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Regulatory and Retail Arrangements for Community-owned Embedded Networks

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Abstract

Currently in Australia there is a strong movement of communities seeking to live more sustainably. This is giving rise to the development of community owned and operated micro-grids which incorporate large amounts of renewable energy technology. While this is an emerging movement in Australia, there are still questions surrounding how these micro-grids can operate within the current regulatory and retail frameworks in Australia. This paper explores how the embedded network framework can be effectively applied to community-owned micro-grids. The objective of this paper is to explore the regulatory and retail arrangements for community-owned embedded networks through a case study of Narara Ecovillage.

Working within the embedded network framework has complexities and challenges. To operate an embedded network, the embedded network operator (ENO) must take on the role of network service provider, local retailer and potentially embedded network manager (ENM). There are significant challenges associated with this such as following evolving Australian Energy Market Commission (AEMC) regulations, ensuring retail competition for customers, guaranteeing operational expenditure recovery and designing appropriate retail tariffs.

Design considerations for the ENO tariffs include: recovering costs paid to the external retailer, recovering network operational expenditure, using tariff price signals to manage demand and ideally providing cheaper electricity for the customers than an external retailer would provide. This study designed and modelled potential tariff arrangements and concluded that the optimal tariff is a “Solar TOU” tariff which incentivizes customers to use more electricity during times of excess solar generation. Using the “Solar TOU” tariff, this case study could generate an annual operational profit, and provide a discount to the customers, when compared to a traditional external retailer tariff.

1. Introduction

The current Australian electricity industry is seeing rising electricity prices for consumers, while the generation mix is still largely fossil fuel based, despite the widespread availability of affordable and clean renewable energy resources. There are growing constituencies of energy consumers dissatisfied with these outcomes, that are instigating movements to develop their own solutions: including grassroots community organisations that are forming community-owned and operated micro-grids. However, this movement is relatively new in Australia and there are challenges associated with coordinating a diverse group of people towards creating a technologically advanced and sustainable solution.

A key component of the business model requires coordinated community investment in generation and storage technologies to optimise the micro-grid design and the use of renewable energy resources at a community level rather than on an individual basis. The business model of an embedded network (EN) structure is one viable option for grid-connected micro-grids in Australia and the model is currently a major focus of the community energy industry (LWP, 2016). Research into how community-owned embedded networks can operate within existing regulatory arrangements is limited, therefore this is the focus of this study.

Embedded networks are private electricity networks which serve multiple premises and are connected to a distribution or transmission system at a parent connection point (AEMC, 2015b). The EN has an embedded network operator (ENO) to operate and maintain the local network and has a separate retail function to sell electricity to the embedded network customers. The ENO therefore acts as a network service provider and retailer. The embedded network operator buys electricity from an external retailer at the parent connection point. It then on-sells this electricity to the customers at the child connection points in the embedded network. Embedded networks are most likely to interface with an external retailer through commercial tariffs which typically have a cheaper energy component price than residential or small business tariffs. In addition, the ENO will only have to pay one set of network access charges for the single point of connection. It can then place customers in the EN on a tariff similar to what the customer would obtain from a traditional external retailer. In this way the ENO can cover costs and potentially generate revenue. Rules for embedded networks in Australia were designed for caravan parks, shopping centers and the like. Therefore, they allow little leeway for innovative electricity service offerings or integration of large amounts of renewables typical of community energy projects. This study explores how community-owned embedded networks can work within the current regulatory environment to provide innovative tariff offerings suited to significant uptake of distributed energy.

This paper is based on a case study of a community-owned embedded network, Narara Ecovillage (NEV). Narara Ecovillage has created an energy utility, "NEV Power" which will own and operate the local embedded network. This energy utility will be a network service provider, retailer and generator. This paper explores the regulatory arrangements and designs retail tariff structures for NEV Power.

2. Regulatory Arrangements

Meeting the evolving AEMC regulatory requirements is a key challenge in the development of a community-owned embedded network.

2.1. Embedded Network Exemption

The ENO acts as a network service provider and local energy retailer. To become a network service provider and a retailer, the ENO has to register as being exempt from the regulations that govern conventional energy network service and retail provision. Usually any entity on-selling electricity in a privately owned and operated embedded network will need both a retail exemption and a network exemption from the AER (AER, 2016).

2.2. *Power of Choice Rule Change*

The regulations around embedded networks have recently come into question as an outcome of the Power of Choice Review, which seeks to give customers choice in the way they use electricity (AEMC, 2016). Embedded networks have been identified as an arrangement that could potentially jeopardise the customers' right to choose their energy retailer. Indeed, customers in an embedded network traditionally have not been provided with a choice of retailer. Therefore, a new procedure change for the National Electricity Rules (NER) was published on 1 September 2016 (AEMO, 2016). As of 1 Dec 2017, embedded networks must provide their customers with the option to enter a new contract with an external authorised energy retailer (AEMC, 2015a).

