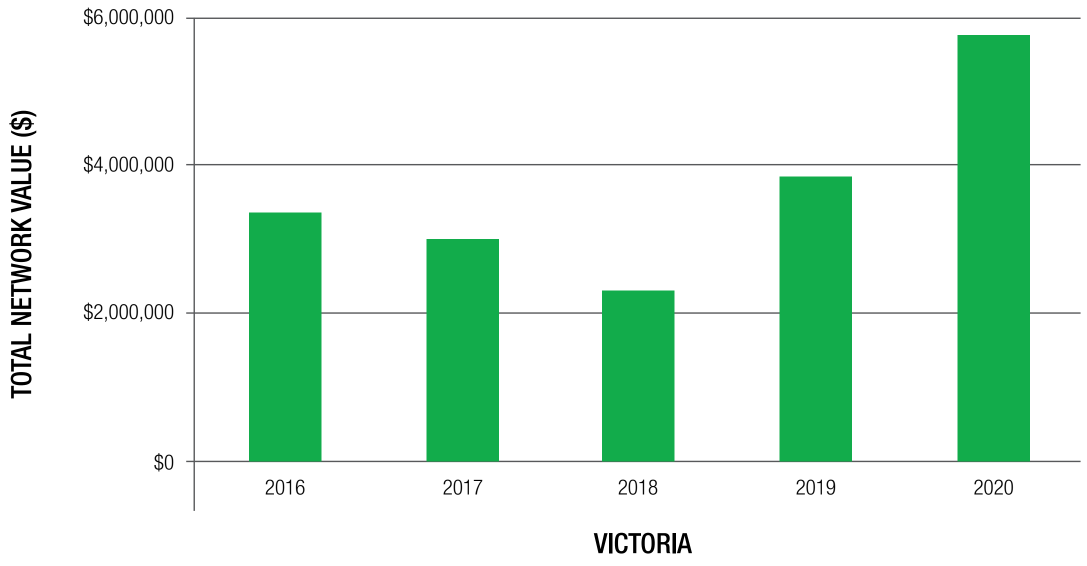
The value in the electricity network from microgrid control is primarily an economic benefit from reduced network investment, reduced constraint on penetration of distributed energy resources, and lower delivered electricity costs from reduced network power losses. This economic benefit may become a commercial benefit to consumers by the following mechanisms:

1. Reduced network investment reduces the revenue requirement of the network owner and for a given level of service should reduce network service prices and costs for consumers;
2. Reduced penetration constraints enable more prosumers to adopt distributed energy resources that lowers their total energy costs; and
3. Reduced network losses reduce the assessed Distribution Loss Factors (DLF) and Marginal Transmission Loss Factors (MLF) and the cost of purchased energy.

The Essential Services Commission in 2016-17 investigated the network value of distributed generation in Victoria on a counterfactual basis. As shown in Figure 5, which is taken from the ESC report of February 2017, the aggregate value of distributed solar PV generation in Victoria under the current regulatory regime is between $3 million and up to $6 million per year by 2020 in 2016 dollar values. This assessment assumed that network investments have been deferred where possible due to the contribution of solar PV in reducing peak power flows in substations and sub-transmission networks. The Report highlighted the absence of a market for network services at the distribution level whereby prosumers with distributed storage and controllable generation facilities could provide services to local networks to manage peak demand with such confidence that network owners could rely on those controlled resources to optimise the timing of network developments to reduce overall network costs.

46. Reducing peak power flow reduces energy losses because power losses are proportional to the square of the electrical current, so the % loss increase with the magnitude of the power flow. Losses are minimised by running a network at constant power flow which would be assisted with the wide deployment of distributed energy storage. This is not currently economic everywhere due to the relative cost of battery storage and network capacity. It is economic to deploy storage where a large network augmentation can be avoided by a modest amount of battery storage capacity to ride through short-term power peaks.

FIGURE 5. **NETWORK VALUE OF DISTRIBUTED GENERATION IN VICTORIA (SOURCE: FIGURE 4.13 OF "THE NETWORK VALUE OF DISTRIBUTED GENERATION" FEBRUARY 2017, ESSENTIAL SERVICES COMMISSION)**



Data Source: Jacobs

There was additional value from schedulable distributed generation although the value for Victoria was only shown as a unit value by zone substation and not in aggregate. These values ranged from zero to $178/kW/year according to the level of network constraint in recent years.

In principle, if microgrid operation can schedule resources to reduce network peak power flows then substantial benefits can be realised. The benefits will increase over time as Victoria grows, electricity consumption grows, and the existing network would otherwise require augmentation. Appendix 6.4 provides an estimated aggregate value for network power control based on Distribution and Transmission Planning Reports for each MW of load reduction at each Terminal Station. This analysis helps to identify where microgrids would have the greatest near-term value in Victoria.

6.1.4 Value for Displacing Wholesale Electricity Production

The energy market value of microgrid operation arises through its impact on the wholesale production and marginal price of electricity. Distributed energy generation is typically based on solar PV or small-scale wind power which have near zero marginal cost of production. From the prosumer's perspective, distributed energy production displaces retail power purchases and is operated without regard to the external market except in circumstances where distributed generation production is constrained. Currently installed inverters for small scale solar PV curtail power production upon sensing high voltage at the inverter or during network outages, but these curtailments are automated and not subject to customers' or centralised control.

Commercial benefits are realised by prosumers in the form of reduced purchase of power at retail prices and the revenue received for electricity exports to the electricity grid, and by customers more broadly as wholesale electricity prices fall in response to increasing distributed generation capacity. Exports are priced either on a retail offer or the regulated minimum feed-in tariff set by the ESC in Victoria.

Grid connected intensive microgrid systems can contribute economic value in the production of electricity through:

- More efficient dispatch of thermal and energy storage resources to reduce energy costs;
- more efficient use of variable energy resources and local storage where available;
- Providing frequency response (ancillary services); and
- Greater system resilience from stronger resource coordination.

Microgrid control enables purchases from and sales to the national electricity market by microgrid participants in response to price variation in the wholesale energy and ancillary service markets, through the co-ordination and control of local consumption and generation and, particularly, storage. Purchases can be shifted to periods of lower prices, reducing power generation costs. Surplus local energy can be stored and exported at times of higher prices. If the microgrid facilities can respond to system frequency changes, then ancillary services can be provided to support frequency control in the external power system. With appropriate bidding and control facilities, total economic costs can be reduced.

Commercial benefits arise to microgrid participants from these services through lower energy purchase costs, higher export revenues, and revenues from providing ancillary services. Some commercial benefits can be appropriated through provision of specific services (such as ancillary services for frequency control) and some will be socialised to the extent that wholesale prices and network losses provide benefits to consumers generally.

To the extent that microgrid operations are widely adopted throughout the electricity system, they may result in lower electricity prices overall by displacing a substantial quantity of higher cost services. This provides a commercial benefit to the electricity market more generally. As the volume of large scale surplus renewable energy grows during periods of high solar power production coincident with low demand, and under high wind conditions across large regions of the NEM, storage will be more valuable because wholesale prices will be zero or even negative during such periods.

The commercial value to microgrid participants depends on energy trading arrangements within the microgrid and the external electricity market, regulatory conditions, the participant's willingness to invest and their willingness/ability to respond to market conditions. The commercial value is possibly more uncertain than the economic value of microgrid development. Prosumers and prospective microgrid operators can be expected to require persuasion that these new arrangements are in their best interests and that they can appropriate value sufficient to exceed their investment costs.

46. Reducing peak power flow reduces energy losses because power losses are proportional to the square of the electrical current, so the % loss increase with the magnitude of the power flow. Losses are minimised by running a network at constant power flow which would be assisted with the wide deployment of distributed energy storage. This is not currently economic everywhere due to the relative cost of battery storage and network capacity. It is economic to deploy storage where a large network augmentation can be avoided by a modest amount of battery storage capacity to ride through short-term power peaks.

6.1.5 Value in the Use of Electricity

The increasing penetration of variable renewable energy generation has increased the focus on load control, so called "demand-side management". In the new world of high penetration of renewable energy, marginal demand is expected to follow supply when in surplus or deficit as much as supply follows demand in the current paradigm. This is enabled by technologies that provide:

- Pre-cooling and pre-heating buildings, shifting energy into a heat storage bank (rocks or ice) and then releasing the heat or absorbing heat into the cold bank as needed for the buildings comfort;
- Load shifting from high price to low price periods including;
    a. Off-peak power purchase for hot water and under-floor heating;
    b. Load reduction of non-critical loads for short periods (refrigeration, aluminium smelters) in response to price spikes and market contingencies; and
- Scheduling of electric car battery charging to avoid periods of high energy prices and local network peak power flows.

Microgrid operations can be designed to combine forecast local and regional load and projected wholesale energy price conditions to schedule local resources to follow the peak and off-peak cycles as weather and demand change.

6.1.6 Value for Reducing Purchasing of Renewable Energy and Efficiency Certificates and Other Charges

A component of a customer's retail bill includes costs for purchasing Large Generation Certificates and Small Technology Certificates as well as Victorian Energy Efficiency Certificates. Even though reduced purchases of electricity from the grid reduces these charges, they are not regarded as providing economic value as the charges predominantly reflect sunk cost recoveries. If the volume of grid purchases decreases, then lost revenue is recovered by increasing consumers' charges in subsequent years. These cost reductions reflect temporary commercial benefits to a prosumer, not a realisable economic benefit.[47]

47. Further, to the extent that the costs are collected from customers unable to achieve the same reduction in their purchases from the grid, there may be adverse distributional impacts as a result of the cost shifting.

6.1.7 Value for Supply Reliability

Can microgrid control improve overall system reliability? Reliability is often measured at the wholesale level as the proportion of energy requested that is not supplied. The NEM target reliability at the bulk system level is for a maximum average unserved energy of 0.002% in each NEM region in each year. This measure applies only for load variation due to weather variability and generation contingencies. The main purpose of the measure is to determine the need for demand side management and generation investment to achieve reliability for normal operating conditions, and to provide a basis for AEMO's Reserve and Emergency Reserve Trader activity to ensure sufficient reliability if there is a shortfall in expected reliability. When AEMO seeks expression of interest for market participants to provide additional reserve services to AEMO, microgrids could provide such services and increase their revenues. This would be achieved by controlling microgrid resources to provide services to AEMO providing demand reductions at times of critical system conditions.

The NEM target reliability assumes the transmission system is fully reliable. It does not include network contingencies which occur in the distribution system, transmission network failures, or for major cascading failures due to extreme conditions or protection system failure.

In the transmission and distribution network, reliability of supply to consumers is more affected by network outages than a shortage of regional energy, and standards are focused on SAIDI and SAIFI: System Average Interruption Duration Index and System Average Interruption Frequency Index. These indices measure respectively, the average time that customers are disconnected from the grid and the frequency of interruption. To the extent that microgrid control can reduce network loadings under normal conditions and network contingencies, then the exposure to interruptions arising from adverse network conditions can be improved.

The advanced control of local distributed resources could increase local supply reliability by reducing exposure to extreme weather conditions causing network outages providing the microgrid is designed to island itself and focus on provision of electricity supply to essential loads.

Even without islanding capability, a microgrid can better utilise the capacity of the external grid connection and reduce the exposure to load shedding caused by inadvertent overloading which would otherwise cause protective customer disconnections.

