Battery Storage and Grid Integration Program

Meter Unbundling

Final Report

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Executive Summary

A critical part of successfully achieving a global energy transition is ensuring significant consumer participation through uptake of distributed energy resources (DER). DER includes technology such as solar PV, battery storage and electric vehicles. One commonly discussed obstruction for further DER uptake by consumers is the cost and complexity of acquiring and benefitting from these technologies through market participation.

The Battery Storage and Grid Integration Program (BSGIP) at The Australian National University (ANU) has been working to address barriers to electrification by developing and advocating for more just, accessible, and equitable system and market participation models for DER. These models aim to explicitly consider and manage the need for complexity with accessibility, consumer value drivers, and contextual factors that may challenge uptake.

The Australian Energy Market Operator (AEMO) has recently proposed a Flexible Trading rule change, intending to help reduce the cost and complexity of consumer market participation and increase consumer DER uptake. To do so, the rule change proposes to provide an easier mechanism for individually metering sub-circuits in households. Within the scope of this rule-change proposal is the concept of *meter-unbundling* – that is, using the increased fidelity provided by these sub-meters to provide simple and understandable ways of integrating DER into the market. The rule change would enable additional metering of circuits or devices within a household, which could be managed by separate retailers. This effectively enables a house to select different retailers and tariffs for different aspects of their energy supply, with the intent of better supporting flexible integration of DER. Historical evidence suggests, however, that the benefits are neither guaranteed to eventuate nor apply in a fair and just manner for consumers. Past attempts to incentivise consumers to actively engage with energy do not appear to have led to widespread adoption of these mechanisms.

It is therefore vital that the uptake landscape is critically analysed before implementing such a change. If we are to learn the lessons of previous attempts we must fully understand their outcomes. This includes analysing the assumptions that have underpinned them. For example, how did the realised benefits differ from the proposed ones? Why were reforms implemented as they were? What defines the edges of what is acceptable behaviour? What could be different if we changed underpinning assumptions? This report and the research underpinning it is an attempt to explore the how such large-scale change can affect consumers both positively and negatively, to help inform the reform process and hopefully lead to better and more consistent outcomes for consumers.

Through a philanthropic donation BSGIP has been given the opportunity to explore ways in which novel metering arrangements can be evaluated as a vehicle to increase household electrification, reduce consumer energy costs, and genuinely improve household experience of their energy supply. In particular we focused on the concept of meter unbundling to provide simple and understandable ways of integrating DER, enabling consumer market participation and benefit.

To develop this report, BSGIP used our strong technical understanding of the Australian energy system, coupled with expertise in socio-techno-economic (STE) analysis to consider a wide array of impacts of energy change, in this case changes to energy metering. The project team leveraged BSGIP’s existing capabilities and expertise to develop an analysis framework – described in detail in Section 1 – which allowed us to gain a deeper insight into the potential impacts of the proposed changes on consumers. This framework enabled a more profound investigation into questions that are inherently difficult to engage with from social, technical and economic perspectives in isolation.

The process that we followed is in Figure 1.

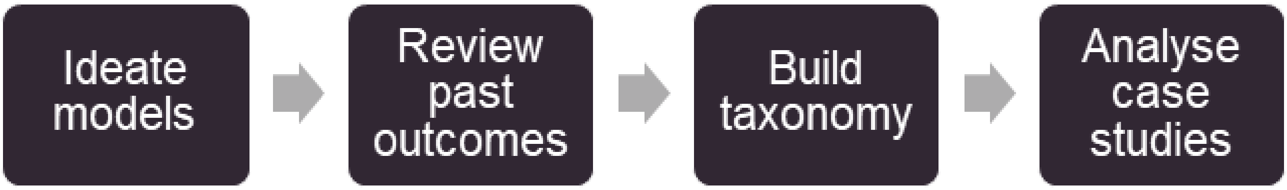

Figure 1 Project process steps

We developed a suite of eighteen models of new approaches to metering; from concepts that are feasible under Flexible Trading through to thought experiments that explore the reasons why metering exists, and what alternatives might be possible.