EN customers which are in a contract with an embedded network retailer and seeking to transition to an external retailer face uncertainty and barriers as there is no party responsible for facilitating this transition (AEMC, 2015c). Therefore, a new AEMO accredited role has been created; that of embedded network manager (ENM). The ENM will perform the market interface functions that link embedded network customers to the NEM systems (AEMC, 2015b), including to facilitate transfer of customers from the embedded network to an external authorised retailer. The ENM must maintain metering information at the parent and child connection points of the EN, and act as an interface between customers in the EN and AEMO retail operations (AEMC, 2015a). The ENs that are required to appoint an ENM are those which have more than 10 occupants. It is the responsibility of the ENO to pay for the ENM services, which increases costs for embedded networks (AEMC, 2015a). This rule change means that embedded networks must ensure that their energy retail services are competitive with external retailers in order to ensure they keep their customers.

3. Case Study

3.1. *Case Study Background*

The case study, Narara Ecovillage (NEV) is pioneering in the community energy space to develop new retail arrangements suitable for their embedded network. NEV will have an embedded network operator (ENO) "NEV Power" which will be a network service provider and retailer. The AER has accepted NEV Power's application for exemptions from both retailer and network operator authorisation (Roxburgh, Evans, & Serjeantson, 2015). The first stage, and the stage that is considered in this study, will include 60 residences, multiple commercial buildings, 533 kW of solar PV, smart system control and power quality control. Each house will have a solar PV system, smart meter and remote energy management technology. NEV Power will also own and operate a 79.9kWh central battery bank and commercial scale PV systems. NEV is currently in the civil works phase and house constructions will begin in 2017.

3.2. *Tariff Design Considerations*

This section explains the design considerations taken into account when developing an internal tariff for NEV Power to charge to the customers of the embedded network. ENOs usually place customers within the EN on standard TOU or flat rate tariffs similar to what they would obtain from a traditional retailer (Metering Dynamics, 2016). However, community-owned embedded networks may be seeking innovative tariff structures to help them meet renewable energy targets which are aligned with the considerations discussed in the following sections.

3.2.1. *NEV Power Cash Flows*

NEV Power will purchase electricity from an external retailer and on sell it to the residences, commercial buildings and NEV Water. Residents, commercial space owners and NEV Water will enter into energy sales contracts with NEV Power. NEV will also facilitate trade of the onsite solar generation from the customer-owned residential PV systems and ENO owned commercial PV systems. It has been assumed in this study that the electricity from the residential PV systems will be purchased from residents through a feed-in tariff (FiT), as NEV has indicated this is necessary (Parris, Roberts, & Roxburgh, 2016). The electricity from the commercial-scale PV systems will be owned by NEV Power. The solar electricity generated by the commercial and residential systems will be used to offset consumption within the NEV grid and avoid purchase of energy from the external retailer. Because it may sometimes be exported to the external grid, NEV Power aims to negotiate a FiT from an external retailer. NEV will enter into a TOU high voltage commercial energy sales contract with an external authorised retailer at the parent connection point.

3.2.2. *Cost Recovery*

NEV Power must set the EN tariffs so that they recover their operational costs. The capital costs of the NEV grid have been excluded from this study, as it is assumed they will be recovered through levy or rent type charges. The operational costs have been included because these are costs that NEV must recover each year through either electricity sales revenue or levy or rent type charges. These costs cannot be recovered directly through tariffs as outlined in the AEMC conditions section below. The two main types of operational costs that NEV must recover are;

1. External party electricity costs. This includes Ausgrid and Transgrid Time of Use (TOU) high voltage network charges and an assumed retail markup of 7c/kWh.
2. Embedded network operation and maintenance (O&M) costs. This includes grid and EN retail operational expenditure of $60,000 p.a. (Parris et al., 2016).

3.2.3. *AEMC Embedded Network Conditions*

NEV Power must also design EN retail tariffs to abide by the relevant AEMC conditions. The AEMC has two major conditions outlined in the National Electricity Amendment (Embedded Networks) Rule 2015 for exempt retailers and network operators with regards to tariff pricing. The first requirement concerns the retail component of the EN tariff. This requirement is that embedded network operators may not charge small commercial or residential customers more than the “standing offer” price of the relevant local retailer for retail services (AEMC, 2015c).