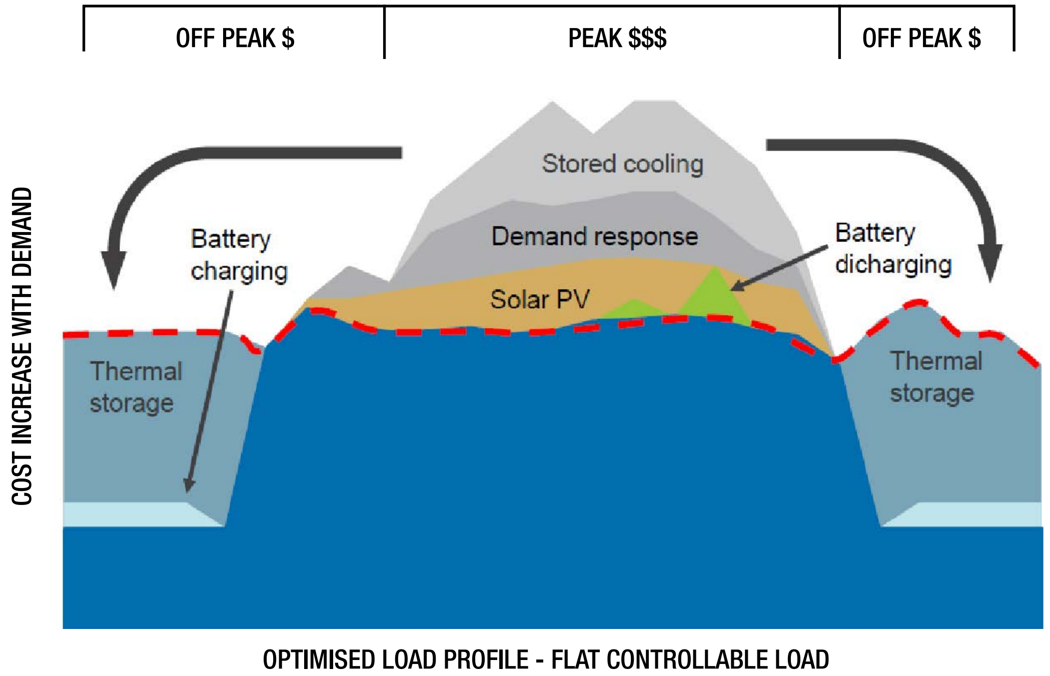
However, quantifying this reliability benefit in any particular network would require detailed simulation of network operations the cost of which would be expected to far exceed the benefit of the analysis. Standardising such assessments for standard network configurations (such as subtransmission loops supplying zone substations) could be a matter for research into feasible analytical techniques. Such methods could assist approximate estimates of the value of microgrid controls based on the network configuration, length and types of connecting power lines and the redundancy in the subtransmission network.

In the absence of this information, the primary objective of microgrid operations in respect of supply reliability would be to ensure that the microgrid operating arrangements are well coordinated with those of the local distributor so that any synergies that improve overall reliability are recognised and codified in operating procedures.

6.1.8 Microgrid Operator Realising the Benefits

Figure 6 illustrates how supply and demand could be matched in the Monash University microgrid for a typical daily profile. Thermal and battery storage are used to flatten the load curve and make the demand more responsive to the supply of renewable energy.

FIGURE 6: **ILLUSTRATION OF VALUE FROM BATTERY CHARGING AND LOAD SHIFTING**



The role of the microgrid operator is to maximise the efficient interaction between the resources connected to the microgrid and the external energy markets (gas and electricity). This process:

- requires investment in microgrid network itself and the infrastructure to support operations and control; and
- involves setting up facilities for loads, power generation and energy storage resources to be controlled to maximise the benefits of trading.

6.1.9 A Compelling Value Proposition

What makes a compelling proposition for intensive microgrid development for an enterprise? Considering the discussion above, we would expect to see:

- Net commercial benefits from the management of microgrid resources, allowing for the costs of microgrid development and operations;
- Transactional arrangements among stakeholders that enable all stakeholders to share in the net economic benefit in the form of a monetary commercial benefit;
- No stakeholders who might be able to block the development to be worse off; and
- Effective engagement of stakeholders that leads to efficient development and the intended sharing of economic benefit.

Establishing comprehensive control and transactive energy trading facilities in a distribution network is a significant investment. The benefits of such arrangements may exceed costs where some or all of the following technical and economic conditions apply as shown in Table 6. However, the impediments to development will need to be cleared by providing:

- clear regulatory frameworks for microgrid operation;
- policies that encourage demand side participation in the electricity market through orchestrated control of resources and aggregation;
- removal of any regulatory barriers that become apparent; and
- stakeholder and customer education and means for engagement in the transition to microgrid operations.

Table 6 describes the Favourable technical and economic conditions for microgrid development.

TABLE 6: **FAVOURABLE TECHNICAL AND ECONOMIC CONDITIONS FOR MICROGRID DEVELOPMENT**

Favourable Condition	Potential Problems or Opportunities	Value Proposition	Linkages and Synergies	Source of Commercial Value	Critical Dependencies
High penetration of renewable energy resources.	High voltage on low voltage feeders requires limit on distributed energy resources (DER).	Creates value by real time control of demand and energy storage and control of voltage for varying power flows.	More valuable if the external network is constrained and more costly to augment the capacity than utilise microgrid services.	Restrictions on high penetration of renewable energy resources can be relaxed, increasing potential benefits to microgrid participants.	Internal costs of service provision are not higher than avoided costs (function of energy and network charges, treatment of generation investments in own price calculation).
	Fault level and electrical safety issues caused by DER potentially feeding faults or electrifying part of the network when system is in emergency switching arrangement.	Microgrid controller disconnects applicable feeds during system recovery instead of hard-wired trips from substations.		Reduces unnecessary disconnection of distributed generation, focusing only on the critical part of the network.	Procedures needs to be coordinated with system recovery procedures to ensure safe operations and avoid power surges on reconnection of loads and DER.
	Local renewable energy generation constrained off due to connection constraints by network preventing exports. Hosting limits on new renewable energy connections may be imposed.	Microgrid control optimises connections and use of renewables.	Use thermal heating/cooling to be charged in high renewable energy times.	Maximise the quantity and value of exported electricity from the local power generation in excess of requirements.	Local voltage control and network monitoring is critical to maximising hosting capacity and utilisation of local generation with high penetration of renewables and storage.
Internal network constraints, such as minor capacity constraints on underground cables that are expensive to upgrade.	Peak demand and exported power flows can cause thermal overload and excessive voltage in distribution networks.	Creates value by more closely controlling customer energy resources to operate within internal network capacity, avoids over-investment in network capacity.	Additional value if there are also external network constraints that can be resolved more cheaply by microgrid investment and operation.	Deferred internal network upgrade and higher local asset utilisation.	Internal capacity shortfall is small but power disruption has high potential cost. Modest investment in storage and its control avoids network upgrade.
External network constraints.	Local supply reliability is degraded; costs incurred in the planning of network upgrades.	Creates value by more closely matching the site peak demand to the existing external network capacity available at any given time.	Additional value of local load control if there are also internal network constraints.	Network support service to support deferment of network investment, lower network prices to consumers.	Assumes network constraints exist and that, absent the internal network, incremental investment would be triggered to remove the constraint;
Many customers with diverse activities.	Forecasting local demand and its sensitivity to business and weather conditions may be difficult and result in over-sizing of microgrid network.	Greater diversity of customers and resources means there is more value in managing them to minimise overall peak demand and network costs.	If the customers also have embedded renewables, - local coordination of peak utilisation of energy might result in higher value use of surplus energy.	Microgrid operator has access to local detail and can better schedule resources among participants with the aim to minimising peak demand and deploying surplus energy.	Access to a diverse customer base – not typical of in embedded networks. However, microgrid technologies could be applied in mixed residential/ commercial neighbourhoods.
Thermal storage is available	Existence of thermal storage provides opportunity for some load shifting to lower energy costs	For large buildings with thermal storage and suitable building control systems, energy use can be shifted to maximise off-peak purchases.	Any kind of energy storage is useful in the presence of power flow constraints to maximise network asset utilisation.	Optimise load shifting from high price to low price periods within the constraint of the energy storage capacity.	Thermal storage must be large enough to be able to shift a significant amount of energy to cover the cost of setting up the control and market infrastructure. Design future buildings for thermal storage increases the value of the microgrid control.
Local battery storage is available	Uncoordinated use of local battery storage can increase network peak power flows during retail price changes under time of use. E.g. all batteries start charging at beginning of off-peak period when hot water services also start charging.	The use of energy storage can be enhanced when spare energy resources are better coordinated to maximise the capture of energy and the value of network support.	Different value streams for electricity storage can be mutually exclusive and in conflict. For example: maximising stored energy at all times to maximise the capacity to provide ancillary service for "generation raise" reduces opportunity to store surplus energy when it becomes available.	Microgrid operations enables the benefit stack from storage to be optimised to earn ancillary service revenue and maximise load shifting within network constraints.	Battery storage needs to be within microgrid if regulatory issues (purchase and sale of electricity, for example) to be minimised. Weather and market forecasts needed to maximise the benefit stack from storage.
Retirement of thermal power plant reduces the supply and increases the demand for frequency control services	High frequency control costs arising from reduced mechanical inertia, the reduced supply of control range and the greater variation in power generation from solar and wind resources.	Local inverter connected resources contribute frequency control services when there is a shortage of supply from wholesale sources. Requires suitable inverter controls and settings.	The power system will increasing seek to supplement voltage and frequency control to make the best use of distributed resources, especially when the surplus power increases the potential rate of change of frequency.	Prosumers will earn additional revenue from providing control services and have lower exposure to high ancillary service costs include in market fees.	Distributed voltage and frequency control need to be coordinated with system recovery procedures for electrical safety and voltage stability during network recovery after widespread network disruptions (e.g. from storms).

6.2 Appendix: Technologies and Processes

6.2.1 Technologies

The concept of microgrid applied in this report consists of physical facilities:

- A local network connected at distribution level (22kV or perhaps 66kV) to a distributor;
- Metering of customer loads within the local network using smart meters and a meter data collection system on a 15 minute cycle or more frequently as required;
- An active grid management information and control system (AGMS) that monitors the local network and its interaction with the external network so that network state, power flows, voltage levels are known and can be optimised if worthwhile to do so;
- An energy management information and control system (EMS) which identifies energy management and energy storage actions including load increases and reductions having regard to the state and pricing in the wholesale energy market and the external network conditions including energy losses and constraints;
- The EMS is responsive to consumer actions and provides services to the internal customers and the external markets. The optimisation may be achieved through a mix of;
    - local price-based responses by customers where decisions are made by the customer's facilities;
    - local optimised control of energy use where targets for action are pre-agreed by stakeholders and customers agreed to control policies rather than take actions;
    - aggregated responses of resources either direct to the wholesale energy market or through an external aggregator. There responses can be informed by customers or formulated centrally as deemed best in each case;
    - a microgrid operator coordinated (auction based) "transactive energy market" that allows customers to set price preference for automated dispatch of energy resources and response if the local resources are enabled and capable of providing the service.
- A Building Automation System (BAS) applied to the larger commercial buildings to control heating, cooling, ventilation and lighting to maintain occupant comfort while minimising energy costs. The BAS has local controllers which respond to energy market information, scheduled activities within buildings and monitor heat flow and energy usage.