To reduce the number of models we need to analyse we developed a taxonomy. This taxonomy emerged through an analysis of the 18 models and was based on the concept of *flex dimensions*. Our observation of the Flexible Trading reform was that it aimed to increase the flexibility of metering, specifically by allowing additional metering points below the existing ones. The 18 models expanded this concept by adding two other dimensions along which metering could be flexible, described in Table 1. These categories are discussed in more detail in Section 3.

Table 1 Flex dimensions

Down flex	Down flex is where additional metering points are created **below** an existing meter. This adds additional meters behind consumer connection points
Up flex	Up flex us where additional metering points are created **above** an existing meter. This adds metering points into the shared network. The existing meter may be removed in some cases.
Friction flex	Friction flex is where the ability to add, remove, or change commercial relationships of meters is increased. This may or may not require additional meters to be added.

Finally, we undertook a more detailed analysis for the core case studies, investigating and modelling a range of potential social and economic impacts on households under each approach. These case studies are best thought of as flags of potential issues or impacts that could arise with different potential meter unbundling models. Some are designed to explore concepts (such as power and equity). Others push the limits of current assumptions (such as price responsive consumers). The outcomes from these case studies are intended to be questions which, if answered, would improve the quality of outcomes of reform. These models, and the corresponding analysis, is explored further in Section 4. Key findings were identified in each model, summarised below in Table 2.

Table 2 Case study summaries and key findings

Case study	Summary	Key findings
Controlled load (Down flex)	This case explores potential meter unbundling impacts on equity. It does this by exploring how capacity to tolerate changing temperature and insulation impacts financial returns of heater flexibility.	It is important that reform processes are responsive to the diverse needs of consumers. Without this consideration, even well-intentioned reforms can increase inequity. The example described here indicates how a consumer's physical health could prevent access to the benefits of meter unbundling for some people. This can exacerbate existing inequities. More generally this means that modelling approaches need to be more aware of contextual issues that could challenge reforms form realising their benefits.
Renters (Down flex)	This case explores power. It does this by considering how power imbalances between renters and owners could corrupt the beneficial outcomes of meter unbundling if applied to rental properties for solar PV.	Down flex meter unbundling could work for the benefit of all here but understanding social 'power' interactions is needed to ensure value is realised in a fair way for all proponents. Proponents of the meter unbundling rule change should explore how the proposed rules may create, reinforce, or dilute social power imbalances in their reforms. This is especially important where some of the relationships being impacted may be outside of the energy system – for example renters and land owners.
Competition in my house (Down flex)	This case explores how diverging drivers between flexible assets in a house could lead to poor outcomes. For example, assets might cancel each other's responses out.	Increasing the number of services in a consumer's home means increasing complexity in interactions between the devices those services control. Without coordination, this increases the chances of deleterious outcomes for the consumer and the wider network. Rule makers should consider how these impacts could be mitigated as they define their rules. For example, some coordination between flexible assets behind a common connection point may be necessary to avoid unexpected grid and consumer outcomes.
Neighbourhood network (Up flex)	This case explores how meter unbundling could facilitate community energy or embedded networks.	Up flex metering is an option for neighbourhoods. The main concerns for the decarbonisation effort of the electricity network are the increased demand from electrification of gas appliances and EV uptake, and increased generation from rooftop solar which will require incredibly expensive network upgrades. Operating a section of network as a neighbourhood network with an appropriately sized neighbourhood battery and neighbourhood solar could be sufficient to negate or postpone these costly network upgrades. Feasibility and costs could be further improved by demand management, using smart hot water systems and smart EV charging. Up flex metering can introduce new mechanisms to reduce costs and inequity for consumers, therefore it is worthwhile for rule makers to broaden the scope of meter unbundling discussions to consider additional use cases.