The second requirement concerns the network component of the EN tariff. This requirement is that the network element of embedded network operators’ charges can only relate to passing through the parent LNSP’s network charges from the parent connection point (AEMC, 2015c). This means that embedded networks cannot charge for the provision or O&M of the embedded network through tariffs. In terms of passing through the LNSP charges, which includes Distribution Use of System (DUOS) and Transmission Use of System (TUOS) charges, two means of doing this have been suggested by the AEMC which include;

1. "Shadow pricing", whereby the ENO charges the customer the same tariffs that the parent LNSP would charge customers of the same type (AEMC, 2015c). Shadow pricing would mean placing the EN customers on the DUOS, TUOS and Climate Change Fund (CCF) prices that they would normally pay if connected to an external authorized retailer. This means placing customers on residential or small business tariffs which can generate a large amount of revenue for the ENO.
2. "Causer pays" pricing whereby the ENO apportions the LNSP costs to the customers in proportion to the metered energy consumption of the customer over the given period (AEMC, 2015c). Charging the network elements on a causer pays basis was modelled by placing the internal EN customers on the same NSP energy component tariff that is faced by NEV Power, dividing network access charges evenly through the customers and passing through the demand charges in proportion to the amount of energy consumed. This therefore represents a straight cost pass through of NEV's parent connection electricity costs, and will result in cost recovery of NEV's electricity costs only, with no profit being generated from electricity sales. These different pricing strategies have been illustrated in Figure 1.

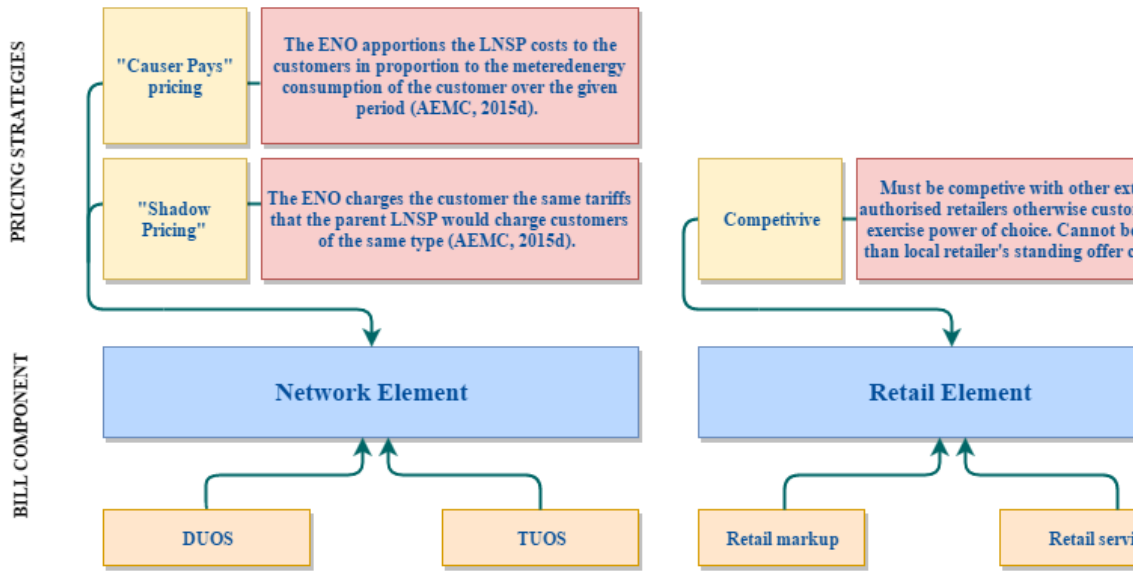

Figure 1: Pricing strategies available with bills components.

The reason that embedded network operators are not permitted to charge for EN O&M expenditure through tariff rates is to prevent ENOs from over-recovering network charges (AEMC, 2015c), and to incentivize ENOs to pass on savings negotiated at the parent connection point (AEMC, 2015c). This means that it is not possible for NEV Power to pass through the O&M cost directly to the customers as a dedicated component of their tariffs. Therefore, there are two ways the ENO can recover O&M costs;

1. By using "shadow pricing" (together with competitive retail charges that are less than the standing offer charges of retailers) the ENO will be able to generate a profit through electricity sales. This does not represent a direct pass through of embedded network O&M costs to the customers but rather works within the limitations set by the AEMC to design tariffs provide a profit to the ENO. This

profit can be used to fund the $60,000 p.a. O&M cost of the network. This is the chosen method and will be tested in the model, and if unsuccessful, a levy or rent type charge can be implemented.

2. A levy, rent or other similar mechanism has been suggested by the AEMC to provide O&M cost recovery; "e*mbedded network operators may be able to recover the costs of running the embedded network through non-electricity charges (for example, rent)*." (AEMC, 2015c).