The MEMO concept is a commercial business with customers and prosumers:

- Local energy price may be used to coordinate the optimisation of local resources interacting with the external network services and energy market;
- Consumers buy electricity from the local network and may adjust their demand in response to the local energy price;
- The local network owner charges a fee to recover the costs of the internal network; and
- The local microgrid operator supervises the energy transactions within and outside the local network and ensures that all accepted transactions are conducted within the capacity of the internal network and the connection to the external network. Least cost dispatch is the goal within safety and security constraints as in the wholesale energy market. The microgrid operator is a commercial business and charges a fee to participants to recover its operating costs and earn a return on capital invested.

Even where all assets of the microgrid and local consumers are owned by one party, there may be a role for assigning responsibility to different parts of the organisation to create pseudo customers according to activities and business units so as to provide efficient incentives to use the available facilities.

The external commercial stakeholders are:

- The external wholesale market operator (AEMO) is a stakeholder in that it accepts aggregated transactions to buy and sell power from time to time and the contribution to ancillary services in the wholesale market;
- The external network is a stakeholder because the microgrid influences the performance and control of its distribution network and the network operator's requirements of the microgrid and its connected equipment influence the microgrid design and functioning; and
- The external transmission network is a stakeholder because the microgrid may have a material effect on the local transmission system especially if the transmission system frequently operates near its capacity.

6.2.2 Processes

The microgrid operates through investment, regulatory and operational decisions and processes.

Investment Processes:

- Design and install control facilities and energy management systems;
- Co-plan with external network on support systems and network capacity upgrades; and
- Ensures that network capacity and control and protection equipment changes are consistent with forecast service requirements.

Regulatory Processes:

- Monitor regulations and contribute to consultation on market rule changes; and
- Ensure that local consumer pricing and service meets regulatory obligations.

Operational Processes:

MEMO:

- consults with consumers on their current and future service requirements;
- maintains software systems and external market interfaces for energy management;
- develops short-term forecasts of supply and demand for scheduling of supply and demand resources for interactions with external markets; and
- settles the energy market transactions between AEMO, retailers, aggregators and customers.

Local Network Owner/Operator:

- maintains the electrical control and protection equipment for the internal distribution system;
- manages development of the internal network; and
- provides control interfaces to the microgrid operator for optimisation of operations.

6.3 Appendix: Data Sources for Microgrid Valuation Model

This section summarises the sources of data used to develop the value of microgrid operations in Victoria.

TABLE 7: **SOURCES OF DATA FOR VALUE OF MICROGRID OPERATIONS**

Source	Document	Website	Data Sourced
AEMO	Integrated System Plan	*aemo.com.au*	Victorian load profile for 2018/19 used for assessment of load shifting on loss factors.
	Electricity Statement of Opportunities 2018	*aemo.com.au*	Victorian peak demand and energy consumption forecast.
	Ancillary Services Payments csv file	*aemo.com.au*	Payments to Victorian participants for ancillary services acquired.
Ausnet Services	Distribution Annual Planning Report 2018	*Ausnetservices.com.au*	Load at risk, transfer capacity and expected unserved energy for substations and subtransmission.
Citipower	Distribution Annual Planning Report 2018	*Citipower.com.au*	
Jemena	Distribution Annual Planning Report 2018	*Powercor.com.au*	Load at risk, transfer capacity and expected unserved energy for substations and subtransmission. The cost of capacitor banks.
United Energy	Distribution Annual Planning Report 2018	*Unitedenergy.com.au*	Load at risk, transfer capacity and expected unserved energy for substations and subtransmission.
	Transmission Connection Report 2018	*Unitedenergy.com.au*	Load at risk, transfer capacity and expected unserved energy for transmission terminal stations.
Powercor	Distribution Annual Planning Report 2018		Load at risk, transfer capacity and expected unserved energy for substations and subtransmission.
ASX	Electricity futures prices	*Asx.com.au*	Flat and peak price futures for Victoria.
Essential Services Commission	Network Value of Distributed Generation	*Esc.vic.gov.au*	Information on value of voltage control and cost of capacitor projects.

6.4 Appendix: Description of Valuation Model

This section describes the structure of the microgrid valuation model including key assumptions.

The value to Victoria estimated herein is the gross value. We have not been able to estimate the costs of implementing all the microgrid needed to realise this value. Table 8 provides a summary of the data used and the methods employed to value microgrid services in Victoria. This is discussed in more detail in the following sections of the Appendix.

All costs and values are estimated in 2018 values and a 5% real discount rate is applied.

Conservatively, it is assumed that provision of microgrid services does not accelerate the growth of distributed solar energy. Such an evaluation would require a detailed model of customer investment and how this would be influenced by microgrid development. This could be a focus of further market analysis using the methods which are used to forecast growth in distributed generation.

6.4.1 Economic Value Components

The economic value is made up of:

- Network savings from displacement of unserved energy up to the value of potentially deferring network augmentation projects;
- Provision of ancillary services through load or generation control;
- The value of shifting up to two hours of load from peak to off-peak periods up to the quantity of load needed to defer network projects;
- The savings in energy costs from the reduced loss factors associated with the load shifting; and
- The savings in capacitor banks from providing distributed voltage control.

These components of value were assessed as described below. In many cases some assumptions had to be made due to the absence of readily available data on technical requirements.

Originally it was intended to assess the potential number of microgrid sites and their size to estimate the value. However, it was soon realised that this was impractical with the available time and resources due to the detailed analysis needed. Rather, it has been more useful to focus on aggregate data already available in the public arena in planning reports and form data available from AEMO and the futures exchange at *www.asx.com.au.*

6.4.2 Carbon Value

There is also the potential value from reduced carbon emissions if microgrid operations were to increase the penetration of distributed renewable energy projects.

Such a valuation would require a detailed estimate of the hosting capacity for solar PV resources that would apply without microgrids and the scope for additional connections with microgrid operations. This has not been assessed as yet due to the lack of public information on these potential limitations.

This would not have any commercial value unless carbon pricing is adopted.

TABLE 8: **SUMMARY OF THE VALUE OF LOAD CONTROL**

Source of Economic Value	Data Used	Methods Employed
Network support to reduce expected unserved energy where it is cheaper than network augmentation.	Load at risk, energy at risk, transfer capacity and expected unserved energy for substations, subtransmission and terminal stations from utility Planning Reports.	Recalculate the expected unserved energy after transfers are effected and viable network projects proceed to assess the residual risk that could be mitigated by demand-side response measured as controllable load or generation. Remove multiple counting of load at risk across zone substations, subtransmission and transmission terminal stations.
Ancillary services in Victoria for generation raise and lower, contingency and regulation services.	Payments made by AEMO in 2018 calendar year for ancillary service payments in Victoria. Assumed 200 MW of capacity provided for raise and lower.	Recognised that ancillary service and network support cannot be provided at the same time, so selected the higher value service at each terminal station.
Two-hour load shift for the controllable load that can serve network support services.	Used Victorian futures prices for peak and flat contracts to estimate peak and off-peak average prices.	Transferred up to 450 MW for 2 hours each week-day from peak to off-peak period, allowing for average losses.
Distributed voltage control to defer capacity banks.	Capacitor bank projects identified by distributors: replacement or new capacity.	Identified terminal stations where capacitor banks need to be replaced or added. If microgrid capacity needed, 44% of the MVA at risk (98% power factor) could be applied for voltage control to defer capacitor banks.
Loss savings due to load shifting from peak to off-peak periods.	2018/19 Victorian load curve and average losses from ESOO demand forecast.	Used Victorian load curve with transmission and distribution average loss curve to match quoted average losses. Shifted up to 450 MW of load and recalculated the average losses to find the loss reduction arising from the load shift.

6.4.3 Network Value

There are two approaches to examine network value:

1. From the components of charges that are incurred by customers and the underlying value drivers; and
2. From the costs that can be avoided by NSPs as presented in their Distribution Annual Planning Reports (DAPR).

The former approach reflects the commercial value arising in the network of changing usage patterns of distributed energy resources (DER). The latter approach reflects the underlying economic value from the demand side response that could be optimised by microgrid operations and is somewhat easier to determine from public reports. The DAPRs define what savings can be made by non-network services to support the grid.

Analysis of Distribution Annual Planning Reports

An analysis of DAPRs from the distributors provides information on planned network augmentation projects, demand growth and expected unserved energy. Even where no augmentation is justified using the approved probabilistic planning basis,[48] there is a residual value for demand side response which can potentially reduce the expected level of unserved energy. The aggregate value of expected unserved energy has been assessed from the Distribution APRs which provide:

- The amount of energy at risk in MWh before emergency transfers between substations and before any network augmentation, usually neglecting the effect of disconnecting solar PV resources which adds about 2-3%[49] to the expected unserved energy;
- The expected unserved energy in MWh allowing for the probability and duration of plant failure. This is usually a very small fraction of the load at risk, typically 0.217% for a single transformer failure for example;
- The maximum load at risk in MVA corresponding to the peak demand (either 50% or 10% probability of exceedance) less the firm capacity allowing for the largest unit out of service (called N-1 firm capacity);
- The number of hours per year when the demand is above the N-1 firm capacity;
- The transfer capacity which may be available to reduce load at a substation or subtransmission loop after a failure. This is accomplished by using spare non-firm capacity at other substations by switching feeders between substations where feasible within network rating and quality of supply conditions. This is stated for the current year only, and will change over time as demand and DER patterns change;
- A measure of transformer reliability (0.217%) and a formula for assessing feeder reliability based on length (but the length of feeders is not published); and
- The number of transformers in each substation.

However, the DAPRs do not provide the following essential information:

- the degradation or change in transfer capacity over time, particularly when subtransmission networks are reconfigured or new substations established;
- how the transfer capacity reduces the energy at risk and the expected unserved energy under contingency conditions;
- the residual expected unserved energy after the preferred network projects are commissioned;
- the reliability parameters calculated for the critical subtransmission feeders which influence the ratio of energy at risk and expected unserved energy (faults per km per year is provided as a line reliability index but the length of critical feeders is not provided); and
- the prospective changes over the next 10 years (5 years only provided) which is needed to assess the value of investment in microgrid operations.

48. The distribution Annual Planning Reports are accessible on the utility websites as listed in Table 7. They incorporate an explanation of how the probabilistic planning basis operates to minimise the total cost of electricity supply including the estimated average cost impact of unreliability on customers.
49. 2-3% extra unserved energy is reported in the 2018 Transmission Planning Connection Report published by the Victorian Distribution Businesses (page 34) at *https://www.unitedenergy.com.au/industry/mdocuments-library/* It is noted that in some locations, the unserved energy can be up 10 10% - 15% higher than the flow at the transmission connection point.