Case study	Summary	Key findings
No meters (Up flex)	This case explores the impacts of removing meters entirely from the energy system.	The main proposal from this section is to consider how energy use and revenue generation could be restructured if the current metering configuration (i.e. everyone has a meter) were removed or reframed (if meters were 'up flexed' into the energy system).
Versatile EV charging (Friction flex)	This case explores how meter unbundling could facilitate assets to move more flexibly between locations.	Electric vehicle charging can be made simpler and easier with small extensions to meter unbundling principles. This can create fairer and more equitable outcomes for consumers. Focus should be placed on benefits to consumers separate to any benefit to the wider network.
Retailer switching (Friction flex)	This case explores the limits of price responsiveness for consumers through the case where consumers can switch retailers every dispatch interval.	Consumers are intended to be responsive to market signals and able to change behaviour to reflect system needs. In its extreme this price-responsiveness could have strong positive outcomes for consumers but to the detriment of other market actors. Rule makers should consider the limits of the behaviour they request of consumers.

This socio-techno-economic analysis and approach has allowed us to better explore the range of potential impacts of proposed energy metering changes, and to present a case for deeper consideration of key issues that have been blockers to past reforms achieving their objectives.

Our goal in undertaking this work was to explore the limits and impacts of increasing metering flexibility, including social, financial, and commercial impacts. Our exploration delved into:

- The role that meters play in intermediating the relationship between households and the market;
- The potential for optimised systems to lead to heavily sub-optimal outcomes;
- How opportunities that involve multiple consumers have the potential to improve or substantially worsen equality; and
- How smarter metering could reimagine how local energy systems are formed and operate.

In undertaking this analysis, we identified several issues that should be explored further by the AEMC and rule proponents to ensure reforms are genuinely for consumer benefit:

- A broader view on consumer's ability to uptake flexible products can mean reforms reinforce existing inequities; and
- Social power imbalances can subvert positive outcomes from reform.

The analysis also revealed several possibilities or positive outcomes that could be enabled by metering reform:

- Potential to reduce the effort required to implement new energy sharing and trading models such as community energy schemes;
- A more explicit way to resolve key issues in adjacent sectors such as charging work vehicles at home; and
- The potential to break normative assumptions around metering and its use cases could enable a fairer and more just energy system.

Clearly, increasing flexibility in metering does not predetermine a good or bad outcome. If implemented carefully it can create benefits for all. But if not, it can reinforce inequity, exacerbate social power imbalances, or create bad financial outcomes for consumers. This work can act as a flag to decision makers to analyse reform more expansively. A socio-techno-economic and critical lens can reveal issues that we have not observed in current regulatory discourse but are key determinants of the outcomes of change. We hope our findings will inform the energy market reform process and lead to better outcomes for all participants, including greatly-improved household electrification with benefits flowing to consumers.

1 Approach

Our initial focus was intended to identify meter unbundling approaches that we felt had not seen sufficient attention from industry. We did this by conducting a series of workshops with participants from across the Program to brainstorm ideas on ways meter unbundling could be used to unlock better outcomes for householders.

In conducting these workshops we adopted an explorative mindset, and in doing so we discovered an array of interesting and novel approaches to metering more broadly. It struck the collective attendees that we, like the energy industry in Australia, naturally tied our thinking to considering only traditional metering; and that this inherently limits our ability to explore more novel approaches. We realised that there were opportunities to rethink what metering is, what it is intended to achieve, and what it does achieve for consumers and for the energy system. We felt that by exploring these questions we would derive a more fundamental understanding of how consumers and energy providers interact on a social, technical and economic level, and this would help to inform our thinking on our original question of meter unbundling.

In addition to expanding our thinking, the workshops and post-workshop discussions highlighted a key gap in addressing issues relating to energy system change – specifically that large changes often do not share benefits in a just manner. Disadvantaged consumers are often left behind when the bulk of benefits from reform accrue to better off people. The project team felt this was a gap that needed to be addressed; however, the tools had not been properly developed to understand the social impacts of change on different cohorts of consumers. So, in addition to identifying a set of metering models that the team felt should be explored, we also set about creating a social analysis framework (based on the Responsible Research and Innovation framework developed by Stilgoe et. al [1]; see the information at the end of this section) that has allowed us to gain a deeper insight into the potential impacts of the suggested changes on consumers. We have used this framework to craft a mindset of closely integrating social, technical and economic thinking to identify and answer questions that are inherently difficult to engage with from only one of these perspectives.