3.2.4. Tariff Design Goals

With the AEMC regulations taken into account, tariff design goals and judgement criteria were formulated as shown in Table 1. In addition to these goals, a FiT of 6 c/kWh for NEV residents has been assumed, which is within the benchmark FiT range of 5.5 -7.2 c/kWh recommended by IPART for 2016/17 (NSW Department of Resources and Energy, 2016), and equal to that offered by the retailer used for comparison, Origin, which offers a 6c/kWh FiT.

Table 1: Design goals and judgement criteria for internal network tariffs

Design Goal	Explanation and Judgement Criteria
Maximise operational profit for NEV Power.	Profit provided to NEV Power is evaluated through cash flow modelling. If the operational profit is positive, it indicates that network O&M expenditure has been recovered and a levy will not be needed.
Provide 15% discount for customers compared to an external retailer tariff.	Provide a discount for customers compared to the relevant local retailer standing offer charges (in order to ensure NEV Power is competitive). NEV aims to provide a 15% discount on current prices for customers, however the final discount will be determined by the project's rate of return (Roxburgh, 2016). This will ensure customer satisfaction and limit any potential grid defection (Roxburgh et al., 2015).
Allocate costs fairly between customers.	Consistency of discounts for customers is a goal, because providing a discount to all customers evenly is better than providing a large discount to one customer and a small one to another. This was judged by evaluating the ratio of the minimum discount to the maximum discount (ideal value is 1).
Incentivize consumption in the solar export period.	The onsite solar energy is either free for NEV Power if coming from the NEV-owned commercial systems, or costs approx. 6c/kWh if bought from the residents through the FiT, which is cheaper than the external retailer tariff. Therefore, the cheapest energy for NEV to purchase is the solar export. The incentive to self-consume solar also applies to NEV residents; if they are net metered, there is more incentive for them to self-consume their solar energy than to pay the (substantially higher) energy tariff to NEV Power to run the appliance at another time. This will ensure the most economically efficient use of the onsite solar generation.
Appropriateness of tariff for customers.	This is based on a subjective review of the tariff.

3.3. Methodology

A model was created in Excel to evaluate the cash flows of NEV Power, NEV residential and commercial customers, the external retailer, DNSP and TNSP. The impacts of potential EN tariff structures were explored through scenario modelling. Note that these scenarios focus on ensuring annual discounts on electricity bills for residences rather than commercial buildings and NEV Water, as the commercial buildings have been shown to have a high discount in all acceptable scenarios (Bowyer, 2016). The potential tariff structure scenarios modelled were;

1. Scenario 1: Straight cost pass through – using "causer pays" network charges.
   a. No residential or commercial PV systems
   b. With residential and commercial PV systems
2. Scenario 2: TOU – using "shadow pricing" of TOU network and retail charges.
   a. TOU standing offer from Origin Energy
   b. TOU with 15% discount on tariff components, giving 22% annual discount.
   c. TOU with 9% discount on tariff components, giving 15% annual discount.
3. Scenario 3: Flat rate – using "shadow pricing" of flat rate network and retail charges.
   a. Flat rate standing offer from Origin Energy
   b. Flat rate with 15% discount on tariff components, giving 3% annual increase.
   c. Flat rate with 24% discount on tariff components, giving 15% annual discount.
4. Scenario 4: Solar TOU, designed specifically for NEV Power, further explained below.

Within the Solar TOU tariff design, various tariff structures were tested as shown in **Error! Reference source not found.** below to determine the optimal tariff design. The Solar TOU was designed so that it provided retail prices less than the standing offer TOU charges from Origin Energy. The Solar TOU tariff was designed based on Origin standing offer TOU charges therefore it is a form of "shadow pricing". In the Origin Energy residential and commercial TOU tariffs, the ratio of peak to shoulder price is approx. 0.5 and the ratio of peak to off peak price is approx. 0.25 (Origin Energy, 2016d). These ratios were used to inform the design of this solar TOU tariff. In the Origin TOU tariffs, the commercial energy tariff prices were approximately equal to the residential energy tariff prices: therefore, commercial energy prices have been set to equal the residential energy prices. The Solar TOU time schedule has been chosen in order to most effectively pass through the Ausgrid TOU time schedule and to incentivize consumption in solar periods. It incentivises consumption in the solar period by setting the off peak period to include the solar export period which was 9am-3pm on average. The solar TOU tariff schedule is shown in Table 2. Various applications of annual electricity bill discounts for customers, daily network access charges, demand charges and metering scenarios were explored (scenarios 4A-4F) to determine the optimal tariff scenario as shown in Appendix B. The daily network access charges were either applied using "shadow pricing" principles or "causer pays" principles. Appendix A shows the tariffs for Scenarios 1, 2 and 3 and Appendix B shows the tariffs for Scenario 4.