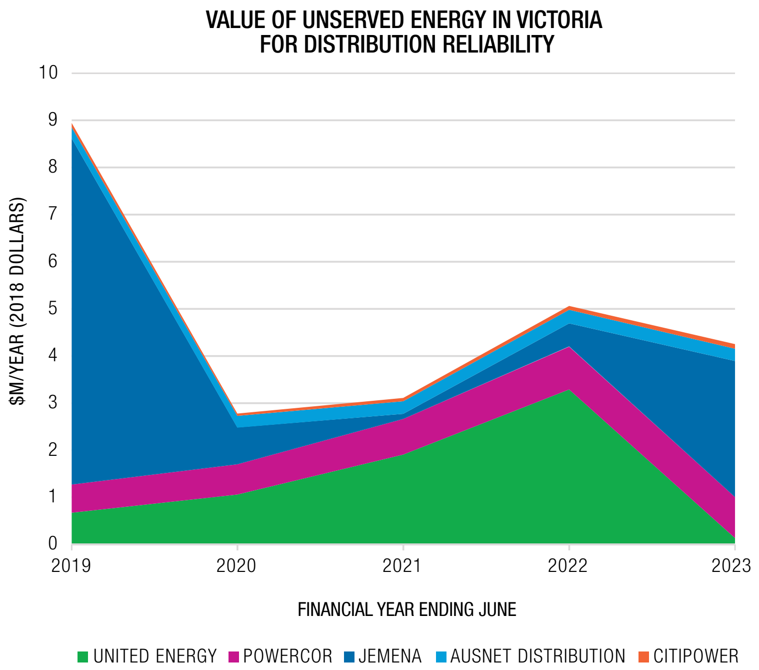
Accordingly, the expected unserved energy has been conservatively estimated by assuming:

- Assuming the transformer reliability (0.217%) also applies to subtransmission and medium voltage feeders on average;
- Applying the transformer reliability according to the number of transformers in each substation where the overall probability of failure is not provided;
- The transfer capacity decreases at 1% per annum geometrically to represent modest load growth eroding transfer capacity to other substations;
- Available transfers after faults are applied to reduce the energy at risk by 30% of the product of the transfer capacity and the hours of peak load at risk. This factor allows for the fact that the peak load at risk is not applicable for the whole period of risk and that sometimes the transfer capacity is not fully available;
- If projects are planned, the expected unserved energy becomes zero in the year when the project commences service, usually prior to the summer peak period when most of the energy is at risk; and
- That the coincident outages of transformers are immaterial in determining the expected unserved energy and its value.

A higher potential value has also been assessed by assuming that the network projects are deferred indefinitely and that DER are orchestrated to avoid the expected unserved energy with a value up to the annual costs of the network project at the weighted average cost of capital for the network utility.

The expected unserved energy is multiplied by the distributor's stated value of customer reliability, typically around $42.2/kWh[50]. The result for the distributors is shown in Figure 7 in 2018 dollars for five financial years ending June. The average value is $4.0m per year. Jemena has 48% of the value and United Energy has 29% of the value, which means that most of the value is in the Melbourne metropolitan area where the network supply/demand balance is excellent with many substations operating at levels close to or slightly above their firm capacity. It may be noted that replacing flexible conductors at Brooklyn Terminal will remove the unserved energy by 2019/20, by which stage United Energy will have the highest contribution to expected unserved energy.

FIGURE 7: **CONSERVATIVE ESTIMATE OF VALUE FROM REDUCING EXPECTED UNSERVED ENERGY FOR DISTRIBUTION**

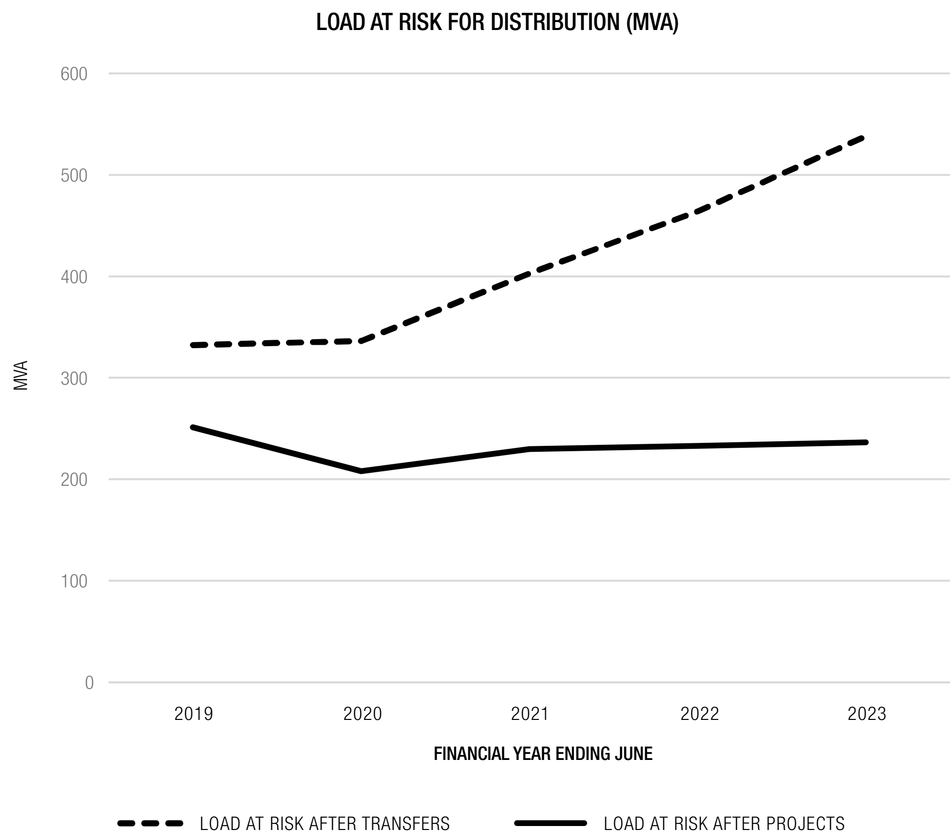


50. Jemena used $40.719/kWh whereas the other Victorian distributors used $42.200/kWh in 2018 dollars. These were based on their average customer mix and the values recommended by AEMO for each sector: residential, commercial, industrial.

The load at risk after transfers and after projects and transfers, assuming that new projects are of sufficient size to remove the load at risk is shown in Figure 8. After the projects planned in the period to 2022/23, there will remain about 237 MVA of load at risk after emergency transfers. This is probably an underestimate because the emergency capacity is only available at the nominated level when all other network assets are in service and not extreme loading levels for unusual weather. This is true with a high probability (typically >99%) but is not guaranteed.

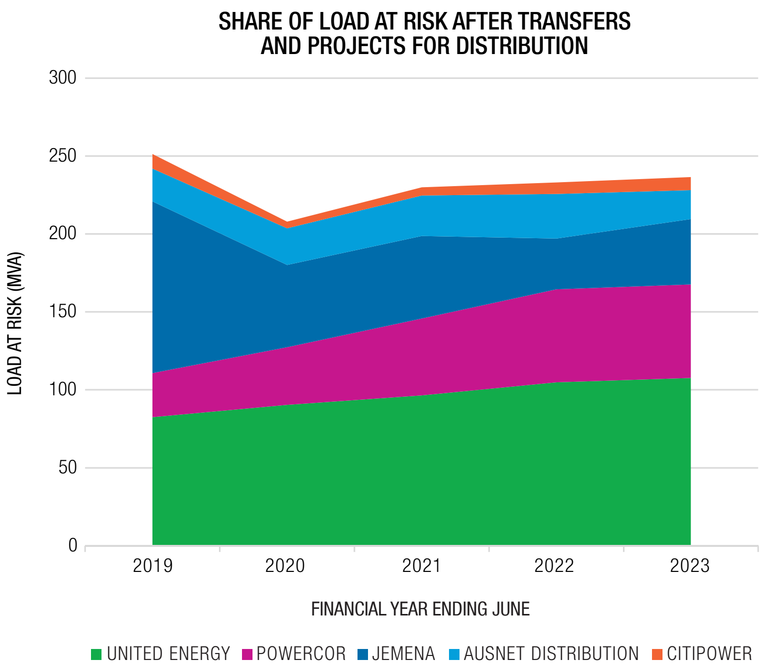
Figure 8 also shows the load at risk after transfers but assuming that network projects are deferred. This represents an upper bound of opportunity for microgrid based demand reductions. By 2022/23, it is almost twice the conservative value in MVA terms.

FIGURE 8: **LOAD AT RISK IN THE DISTRIBUTION SYSTEM FROM EXPOSURE TO FAILURES IN THE DISTRIBUTION NETWORKS**



The share of the conservative amount among the distributors is shown in Figure 9. United Energy and Powercor dominate the load at risk. The average quantity of 232MVA[51] gives an indication of how much distributed load control would be needed to eliminate this risk and achieve the value of $4.0 m per year assessed above. Each MVA of load control in the right place is worth about $20,800 per year on this basis, or $21/kVA per year in rounded terms.

FIGURE 9: **SHARE OF LOAD AT RISK AFTER TRANSFERS AND PROJECTS AMONG DISTRIBUTORS**



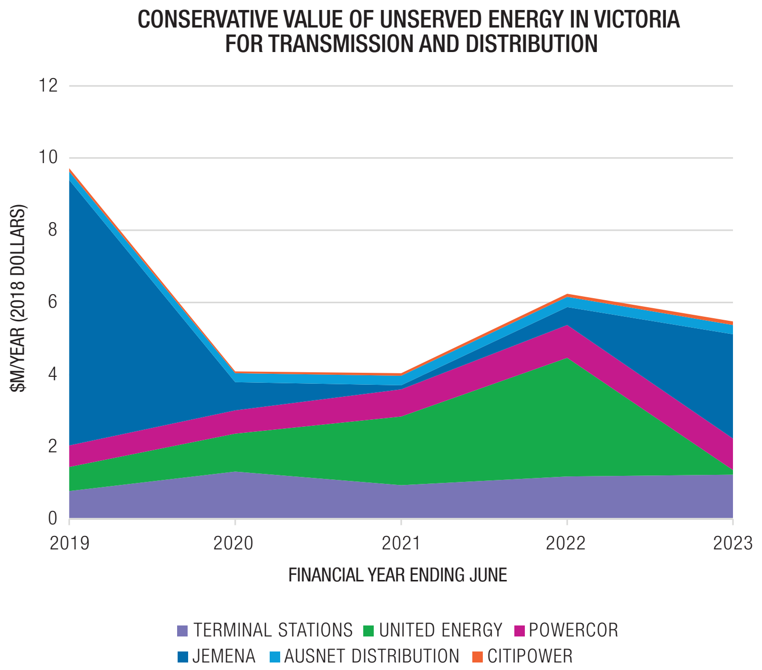
Analysis of Terminal Station Report

The equivalent analysis for terminal stations is based on the report issued on the loads and capacity at Victoria's terminals stations. A joint report entitled "Transmission Connection Planning Report 2018"[52] presents this information. The data was examined in similar for, calculating the expected unserved energy and load at risk after available transfers and projects. The information was then aligned with the distribution data to assess the total load at risk allowing for overlap with distribution load at risk at each terminal station. The total load at risk is shown in Figure 10. The average value is $5.4 m/year in 2018 dollars. Note that the value at transmission level is about $1.1 m/year. This is the conservative assessment again assuming that transmission projects remove all expected unserved energy in the year of service.

A higher level was also assessed assuming that projects could be deferred beyond 2022/23 and that DER could remove expected unserved energy up to the annual value of the deferred project. This gave an average transmission value of $1.8 m/year and a combined average value of $7.4 m/year, that is 37% higher than the conservative value.

52. Available at https://www.unitedenergy.com.au/industry/mdocuments-library/

FIGURE 10: **CONSERVATIVE ESTIMATE OF VALUE FROM REDUCING EXPECTED UNSERVED ENERGY FOR TRANSMISSION AND DISTRIBUTION**



Combining the load at risk at transmission and distribution level is shown in Figure 11.