In parallel with developing the social analysis framework we took time to consider the breadth of models that had emerged from our initial workshops. At this stage we had identified a set of 18 prospective models for consideration and preliminary analysis, many of which intentionally went far beyond the original scope of meter unbundling related to Flexible Trading. By producing a visual taxonomy of these models and using it to identify overlap between them (both technical and conceptual overlap) we were able to distil them down to a set of seven core models to take forward as part of our full analysis.

At the same time we were identifying a set of commonalities between subsets of our selected models. Specifically, we recognised that the ways in which meters and metering as a concept were considered, broadly fell into three categories: sub-metering for greatly fidelity, in-network meters for aggregation, and eliminating complexity relating to the integration and use of meters. We titled these categories *Flex Dimensions*, and we explore this concept further in Section 3.

From here we conducted a detailed analysis of the feasibility and potential impacts of our selected models. We explored our models on a much deeper level to provide additional detail on how they could be implemented, and how may be impacted by their adoption. Our analyses then investigated a wide array of potential impacts, both good and bad. We considered the financial impact on different classes of consumer and other market actors, both broadly and with specific examples. We looked at how the model might impact power dynamics between participants, whether we may be reinforcing existing power dynamics or creating new ones, and whether these changed dynamics could solve, or potentially reinforce existing inequalities. And where relevant we identified potential roadblocks to implementation (whether technical, regulatory or social) that may need to be considered when determining whether to adopt these approaches. These models, and the corresponding analysis, is explored further in Section 4. Finally, we presented our preliminary findings to a set of key industry stakeholders, and their feedback was substantially positive, with significant support for our approach and related findings.

Responsible Research and Innovation (RRI) framework

Responsible Research and Innovation (RRI) is a framework that helps researchers and innovators be more responsible in their activities. It tells us that it is important to take care of the future through collective stewardship in the present. Stilgoe et. al. described RRI through four dimensions [1]:

- **Anticipation** which asks us to anticipate the outcomes of innovation. It encourages us to ask "what if" questions and consider contingency, what is known, what is likely, what is plausible, and what is possible.
- **Reflexivity** which encourages us to "hold a mirror" up to ourselves. It asks us to analyse our own commitments, assumptions, and activities. It asks us to understand our own roles, assumptions, and activities and the limits of our own knowledge.
- **Inclusion** which tells us that we need to include space for participation in innovation process. It especially asks us to understand how power is distributed and shared within processes such as undertaken by this project.
- **Responsiveness** requires us to change direction when things indicate our direction is wrong. Fundamentally this underpins the other dimensions: what is the point of anticipation, reflexivity, or inclusion if you don't act on what they tell you?

The project, and its methodology were initially framed around what we felt was a lack of **reflexivity** in the energy system and the solutions it proposes. Similarly, our literature review (albeit limited) was undertaken to build our own reflexivity and inclusion of diverse voices in our project. As energy researchers we must also understand our own biases. Our research focusses on renewable energy, people, and their interactions. This leads to a mindset that foregrounds issues around equity, justice, and decarbonisation. Similarly, as researchers we are not low or high income which colours our perceptions of life experiences for others. In this case we feel that this report adds to the debate rather than detracts, because it considers issues we have not seen discussed currently in the AEMC rule change process.

Within the scope of this project our ability to directly **include** consumers was limited. As a surrogate we have used a literature review, reference to our past work, and a workshop with some key advocacy orgs and research institutions. While this is not a full substitute for dedicated consumer research, we are confident that this work has revealed the key themes that could be further investigated as part of the reform process.

The way we undertook analysis in this project was intended to be **responsive** to the issues raised in our background research. We specifically analysed power and equity for example. Responsiveness was the main reason we adopted the "case study" approach in our work because it allowed us the freedom to respond to themes that became apparent during our work.

This report mainly aims to improve **anticipation** generally around this rule change by painting several potential futures and understanding what their impacts would be. Key findings illustrate the impact of power, intersection of disadvantages, and push the edges of price responsiveness. These hope to increase the fidelity of discussion around the meter unbundling reforms.