Table 2: Solar TOU Tariff and Schedule

TOU Period	Charge	Time Schedule
Residential Peak TOU (c/kWh)	49.7	Working weekdays 3pm – 8pm
Residential Shoulder TOU (c/kWh)	21.5	Weekdays 7am-9am and 8pm-10pm, weekends 3pm-10pm
Residential Off peak TOU (c/kWh)	10.7	All other times

3.4. Results

The revenue and costs of external parties are shown in Figure 2. The external retailer was found to obtain a loss through their energy retail with NEV, due to paying NEV a large FiT. In the model, the retailer was assumed to provide a retail mark-up of 7c/kWh on DUOS and TUOS charges. As direct retail with NEV Power is not profitable for the retailer, it is possible that NEV may not be able to access the proposed 7c/kWh retail mark-up. However, the retailer can onsell the electricity bought from NEV through the FiT, thereby offsetting their loss and increasing the chance that a low retail mark-up will be negotiated at the parent connection point.

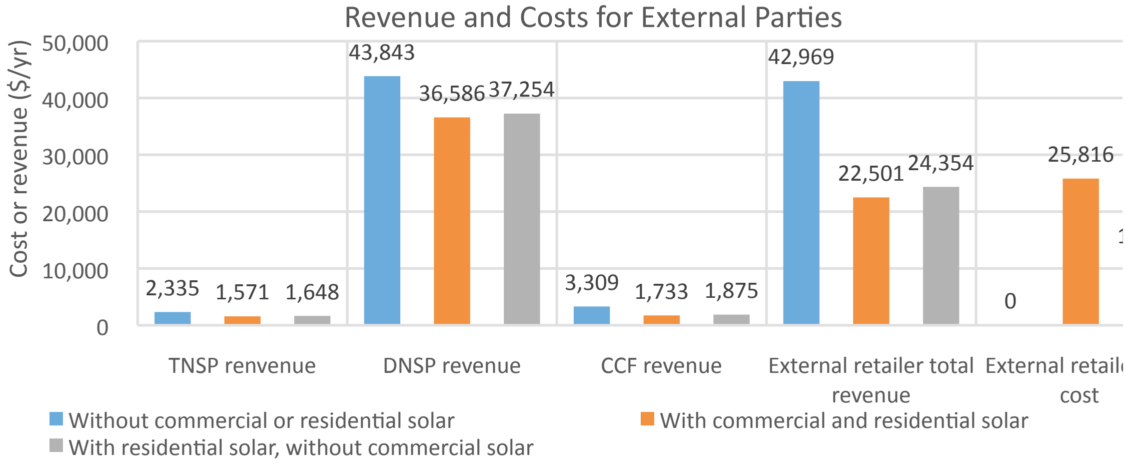

Figure 2: Revenue and Costs for External Parties

The average residential discount and NEV operational profit (taking into account annual O&M cost of $60,000) are shown in Figure 3 below. The acceptable cases are when the residential discount is positive and approximately 15%, and when the NEV operational profit is greater than zero and the discount ratio is as close as possible to 1. Therefore, the acceptable scenarios are 2C, 3C and 4A.