The total load at risk in Victoria from single network contingencies is between 400 and 510 MVA over the next five years assuming all projects proceed and network transfer capacity is available for use during emergencies. This capacity indicates the potential opportunity for load control and the scope for microgrid development. The average value over these five years on a levelised based at 6% real discount rate is $12.04/kW/year. The arithmetic average is also $12.04/kW/year.

The higher estimate is shown in Figure 12 and has a levelised value of $13.38/kW/year and an average value of $13.44/kW/year. There is potential for up to 700 MVA of load control to defer network investments across Victoria.

51. 225 MVA if transfer capacity does not reduce from the initial value.

FIGURE 11: **COMBINED LOAD AT RISK IN VICTORIA FOR NETWORK CONTINGENCIES**

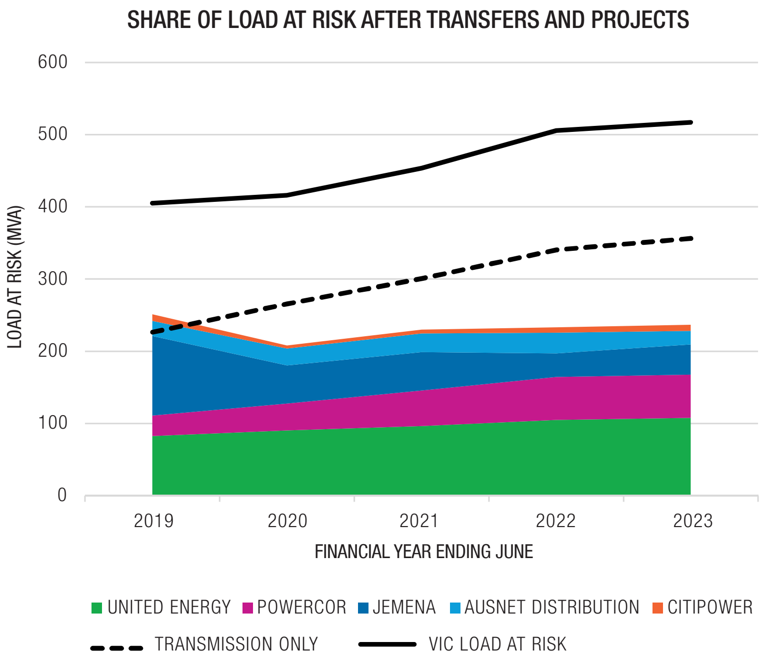
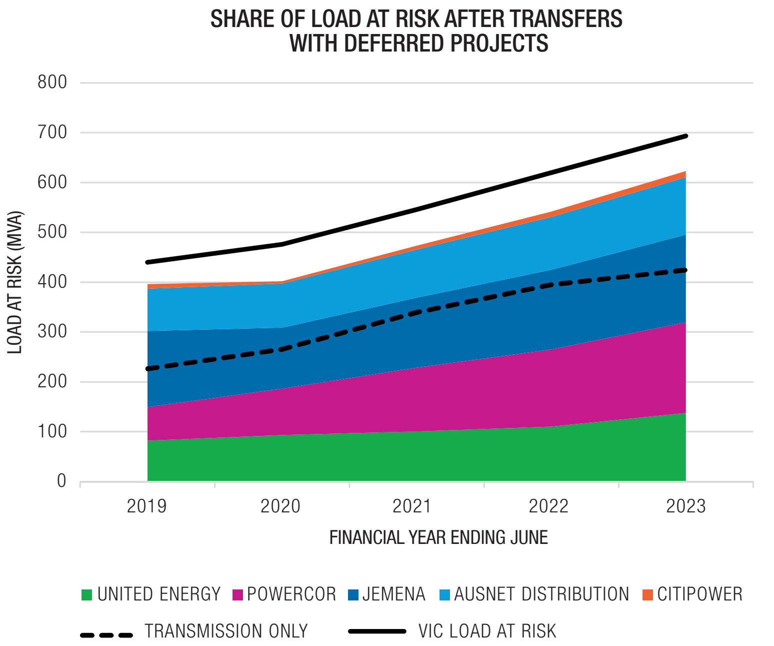


FIGURE 12: **HIGHER ESTIMATE OF COMBINED LOAD AT RISK IN VICTORIA FOR NETWORK CONTINGENCIES**



The distribution of value by location is quite diverse as shown in Table 9. The Table shows the values assuming network projects proceed as planned and also if they are deferred beyond the period to 2022/23 financial year. If network projects proceeded as planned, the highest value non-metropolitan locations are Horsham and Mount Beauty, or in the northern & western metropolitan area at Thomastown, Keilor and West Melbourne. The value distribution is quite skewed with only seven locations having a value higher than the average levelised value of $12.04/kW. If network projects can be deferred, these same locations remain favourable, but Brooklyn and Springvale come into consideration.

Contracted Energy Market Value

The energy market value of microgrid operations depends on the ability to shift load purchases from peak to off-peak and shoulder periods to take advantage of lower prices. Assuming adequate competition in the spot and contract markets, the energy price should be reflective of true economic benefit because energy is priced at its marginal value in wholesale markets except under extreme conditions. The value of microgrid operation is to better deploy storage resources and to create the incentive to install energy storage. In this section we estimate the levelised value over five years for each kWh shifted from peak to off-peak periods based on forward contract prices.

The energy market value is estimated here from the ability to shift load from peak to off-peak periods. The peak and off-peak prices were based on the Futures Prices for Victoria as at 13-Feb-2019 and are shown in Figure 13. The prices have been adjusted to 2018 dollars using 2% price inflation from June 2018 to be consistent with the analysis on network values. These prices were used to estimate the value of shifting 1 MW for 1 hour from peak to off-peak periods once per working weekday for each financial year, allowing for 7.17% average loss[53] from the wholesale electricity price to the consumer's terminal where the load is measured. This result is shown in Figure 14. It shows a declining value for load shifting as wholesale prices and price volatility are expected to fall in both nominal and real terms based on the future contract prices for peak and flat volume profiles. When levelised over the five years to 202/23, the potential value is $9.91/kW/hour/year of load shift per hour shifted averaged across Victoria.

53. The 2018 Electricity Statement of opportunities shows 7.17% loss added to demand and 7.37% add to load at peak to obtain operational demand sent out from power stations at *http://forecasting.aemo.com.au/Electricity/MaximumDemand/Operational*
Marginal transmission losses at the loaded terminal stations range from 0.9712 to 1.0192 relative to Thomastown 66kV. We estimate the average transmission loss as (1.0192-.9712)/2 = 2.40%

TABLE 9: **VALUE OF LOAD CONTROL FOR NETWORK SUPPORT BY TERMINAL STATION LOCATION**

		Levelised Value of Load Control $/kW (2019-2023 financial years)	
Supply	Location	Service for Network Projects as Planned	Service for Deferred Projects
HOTS 66 kV	Horsham	155.29	152.2
TTS 66 kV	Thomastown	107.32	62.9
KTS 66 kV	Keilor	91.13	207.8
WMTS 66 kV	West Melbourne	59.38	70.6
MBTS 66 kV	Mount Beauty	38.54	37.5
CBTS 66 kV	Cranbourne	19.63	22.2
TBTS 66 kV	Tyabb	17.94	22.4
TGTS 66 kV	Terang	9.67	9.8
GNTS 66 kV	Glenrowan	8.85	8.3
MTS 66 kV	Malvern	4.97	4.8
RTS 66 kV	Richmond	4.23	4.2
SHTS 66 kV	Shepparton	4.09	4.4
GTS 66 kV	Geelong	3.98	3.9
SMTS 66 kV	South Morang	2.99	3.0
BETS 66 kV	Bendigo	2.50	2.7
WOTS 66 kV	Wodonga	2.04	2.0
TSTS 66 kV	Templestowe	2.04	7.6
BTS 66 kV	Brunswick	1.91	0.9
KGTS 66 kV	Kerang	1.56	1.6
MWTS 66 kV	Morwell	1.26	1.5
HTS 66 kV	Heatherton	0.87	10.5
BLTS 66 kV	Brooklyn	0.00	77.7
RCTS 66 kV	Red Cliffs	0.00	0.0
ATS 66 kV	Altona	0.00	0.0
ATS/BLTS 66 kV	Altona/Brooklyn	0.00	0.0
DPTS 66 kV	Deer Park	0.00	0.0
FBTS 66 kV	Fisherman's Bend	0.00	0.0
WETS 66 kV	Wemen	0.00	0.0
WMTS 22 kV	West Melbourne	0.00	0.0
BATS 66 kV	Ballarat	0.00	0.0
RWTS 66 kV	Ringwood	0.00	0.0
BTS 22 kV	Brunswick	0.00	0.0
RTS 22 kV	Richmond	0.00	0.0
SVTS 66 kV	Springvale	0.00	176.4
ERTS 66 kV	East Rowville	0.00	0.0
FTS 66 kV	Frankston	0.00	0.0

FIGURE 13: **VICTORIAN FUTURES PRICES 13-FEB-19**

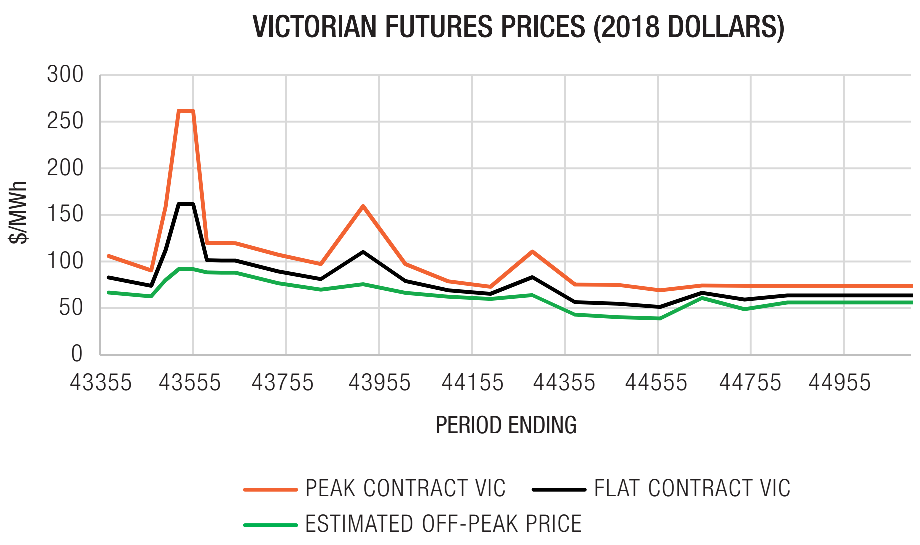
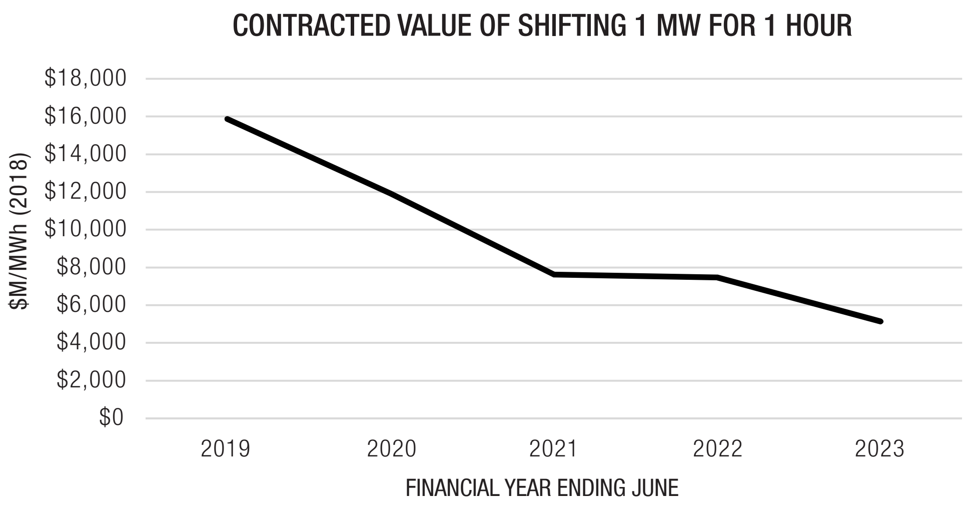


FIGURE 14: **VALUE OF LOAD SHIFTING FROM PEAK TO OFF-PEAK PERIOD**



Spot Energy Market Value

Alternatively, the load shifting could be controlled by bidding in the wholesale market to dynamically shift load according to the occurrence of high and low prices. Estimations of value for this purpose are more uncertain as they cannot be fixed ahead of time and are dependent on both long-term market trends (as indicated by the contract price above) and short-term operational contingencies as well as weather variation. In general, there is more value in responding to spot prices than there is in contracting based on futures prices. However, when investing in new facilities such as microgrid controls, it is prudent to rely on contracted valuation as this can value be secured through purchase of hedge contracts according to the intended load to be rescheduled.