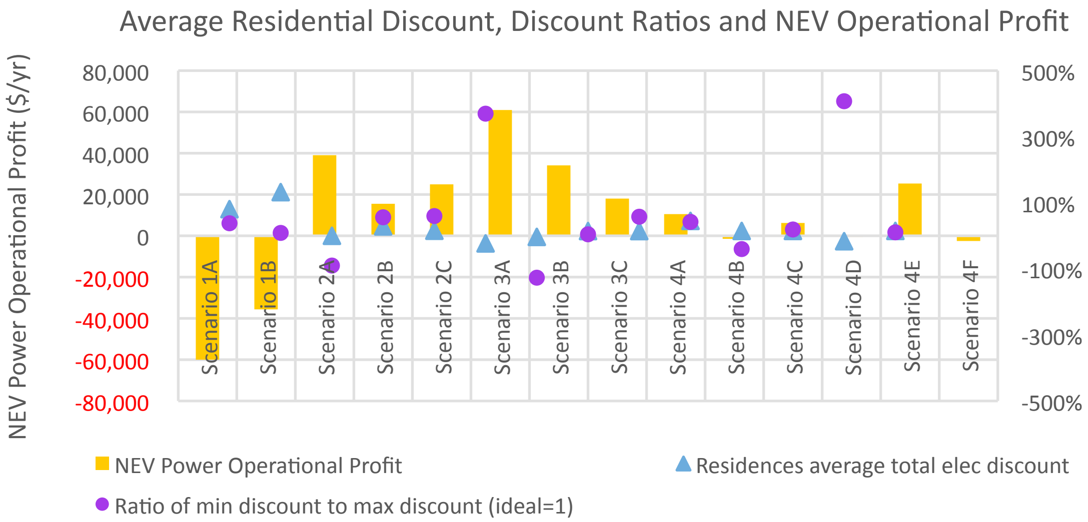

Figure 3: Average residential discount and NEV operational profit

Scenario 1, using straight cost pass through in a "causer pays" manner, did not perform well as although it recovered the external electricity costs of NEV, it does not recover the EN O&M costs. As expected, Scenario 1A with no residential or commercial solar PV systems resulted in a profit of -$60,000 for NEV because this scenario represented a straight pass through of electricity costs, therefore there was no recovery of O&M costs.

The Origin TOU tariff with 9% discount on tariff components (scenario 2C) provided the highest profit to NEV while also providing an average 15% annual electricity price discount to residences. The Origin flat rate tariff with 24% discount on tariff components (scenario 3C) was the next best scenario as it provided the second highest profit to NEV while also providing an average 15% annual electricity price discount to residents. The Solar TOU scenario 4A, which is a TOU tariff with a new time schedule providing cheap electricity in solar periods, was the third best scenario as it also provided 15% average discount to residents and a high NEV operational profit. The recommended tariff scenario was therefore scenario 4A, as NEV has indicated the desired tariff structure is the Solar TOU as it incentivises consumption of solar generation.

The various sub categories in Scenario 4 explore different ways to set the Solar TOU tariff including different network access charges, demand charges and gross metering. Demand charges, used in tariffs 4C and 4D, were concluded to be too variable, evident in the high discount ratio for these scenarios. They are likely to be unequitable and rejected by residents at NEV, therefore demand charges have been excluded. In addition, “shadow pricing” network access charges were concluded to be more appropriate than “causer pays” (4B) as the shadow pricing option provides a larger network access charge. Since all customers pay the same network access charge regardless of consumption, then a larger network access charge gives a more consistent discount ratio. Net metering for NEV residents is preferred over gross metering (4E, 4F) as net metering provides a higher discount for NEV customers and a larger incentive for residents to use energy during solar periods.

A notable finding was that Origin standing offer flat rate charges from Scenario 3 resulted in residential energy bills that were, on average, 23% more expensive than standing offer TOU energy bills. This could be partly due to the structure of the flat rate tariff, which is a declining block tariff. Since most of the customers at NEV are expected to be low energy users, and were based on a sample of load profiles with average energy use of 2,962kWh/yr (compared to the average customer in the Ausgrid solar homes dataset which has average energy use of 6,416 kWh/yr) and also export solar for most of the day, then they will be falling into the first, most expensive energy consumption bracket for the majority of the time, thus giving them more expensive electricity that the average customer.

It is acknowledged that assessing the equity of tariffs according to the discount they provided compared to an Origin TOU standing offer tariff is a limitation of this study. When customers were placed on tariffs that were more similar to Origin TOU tariffs, they would seemingly have a more consistent discount. This meant that tariffs that were more similar to Origin TOU tariffs performed more favourably on this point.

4. Discussion

A major issue identified through this study is that the AEMC regulations for embedded networks do not allow ENOs to recover EN operational expenditure directly through electricity tariffs. The results have shown that these grid O&M costs can however be recovered through electricity sales revenue. However, if the O&M expenditure is more than the proposed $60,000 pa, then there is a high risk of the costs not being recovered. This is because NEV's operational profit is $10,502 p.a. in the recommended tariff scenario 4A (after the $60,000 O&M expenditure) and so there is not a large amount of leeway to contribute towards potential additional costs. Additional O&M costs could come in the form of large upgrades to the EN.

There is also a risk that external electricity costs and O&M costs will not be recovered if the external retailer and NSP tariffs are changed when the ENO is using "shadow" pricing. The external retailer was found to obtain a loss through direct energy retail with NEV due to the large FiT that the external retailer must pay to NEV (Bowyer, 2016). Therefore, there is a risk that NEV may not be able to access the proposed retail mark-up of 7c/kWh as it results in an overall loss to the external retailer. However, as the retailer can on-sell the energy bought from NEV in the FiT, they can offset this loss. Nonetheless there is still a small risk that the retailer will be unhappy with the arrangement with NEV, and increase retail prices for NEV. This may result in an annual operational loss rather than profit. In addition, if NSP tariffs increase in the future this could also result in NEV Power costs not being recovered when the ENO is using "shadow" pricing. NSPs may be influenced by the increasing number of embedded networks through reduced connection charges, lower regulated asset base (RAB) growth and lower distribution use of system (DUOS) charges (MHC, 2016). Future DNSP charges may incorporate some means to make up for these lost revenue streams. Under both "shadow" pricing and "causer pays" pricing approaches, if retailers or NSPs increase their tariffs then the ENO must also increase their EN retail tariffs, which may cause pushback from embedded network customers or cause the customers to leave the embedded network. This may also result in O&M expenditure not being recovered. Stable O&M expenditure and external tariffs (e.g. via long term contacts with external parties) are therefore key to de-risking community-owned embedded network projects.

In addition, although the modelling shows that the operational costs will be recovered, it should be noted that there is significant uncertainty in the modelling because not all NEV system information was available and NEV's customers may have different load profiles than those used for the modelling. This indicates that a levy or another form of charge may be necessary to ensure operational expenditure is recovered. This would help de-risk the project and is a potential area for future work.

The Power of Choice rule change which mandates retail competition for embedded network customers is likely to have detrimental impacts on the business case for community-owned ENs. A key consideration in owning and operating an embedded network is the ability to lock in customers over a reasonable payback period. The retailer of choice provision will have a significant impact on embedded network models because it allows the users to 'bypass' the embedded retail supplier and enter into a contract with an external retailer (Howard, 2016). Once a customer opts out it changes the viability of the system, and there is a risk of O&M costs not being recovered from the changing customer base. If a customer leaves the EN, NEV Power will no longer obtain the retail mark-up from that customer, therefore they may not be able to recover the O&M costs. In addition, implementing an embedded network manager has been found to be potential challenge and additional cost. It should also be acknowledged that since customers have made a choice to live in an ecovillage, they may be loyal to the cause and therefore unlikely to leave the EN retailer. In addition, tariffs have been designed to provide a discount for customers in the embedded networks, therefore ensuring that customers are unlikely to opt out of EN retail. If customers do not opt out, this may prevent NEV from the need to employ an embedded network manager, as the services of the ENM will not be required to transfer customers out of the EN. It will also ensure that NEV obtains the predicted electricity sales revenue from its customers thereby ensuring O&M cost recovery.

The risk of not recovering costs could be mitigated through regulation that allows for cost recovery for the owner of the embedded network. While retail competition is a sensible goal in many circumstances, in embedded networks it is important to recognise that the retailing of electricity and network ownership and operation are intrinsically linked, particularly when the ENO has installed advanced control, monitoring and pricing arrangements (Howard, 2016). A potential solution is to allow for multiple retailers in an embedded network and specific regulations that allow system cost recovery for the embedded network owner (Howard, 2016).

5. Conclusion

In conclusion, the retail and regulatory arrangements currently in place for embedded networks place restrictions on community projects. Ideally they would provide for flexible to ensure the EN framework can be applied to new and innovative community living approaches, however evidently the regulations are becoming more prescriptive and creating barriers for ENs. In protecting consumer choice, regulators should recognise that ENs are one of the emerging electricity retail options that consumers are increasingly choosing, and take a whole systems approach to EN regulation that enables cost recovery, recognises the potential benefits ENs can provide to the external grid, and recognizes the inextricable link between retail and operation of ENs.

Despite the challenges, this study has showed how communities can work within the regulations to ensure the embedded network structure can be effectively applied to community energy projects throughout Australia and how these communities can best use their solar assets through retail tariff design. The most suitable retail tariff was found to be a Solar TOU which provides cheap electricity during the solar period, thereby encouraging onsite consumption of solar PV generation. Future work should include exploration of other tariff arrangements, integration of the embedded network manager, implementation of multiple tiers of retailers and exploration of suitable regulatory instruments to allow cost recovery for the embedded network owner.