Ancillary Services Market Value

The Ancillary services payments summary from AEMO[54] shows payments for generation raise and lower and regulation to be $22.5 m/year in 2018 calendar year. Information was sourced from AEMO on the maximum and average quantities of ancillary services cleared in the Victorian region. This data is shown in Table 1 for the period 1-Jul-2018 to 28-Feb-2019. The values are combined into a raise and lower capacity by adding the regulation component to the maximum of the slow, delayed and fast components on the basis that DER control could probably provide all three services over the period of 6 seconds (fast) to 5 minutes (slow) for the slow response[55]. Note that the average service level is typically around 30% of the maximum requirement.

TABLE 10: **QUANTITIES OF ANCILLARY SERVICE CLEARED IN VICTORIA 1 JULY 2018 TO 28 FEBRUARY 2019 INCLUSIVE (MW)**

	Maximum	Average
Regulation Raise	163.0	7.0
Regulation Lower	64.0	4.6
Slow Lower	188.8	35.4
Slow Raise	268.7	52.8
Delayed Lower	253.3	88.3
Delayed Raise	192.0	62.5
Fast Lower	115.0	8.8
Fast Raise	190.2	61.6
Total Raise	276.7	76.1
Total Lower	285.1	93.0

If we use these data assume this requires up to 260 MW of capacity in each direction to deliver this service[56], then the maximum inherit value of using load control for this purpose is $86.57/kW for raise and $2.51/kW for lower services. Lower services are inherently cheaper because the generator does not need to forego production to deliver the lower service, whereas the raise service requires providing unused generation capacity which has a shadow value similar to the load weighted spot electricity price which was $97.4/MWh in 2018[57].

The ancillary services value is greater than the network support value for all but one location (Table 10). Since, to be effective the network support service must be enabled during critical loading periods, this may preclude the same controls from also providing the generation raise or lower service at the same time because the controls would be directed toward managing the network contingency, and not respond to frequency. There may be scope to provide regulation or 6 second service at the same time as supporting the network because the thermal capacity of the network elements may absorb the impact of the short-term variation in control, but this would complicate the coordination of simultaneous obligations to achieve all the control objectives. Ancillary service could be provided when there is no need to activate the network support, but the value would be likely much lower than the average of $86.57/kW for the generation raise service at such times due to lower energy prices.

For the purposes of valuation, we shall assume that 260 MW is needed to capture the full value of ancillary services and that half this quantity (130 MW) can capture half the value for the conservative case.

It is possible that if existing ancillary service supply were replaced by microgrids bidding for this service, that there may be some reduction in the market price, especially if microgrids also depressed the market energy prices. We might therefore expect that the realisable commercial value of these services could be less than the historically observed values for the same overall supply/demand conditions (apart from microgrid development).

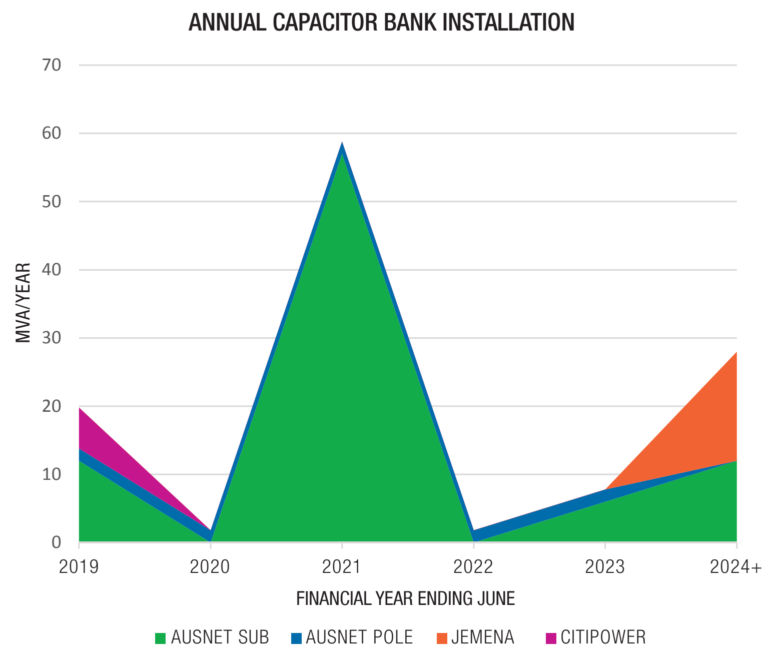
54. http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Ancillary-Services
55. Delayed is required by 60 seconds
56. Allowing for 7% loss to the customer
57. *https://www.aer.gov.au/wholesale-markets/wholesale-statistics/quarterly-volume-weighted-average-spot-prices*

Distributed Voltage Control

The Essential Services Commission in 2016 reviewed the network value of distributed resources. Distributed voltage control was considered in that review. It was concluded that there were at that time few cases where voltage control was an issue requiring investment and that at most distributed voltage control could save less than $500,000/year according to Jacobs[58]. This would avoid investment in 50 MVar of capacitor banks and two voltage regulators for a total investment of about $3.3m which would have an annual cost of about $270,000. If we allocate this value to the current potential capacity of 400 – 500 MVA of load control, it is negligible at $1.2/kVA. However, distributed voltage control where there is a voltage constraint would be worth about $5.9/kVA[59] which is still small but may help make a microgrid project viable. If we assume inverters could have power factor of 90%, then 1kW power could offer 0.44kVA of reactive support. If we associate the value to the active power control then we obtain a value of $2.6/kW at favourable locations, for the displacement of reactive support.

The analysis of the latest DAPRs shows that Ausnet has plans to replace about 84 MVA of capacitors over the next 5 years, much of it due to the installation of Rapid Earth Fault Current Limiters (REFCL) which requires compliant capacitor banks to withstand the voltages on the unfaulted phase conductors. The timing of installations is shown in Figure 15, including the lesser quantities planned by the other distributors. Much of this is planned for 2021 to manage bushfire risk by limiting phase to ground fault currents. It's difficult to see how distributed voltage control could replace these installations and therefore not feasible to include any value for microgrid operations. This would be very site specific.

FIGURE 15: **PLANNED CAPACITOR BANK REPLACEMENT AND NEW INSTALLATIONS**



We have therefore identified the overlap where microgrid control has value and there are capacitor banks that could be deferred. There are only four terminals stations where this applies: Richmond (RTS 66 kV), Templestowe (TSTS 66kV), Wodonga (WOTS 66 kV) and Morwell (MWTS 66 kV). Over the five years this allows scope for 27 MVAr of reactive support from microgrid at most out of 81 MVA installed over the period to 2022/23.

More importantly, distributed voltage control will become essential to higher levels of penetration of solar PV resources, so there is an additional benefit in lifting restrictions on the connection of solar PV systems at low voltage. This will flow through to additional emission abatement which has a considerable environmental value through reduced carbon emissions and fossil fuel extraction. However, the quantification of this value requires a much more sophisticated analysis than has been able to be conducted herein.

58. *https://www.esc.vic.gov.au/sites/default/files/documents/distributed-generation-inquiry-stage-2-final-report-network-value.pdf* page 72
59. This is based on the ESC report cost of $2.2m in 2016 for 32 MVar of capacitors plus allowing two years of cost escalation at 4.05% in total (=113/108.6-1).

Reduced Energy Losses

To the extent that microgrid operations reduce peak power flows, they will also reduce assessed transmission marginal loss factors (MLF) and average distribution loss factors (DLF). There is no easy way to predict how these loss factors would change due to microgrid controls. There is a degree of variation from year to year as new generators are connected and old plants retired. As distributed energy resources change. If we assume that microgrid operation leads to peak reduction of 5.7% of Victorian peak customer demand (450 MVA) out of 7884 MW peak demand and we have typical load MLFs of 1.0006 across all the Victorian Terminal Stations. According to the ESOO 2019 forecasts for Victoria, average losses are 7.17% of customer net demand. We allow average losses of 2.4% transmission and 4.66% distribution added to the customer load at each stage. If 5.7% of load (450 MW) is shifted for two hours from when the system is at 84.3% to 90% loaded and to when it is 44.3% to 50% loaded, once per weekday day for two hours, then the average transmission loss would be reduced by approximately 0.025% and the average distribution loss would be reduced by approximately 0.508% giving a total loss saving of 0.55% for consumers throughout the market[60].

This has been estimated from the 2018/19 Victorian load shape as modelled for the Integrated System plan and assuming fixed losses of 0.2% at transmission level, 0.4% at distribution level and finding equivalent peak marginal losses at transmission and distribution level which matches the average loss of 7.17%. This 0.55% improvement represents a saving on energy purchases for the whole of demand. Using the contract prices above, the projected loss savings from the proposed regular load shifting from high price periods to low price periods is as shown in Table 11. The levelised value of the stream is $3.5 m/year. This value accrues to all customers as a commercial benefit through lower energy costs.

TABLE 11: **ESTIMATED VALUE OF LOSS SAVINGS FROM LOAD SHIFTING 450 MW FOR TWO HOURS ON EVERY WEEK DAY**

Financial year ending June	2019	2020	2021	2022	2023
Annual value of loss savings to all Victorian consumers $M/year for 450 MW of load shifting	$5.5	$4.9	$3.7	$3.2	$3.5

It should be noted that this is not an accurate assessment as a full analysis would examine load flows throughout the networks based on where and when the load is shifted. Here only an indicative value is estimated based on the aggregate level of network energy losses in the Victorian network. There would be higher values in areas with higher loss factors.

Summary of Value of Control of Distributed Resources

In summary we estimate the total gross value of distributed control as $22 m/year to $36 m/year levelised over the period 2018/19 to 2022/23 as summarised in Table 12. The loss factor benefit has been scaled back as the Terminal Station analysis shows about 373 MVA of effective load control value (Table 13). This excludes external benefits of reduced carbon emissions that may arise if microgrid operation encourages further development of distributed solar power.