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Appendix A

Table 3: Tariff scenarios pricing and structure for Scenario 1, 2 and 3

Scenario	**Scenario 1**		**Scenario 2 (TOU)**				**Scenario 3 (flat rate)**			
Case	**1A (no solar) and 1B (with solar)**	Time	**Scenario 2A**	**Scenario 2B**	**Scenario 2C**	Time	**Scenario 3A**	**Scenario 3B**	**Scenario 3C**	Block
Description	Straight Cost Pass Through - "causer pays"		TOU Standing Offer –"shadow pricing" (Origin Energy, 2016b)	15% discount on all tariff components	9% discount on all tariff components		Flat Rate Standing Offer - "shadow pricing" (Origin Energy, 2016a)	15% discount on all tariff components	24% discount on all tariff components	
Residential network access charge (c/day)	57.508		99.000	84.150	90.090		88.660	75.361	67.382	
Residential Peak TOU OR FR Block 1 Price (c/kWh)	11.891	Working weekdays 2pm-8pm	52.800	44.880	48.048	Working weekdays 2pm-8pm	27.005	22.954	20.524	First 10.9859 kWh/day
Residential Shoulder TOU OR FR Block 2 Price (c/kWh)	10.239	Working weekdays 7am-2pm and 8pm-10pm	21.450	18.233	19.520	Working weekdays 7am-2pm and 8pm-10pm, weekends 7am-10pm	26.510	22.534	20.148	Second 10.9859 kWh/day
Residential Off-peak TOU OR FR Block 3 Price (c/kWh)	9.583	All other times	13.200	11.220	12.012	All other times	24.200	20.570	18.392	Third 10.9859 kWh/day
Residential demand charge (c/kVA/day)	24.275		0.000	0.000	0.000		0.000	0.000	0.000	
Residential demand charge application	Time of NEV's max demand		NA	NA	NA		NA	NA	NA	
Residential Metering scheme	Net		Net	Net	Net		Net	Net	Net	
Residential Feed in tariff (c/kWh)	6		6	6	6		6	6	6	
Commercial network access charge (c/day)	115.017		192.500	163.625	175.175		194.700	165.495	147.972	
Commercial Peak TOU OR FR Block 1 Price (c/kWh)	11.891	Working weekdays 2pm-8pm	51.500	43.775	46.865	Working weekdays 2pm-8pm	30.910	26.274	23.492	First 27.3973 kWh/day
Commercial Shoulder TOU OR FR Block 2 Price (c/kWh)	10.239	Working weekdays 7am-2pm and 8pm-10pm	24.233	20.598	22.052	Working weekdays 7am-2pm and 8pm-10pm, weekends 7am-10pm	30.580	25.993	23.241	Second 27.3973 kWh/day
Commercial Off-peak TOU (c/kWh)	9.583	All other times	13.365	11.360	12.162	All other times	NA	NA	NA	
Commercial demand charge (c/kVA/day)	24.275		0.000	0.000	0.000		0.000	0.000	0.000	
Commercial demand charge application	Time of NEV's max demand		NA	NA	NA		NA	NA	NA	

Appendix B

Table 4: Tariff scenarios pricing and structure for Scenario 4 - Solar TOU

	Parameter	Scenario 4A	Scenario 4B	Scenario 4C	Scenario 4D	Scenario 4E	Scenario 4F	Scenario 4G	Scenario 4H	Times
Scenario Information	Residential Discount Target	15%	15%	15%	15%	NA	15%	NA	15%	
	Network access charge application	Shadow	Pass through	Shadow	Shadow	Shadow	Shadow	Shadow	Shadow	
	Demand charge application	None	None	Time of NEV's max demand	Time of residence's max demand	None	None	None	None	
	Metering scenario	Net	Net	Net	Net	Gross	Gross	Net	Net	
	Solar scenario	All	All	All	All	All	All	No PV commercial	No PV commercial	
Tariff Charges	Residential network access charge (c/day)	99.000	57.508	99.000	99.000	99.000	99.000	99.000	99.000	
	Residential Peak TOU (c/kWh)	49.700	52.800	45.000	44.000	49.700	44.000	49.700	47.000	Working weekdays 3pm – 8pm
	Residential Shoulder TOU (c/kWh)	21.500	21.450	16.000	15.000	21.500	14.000	21.500	19.000	Working weekdays 7am -9am and 8pm -10pm, weekends 3pm - 10pm
	Residential Off peak TOU (c/kWh)	10.700	13.200	9.000	7.500	10.700	7.500	10.700	10.000	All other times
	Residential demand charge (c/kVA/day)	0.000	0.000	24.275	8.800	0.000	0.000	0.000	0.000	
	Residential Feed in tariff (c/kWh)	6	6	6	6	6	6	6	6	
	Commercial network access charge (c/day)	192.500	115.017	192.500	192.500	192.500	192.500	192.500	192.500	
	Commercial Peak TOU (c/kWh)	49.700	52.800	45.000	44.000	49.700	44.000	49.700	47.000	Working weekdays 3pm – 8pm
	Commercial Shoulder TOU (c/kWh)	21.500	21.450	16.000	15.000	21.500	14.000	21.500	19.000	Working weekdays 7am -9am and 8pm -10pm, weekends 3pm - 10pm
	Commercial Off peak TOU (c/kWh)	10.700	13.200	9.000	7.500	10.700	7.500	10.700	10.000	All other times
	Commercial demand charge (c/kVA/day)	0.000	0.000	24.275	8.800	0.000	0.000	0.000	0.000	