The analysis is based on an assessment of the opportunity by Terminal Station as shown in Table 16. The locations are ranked from highest value per kW of load control to lowest Terminal Station location. The ancillary services value is added up to 200 MW to those areas where the other values are such as to contribute to the highest overall value. The highest value site is Horsham (HOTS 66 kV) where a relatively small amount of load at risk has significant associated expected unserved energy. The next four highest value sites per kW of control are in the Melbourne metropolitan area at Thomastown, Keilor, Richmond and Brooklyn.

Table 14 shows the Terminal Station assessment for the higher value estimate with network projects deferred. Keilor and Thomastown move to the top of the list with the remaining ranking in the top of the table unchanged.

60. Note loss factors are multiplicative (1+loss), not additive

TABLE 12: **SUMMARY OF THE VALUE OF LOAD CONTROL**

Source of economic value	Levelised value per year 2018/19 to 2022/23 million/year		Qualifications
	Projects proceed as planned	Network Projects Deferred	
Network support to reduce expected unserved energy where it is cheaper than network augmentation	$4.0	$7.3	Assumes network projects proceed and that transfers occur before microgrid resources are called upon
Ancillary services in Victoria for generation raise and lower, contingency and regulation services	$7.4	$15.4	Up to 260 MW of service available and allocated to the most profitable locations for microgrid services. Assume 130 MW for conservative case.
Two-hour load shift for the controllable load that can serve network support services	$7.2	$8.3	Assume contracted transfer from peak to off-peak pricing using the forward price for peak and flat profile contracts. Two hour storage based on typical thermal characteristics of buildings and electricity battery storage. Higher value based on half the rate of value decline of base case.
Voltage control to defer capacity banks	$0.2	$0.3	Where the microgrid capacity is large enough to defer some capacitor banks, either for replacement or new assets. Higher value based on doubling the value.
Loss savings due to load shifting from peak to off-peak periods	$3.5	$4.5	Indicative only. based on a load shift of 373 MW from 84.3% to 90% percentile load to 44.3% to 50% load for two hours on every work-day using electricity contract prices. Higher value using half the contract price decline from 2018/19
Total value $M/year	$22.3	$35.8	

The highest aggregate values are at Morwell ($3.7 m/yr), Bendigo ($3.0 m/yr) and Tyabb ($2.8 m/yr). If network projects are deferred, Geelong moves to the top of the list of highest aggregate values at $4.9 m/yr). Geelong, Morwell and Bendigo have higher quantities of load at risk and would benefit more from provision of ancillary services than network support.

6.4.4 Unquantified Economic Value

The following sources of economic value of microgrid control have not been quantified:

- The extra emission abatement achieved because enhanced control reduces barriers to connection of solar PV resources. This would require analysis of hosting limits for connection of solar PV and the impact of distributed voltage control.
- The scope to synchronise emergency power plants than currently only run in island mode. It is considered that existing plants are costly to connect and do not offer net economic value.
- Local disposition of distributed resources through local electricity markets. It is likely that such mechanisms would not create much economic value but may create commercial value for prosumers who become less exposed to retailer margins by buying less power through large scale retail functions.
- Explicit markets for under-frequency and emergency load shedding schemes that allow prosumers to earn revenue by being on an emergency load shedding register effected by microgrid control rather than distribution feeder disconnection as happens currently.
- The value of resiliency if microgrids can island and continue to provide essential services when the local power system is blacked out under extreme conditions or multiple outages.

TABLE 13: **DISTRIBUTION OF CONSERVATIVE MICROGRID VALUE ACROSS THE TERMINAL STATIONS (LEVELISED AT 6% DISCOUNT RATE 2018/19 TO 2022/23)**

Levelised Values/Year		TLF (2018/19)	Network	Ancillary Service	2 Hour Load Shift	Voltage Control	Levelised MVAr	Total Value	Levelised Quantity	Value $/ year
			$/kVA/yr	$/kW/yr	$/kW/yr	$/kVA/yr		$/kW/yr	MVA	$m/year
HOTS 66 kV	Horsham	0.9957	155.29	64.32	19.73	5.9	0.00	178.19	2.99	0.5
TTS 66 kV	Thomastown	1	107.32	64.60	19.82	5.9	0.00	129.33	6.10	0.8
KTS 66 kV	Keilor	1.0024	91.13	64.75	19.87	5.9	0.00	112.86	0.15	0.0
RTS 66 kV	Richmond	1.0012	4.23	64.67	19.84	5.9	3.62	87.09	8.31	0.7
BLTS 66 kV	Brooklyn	1.0192	0.00	65.84	20.20	5.9	0.00	86.04	0.00	0.0
KGTS 66 kV	Kerang	1.0192	1.56	65.84	20.20	5.9	0.00	86.04	1.42	0.1
BETS 66 kV	Bendigo	1.0139	2.50	65.49	20.09	5.9	0.00	85.59	36.28	3.0
MWTS 66 kV	Morwell	0.9879	1.26	63.81	19.58	5.9	18.15	85.82	44.20	3.7
RCTS 66 kV	Red Cliffs	1.0062	0.00	65.00	19.94	5.9	0.00	84.94	1.09	0.1
ATS 66 kV	Altona	1.0054	0.00	64.95	19.93	5.9	0.00	84.87	0.00	0.0
ATS/BLTS 66 kV	Altona/Brooklyn	1.0054	0.00	64.95	19.93	5.9	0.00	84.87	0.00	0.0
DPTS 66 kV	Deer Park	1.0038	0.00	64.84	19.89	5.9	0.00	84.74	0.00	0.0
FBTS 66 kV	Fisherman's Bend	1.0034	0.00	64.82	19.89	5.9	0.00	84.70	0.00	0.0
WMTS 66 kV	West Melbourne	1.0029	59.38	64.78	19.88	5.9	0.00	84.66	4.92	0.4
MBTS 66 kV	Mount Beauty	0.9882	38.54	63.83	19.58	5.9	0.00	83.42	2.11	0.2
CBTS 66 kV	Cranbourne	0.9957	19.63	64.32	19.73	5.9	0.00	84.05	9.80	0.8
TBTS 66 kV	Tyabb	0.9958	17.94	0.00	19.74	5.9	0.00	38.04	73.98	2.8
TGTS 66 kV	Terang	1.0149	9.67	0.00	20.11	5.9	0.00	29.98	23.85	0.7
GNTS 66 kV	Glenrowan	0.9903	8.85	0.00	19.63	5.9	0.00	28.66	9.18	0.3
MTS 66 kV	Malvern	0.9971	4.97	0.00	19.76	5.9	0.00	24.84	4.86	0.1
TSTS 66 kV	Templestowe	1.0006	2.04	0.00	19.83	5.9	2.52	24.49	5.79	0.1
SHTS 66 kV	Shepparton	1.0002	4.09	0.00	19.82	5.9	0.00	24.00	2.45	0.1
GTS 66 kV	Geelong	1.0002	3.98	0.00	19.82	5.9	0.00	23.88	51.07	1.2
WOTS 66 kV	Wodonga	0.9712	2.04	0.00	19.25	5.9	3.39	22.91	12.67	0.3
SMTS 66 kV	South Morang	0.9979	2.99	0.00	19.78	5.9	0.00	22.83	59.80	1.3
BTS 66 kV	Brunswick	0.9992	1.91	0.00	19.80	5.9	0.00	21.75	2.88	0.1
HTS 66 kV	Heatherton	1.0001	0.87	0.00	19.82	5.9	0.00	20.71	8.96	0.2
WETS 66 kV	Wemen	1.0066	0.00	0.00	19.95	5.9	0.00	19.95	0.00	0.0
WMTS 22 kV	West Melbourne	1.0019	0.00	0.00	19.86	5.9	0.00	19.86	0.00	0.0
BATS 66 kV	Ballarat	1.0016	0.00	0.00	19.85	5.9	0.00	19.85	0.00	0.0
RWTS 66 kV	Ringwood	1.0012	0.00	0.00	19.84	5.9	0.00	19.84	0.00	0.0
BTS 22 kV	Brunswick	1.0008	0.00	0.00	19.83	5.9	0.00	19.83	0.00	0.0
RTS 22 kV	Richmond	1.0007	0.00	0.00	19.83	5.9	0.00	19.83	0.00	0.0
SVTS 66 kV	Springvale	0.9986	0.00	0.00	19.79	5.9	0.00	19.79	0.00	0.0
ERTS 66 kV	East Rowville	0.9956	0.00	0.00	19.73	5.9	0.00	19.73	0.00	0.0
FTS 66 kV	Frankston	0.9956	0.00	0.00	19.73	5.9	0.00	19.73	0.00	0.0
Total Value	$m/year		$3.99	$7.43	$7.23	$0.16			372.84	$17.47

Note: the "Total value" is less than the sum of the potential components by $1.33 m because network support conflicts with ancillary service value. The higher of the two values has been taken at each location.

TABLE 14: **DISTRIBUTION OF MICROGRID VALUE ACROSS THE TERMINAL STATIONS WITH DEFERRED NETWORK PROJECTS (LEVELISED AT 6% DISCOUNT RATE 2018/19 TO 2022/23)**

Levelised values/year		TLF (2018/19)	Network	Ancillary Service	2 hour load shift	Voltage Control	Levelised MVAr	Total Value	Levelised Quantity	Value $/ year
			$/kVA/yr	$/kW/yr	$/kW/yr	$/kVA/yr		$/kW/yr	MVA	$m/year
KTS 66 kV	Keilor	1.0024	207.77	77.02	19.87	5.9	0.00	231.88	0.23	0.1
SVTS 66 kV	Springvale	0.9986	176.42	76.73	19.79	5.9	0.00	199.81	0.33	0.1
HOTS 66 kV	Horsham	0.9957	152.17	76.50	19.73	5.9	0.00	175.01	3.08	0.5
RTS 66 kV	Richmond	1.0012	4.15	76.93	19.84	5.9	3.75	99.35	8.60	0.8
BLTS 66 kV	Brooklyn	1.0192	77.72	78.31	20.20	5.9	0.00	99.51	15.48	1.5
KGTS 66 kV	Kerang	1.0192	1.56	78.31	20.20	5.9	0.00	98.51	1.43	0.1
BETS 66 kV	Bendigo	1.0139	2.65	77.90	20.09	5.9	0.00	98.00	36.28	3.5
MWTS 66 kV	Morwell	0.9879	1.55	75.91	19.58	5.9	18.15	97.91	44.20	4.2
RCTS 66 kV	Red Cliffs	1.0062	0.00	77.31	19.94	5.9	0.00	97.25	1.09	0.1
ATS 66 kV	Altona	1.0054	0.00	77.25	19.93	5.9	0.00	97.17	0.00	0.0
ATS/BLTS 66 kV	Altona/Brooklyn	1.0054	0.00	77.25	19.93	5.9	0.00	97.17	0.00	0.0
DPTS 66 kV	Deer Park	1.0038	0.00	77.13	19.89	5.9	0.00	97.02	0.00	0.0
FBTS 66 kV	Fisherman's Bend	1.0034	0.00	77.10	19.89	5.9	0.00	96.98	0.00	0.0
WMTS 66 kV	West Melbourne	1.0029	70.61	77.06	19.88	5.9	0.00	96.93	5.14	0.5
BATS 66 kV	Ballarat	1.0016	0.00	76.96	19.85	5.9	0.00	96.81	0.00	0.0
RWTS 66 kV	Ringwood	1.0012	0.00	76.93	19.84	5.9	0.00	96.77	0.00	0.0
BTS 22 kV	Brunswick	1.0008	0.00	76.90	19.83	5.9	0.00	96.73	0.00	0.0
RTS 22 kV	Richmond	1.0007	0.00	76.89	19.83	5.9	0.00	96.72	0.00	0.0
GTS 66 kV	Geelong	1.0002	3.90	76.85	19.82	5.9	0.00	96.67	51.52	4.9
SHTS 66 kV	Shepparton	1.0002	4.39	76.85	19.82	5.9	0.00	96.67	2.45	0.2
HTS 66 kV	Heatherton	1.0001	10.48	76.84	19.82	5.9	0.00	96.66	10.72	1.0
TTS 66 kV	Thomastown	1	62.87	76.83	19.82	5.9	0.00	96.65	20.96	2.0
MBTS 66 kV	Mount Beauty	0.9882	37.53	75.93	19.58	5.9	0.00	95.51	2.18	0.2
TBTS 66 kV	Tyabb	0.9958	22.41	0.00	19.74	5.9	0.00	42.60	77.61	3.2
CBTS 66 kV	Cranbourne	0.9957	22.22	0.00	19.73	5.9	0.00	42.40	39.38	1.6
TGTS 66 kV	Terang	1.0149	9.78	0.00	20.11	5.9	0.00	30.09	23.85	0.7
TSTS 66 kV	Templestowe	1.0006	7.60	0.00	19.83	5.9	3.39	29.92	8.56	0.3
GNTS 66 kV	Glenrowan	0.9903	8.30	0.00	19.63	5.9	0.00	28.09	10.55	0.3
MTS 66 kV	Malvern	0.9971	4.81	0.00	19.76	5.9	0.00	24.67	5.31	0.1
WOTS 66 kV	Wodonga	0.9712	2.04	0.00	19.25	5.9	3.39	22.91	12.67	0.3
SMTS 66 kV	South Morang	0.9979	3.04	0.00	19.78	5.9	0.00	22.88	59.80	1.3
BTS 66 kV	Brunswick	0.9992	0.91	0.00	19.80	5.9	0.00	20.74	25.09	0.5
WETS 66 kV	Wemen	1.0066	0.00	0.00	19.95	5.9	0.00	19.95	0.00	0.0
WMTS 22 kV	West Melbourne	1.0019	0.00	0.00	19.86	5.9	0.00	19.86	0.00	0.0
ERTS 66 kV	East Rowville	0.9956	0.00	0.00	19.73	5.9	0.00	19.73	0.00	0.0
FTS 66 kV	Frankston	0.9956	0.00	0.00	19.73	5.9	0.00	19.73	0.00	0.0
Total Value	$m/year		$7.32	$15.36	$9.05	$0.17			466.51	$28.15

Note: the "Total value" is less than the sum of the potential components by $3.75 m because network support conflicts with ancillary service value. The higher of the two values has been taken at each location.

6.4.5 Commercial Value Components

Assessing whether the above economic value can be acquired by microgrid operators and their customers depends on the regulatory and commercial framework in which they operate. Assuming no barriers to commercial activity, we outline how each of these value streams could be accessed in theory. There are also some non-economic values which can be accessed even where there is no economic value. These issues are summarised in Table 15.

A further analysis of the quantified economic value components is provided in Table 15 to show how the economic value may be distributed in the form of commercial values. All of the value streams would be accessible to microgrids and their participants except the benefits from reduced loss factors. There is no mechanism in the NEM to transact loss reduction benefits. These benefits would flow to non-participants and the prosumers would receive the estimated loss reduction for their own consumption.

This raises the important regulatory question about the ability to contract loss reduction benefits in the electricity market. There is currently no scope for this. Generators are exposed to low loss factors and consumers are exposed to high loss factors and some investments can be generally beneficial or of adverse impact to some parties. If microgrid control can generate significant value for non-participants by flattening load profiles, and require some incentive to do so, then ways of transacting this way may be useful.

TABLE 15: **SUMMARY OF THE VALUE OF LOAD CONTROL – COMMERCIAL DISPOSITION**

Source Of Economic Value	Associated Transactions	Disposition of Commercial Value
Network support to reduce expected unserved energy where it is cheaper than network augmentation	Requires network support contracts between prosumers, microgrid, aggregators and NSP.	Commercial value may be less than economic value due to competition and regulation; value would be distributed down the service chain to all contributors based on commercial negotiation. Regulation prevents commercial value exceeding the assessed economic value.
Ancillary services in Victoria for generation raise and lower, contingency and regulation services	Requires market ancillary services contracts between microgrid, aggregators and AEMO to acquire a qualifying quantity for market participation	Commercial value based on ancillary service payments would be distributed down the service chain to all contributors based on commercial negotiation.
Two-hour load shift for controllable load that can serve network support services	Prosumers and microgrid either respond to wholesale or retail price, or aggregate load control for bidding to AEMO as demand side response.	Prosumers receive lower costs in their electricity bills, including network demand and energy charges. Microgrids/Aggregators receive a fee from providing control and communication services. Total commercial value should equal economic value as reflected in electricity trading.
Distributed voltage control to defer capacity banks	May be required as part of solar PV connection or contracted as an aggregated service for NSP.	Prosumers receive a fee for providing voltage control and compensation when energy production is curtailed to increase reactive power support from inverters. Commercial value may be less than economic value.
Loss savings due to load shifting from peak to off-peak periods	Annual adjustment of marginal and average loss factors flows through to all market participants. There is no scope to trade loss reduction benefits among electricity market participants.	Commercial value flows through the whole market with localised benefits where load shifting affects local loss factors. Some prosumers at the fringe of grid may receive much better than the average 0.58% reduction in energy prices that was assessed as the average economic benefit.
Carbon emission abatement from additional solar PV generation	Not assessed but flows to the whole global community.	Commercial benefit arises due to reduced exposure to the risks arising from storms, floods, droughts which become more severe under global warming.

6.5 Appendix: The Unanswered Questions

The outcomes of this White Paper make it clear that there is still a great deal of work required to evaluate the benefits and shortcomings of microgrids and microgrid operators. A number of unanswered questions arise from this review of valuation, policy, market design, and regulation, which may benefit from further analysis.

In some cases, this may be a matter of refining the quantitative analysis; in others, the financial viability of certain actions is uncertain. These items are listed in Table 16 and Table 17.

Matters relating to business models and financial viability of microgrid operations will be investigated in subsequent work.

TABLE 16: **MATTERS AFFECTING QUANTIFICATION OF VALUE**

Unanswered Questions	Recommended Action	Rationale
Valuation of Network Support		
It is unclear from Distribution Annual Planning Reviews (DAPR) how transfer capacity degrades over time and how transfer capacity reduces the energy at risk and the expected unserved energy.	Add the following information to the DAPR; Show the estimated transfer capacity over the forecast period Show how energy at risk is affected by using the transfer capacity Show how the load and energy at risk changes if the preferred network project is added	The information would assist in more quickly assessing the viability of investment in providing load control to address the network support requirement.
The assessment of unserved energy at distribution level is only provided for 5 years on the basis that this period covers the lead time for network expansion and the provision of demand side services. This period is not long enough for investment analysis for microgrid operation. How can DNSPs be required or incentivised to provide a longer term view of value?	Extend the period of review for the DAPR assessment of substations and subtransmission to 10 years to line up with the transmission planning documents. This may need to include sensitivity to options for network reconfiguration which substantially changes subtransmission and substation loading.	The 10 year period is better matched to the lifecycle of monitoring and control technology which is more like 5 to 15 years. This information is needed to assess the value of investment and the life cycle of microgrid controls. The 10 year outlook would also imply the sensitivity to changes in the rate of load growth through the time dimension.
The longer term assessment of the value of alternative provision for ancillary services requires detailed market modelling based on scenario analysis of the transition to renewable energy.	Funding be sought to enhance the investigation of the potential for DER to provide ancillary services as the market transitions to renewable energy.	It appears that this benefit source could be some 25% of the value of microgrid control. A more robust quantification would support investment analysis and the development of aggregated services for aggregated ancillary services.
The magnitude of the potential loss saving from load shifting has only been estimated based on average state loss factors. It is not an accurate assessment. The value would depend very much on location based on local loss factors.	A more detailed assessment based on load flow analysis could show how these loss benefits would flow from specific locations identified as beneficial for microgrid control.	It would provide a more accurate assessment for the aggregate benefit and it would assist in prioritising sites for pilot investment in microgrid control projects where benefits are substantial.

TABLE 17: MATTERS AFFECTING MARKET DESIGN AND DEVELOPMENT

Unanswered Questions	Recommended Action	Rationale
Market Design - Commercialisation		
The review has identified that the value of loss reduction flows generally across all consumers. This represents a part of the current value stream which is not able to be appropriated by microgrid operators and their customers. How could this value be transacted in the energy market? This is a question of market design.	Examine the feasibility of creating a certificate which values the loss saving impact of load shifting through demand side response and battery storage. This may need to be separately evaluated by substation location to reflect local conditions and could be formulated from published loss factors. The value would be based upon actual scheduling of control actions to reduce loads and manage local energy storage.	This would enable the local and system wide benefits of load control to be commercially appropriated by providers of microgrid controls from consumers generally.
Market Design – Roles		
Given the distribution of the benefits of microgrid control, it is preferable if microgrids can be developed in public networks and not be limited to embedded private networks. The roles and responsibilities of network service providers, retailers and microgrid operators in such a scenario have not been defined.	Further work is needed to define the roles and responsibilities of network service providers, retailers and microgrid operators in a microgrid control environment in a public network, say a set of Low Voltage feeders connected to a substation feeder through a distribution transformer, all owned by the local DNSP.	Limiting microgrid operations to private embedded networks would adversely limit the potential for this technology to reach its economic potential.
One concept worthy of consideration is whether microgrid services is an advanced form of retailing or whether it is something entirely different, for example, merely a system control function albeit at a local level.	Further work is needed to investigate the concept of microgrid control as a system control service which can operate independently of the retailing function. The development of the business model in conjunction with any needed regulatory changes is warranted to clarify the role of the microgrid operator.	The retailer would still manage price and volume risk and billing for the consumer in the knowledge of the microgrid arrangements. The microgrid focuses on optimisation and capture of value streams that are opaque at the retail level, such as ancillary services and network support commitments from local resources.
How does a microgrid and customer access the wholesale market value of microgrid controlled load shifting within a retail pricing period when it would normally accrue to the retailer?	A standard form of commercial contract between Retailer, Microgrid and Customer may be needed to facilitate the transfer of commercial value from Retailer to Microgrid and Customer when the retail pricing does not fully capture the value of operations.	Retail pricing arrangements may result in some commercial value of microgrid operations remaining with the Retailer of the Customer unless other arrangements are made. No basis for value transfer would be a disincentive to microgrid operations.
Market Design - Competition		
Is there any evidence that the cost of network support is provided at a price that is closely matched to the avoided network expansion cost and value of expected unserved energy? Does this indicate lack of competition in the provision of demand side services or merely that the industry is immature and that costs are inherently high with existing industry development?	A survey of the cost of network support services as they develop would provide insight as to the state of development of the microgrid services and the level of competition and state of development of commercialisation of these services for policy development.	Promotion of microgrid operations could help the industry down the cost learning curve and deliver lower DER control service costs and prices through increased competition.

FOR MORE INFO, PLEASE VISIT OUR WEBSITE:
monash.edu/net-zero-initiative

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