2 The context of metering

Meter unbundling is another step in a long series of reforms the energy system has undertaken over the past few years. Part of our analysis included an analysis of the impacts of those past reforms. Most relevant for this study was the Australian Energy Market Commission (AEMC) 2015 change to introduce contestability in metering[1]. This rule change transitioned meters from distribution networks' asset bases to being the responsibility of energy retailers. This change is relevant because the purported benefits are similar from a consumer point of view.

The following excerpts describe the key benefits proposed by the AEMC for the "competition in metering services" and "Unlocking CER benefits through flexible trading" reforms respectively:

Competition in metering services:

> *"The final rule will facilitate a market-led approach to the deployment of advanced meters where consumers drive the uptake of technology through their choice of products and services. This competitive framework for metering services is designed to promote innovation and investment in advanced meters that deliver services valued by consumers.*
>
> *This rule change is part of a series of changes recommended in the AEMC's Power of Choice review to support demand side participation in the National Electricity Market, including network pricing arrangements and access to energy consumption information."* [2]

Flexible trading:

> *"Flexible trading arrangements enable the separation of controllable electrical resources (e.g. battery, solar system and electric vehicle charging) from passively connected electrical resources (e.g. household lighting and general appliances) in an end user's home or business. This would enable the end user to access competitive offers and services for their controllable resources, independent from their general electricity supply, enhancing their ability to be rewarded for their flexibility and maximising the value of their distributed energy resources (DER)"* [3]

In this project, we used a small selection of academic papers that described the outcomes of earlier metering reform from a social science perspective to determine the key factors that should be considered in this work [4], [5]. These papers described two main themes:

- Social power
- Equity

Power is *"the ability of an individual, group, or institution to influence or exercise control over other people and achieve their goals despite possible opposition or resistance."* [6]. Power is important in the energy system of today. For example, Chandrashekeran discussed how metering reforms had created new avenues of power for energy retailers and distribution networks through assignment of the main responsibility of metering to them. In this paper we have explored power more specifically in the "renters" scenario. This scenario focusses on how power dynamics might influence outcomes in the context of meter unbundling and renting.

Previous metering reforms have also raised concerns with equity. For example, Lovell called to distributional inequity in Victoria's smart meter rollout. Specifically, the risk that value would not be realised from smart

[1] https://www.aemc.gov.au/rule-changes/expanding-competition-in-metering-and-related-serv

meters was borne by consumers, as the costs they paid were not directly related to realisation of benefits. Similarly, all consumers paid the same metering charge, regardless of their capacity to pay [5]. Chandrashekeran described that capacity to engage with the opportunity offered by smart meters was another determinant of inequitable outcomes [4]. There is limited scope to explore many of these issues in this project due to specific user engagement being infeasible in the project timeframe. We have considered equity as part of the “controlled load” scenario. This scenario explores how insulation levels and capacity to tolerate changing temperature is a determinant to the financial value that can be delivered by a controlled heating scheme.

These factors been explored in more detail as part of the models in Section 4.

3 Flex dimensions

Energy metering, and in particular revenue metering, has a powerful role mediating the relationship between energy consumers and the energy system. However, this can lead to a situation where viable alternatives are not considered, which can be seen as a lack of reflexivity amongst rule makers.

The Flexible Trading rule change proposal would create additional metering points behind existing meters, which aim to empower consumers and enable easier market participation of ‘flexible’ demands such as batteries and electric vehicles. This proposal could be considered an extension of the dominant metering paradigm of today. In this report we aim to think more broadly about how metering could be made flexible, and potentially unlock additional value, relationships, or mechanisms that could overall improve the energy system.

To unlock a wider array of models for analysis, we considered a broader range of metering opportunities than the proposed more granular sub-metering for households. The project team developed a lens through which these opportunities could be identified and evaluated – a lens we have called ‘flex[ability] dimensions’. We have considered three such flex dimensions, described below and pictured in Figure 2:

- **Down-flex** – move or add metering further ‘down’ (or deeper) into the household, which may enable more granular measurement of power usage and generation; the Flexible Trading rule-change as currently proposed would fall within this category.
- **Up-flex** – move or add metering further ‘up’ in the network, allowing collective metering of a number of households.
- **Friction-flex** – Reduce the ‘friction’ by which metering currently operates. For example, making it easier to create and remove metering points or making it easier to change energy retailers.

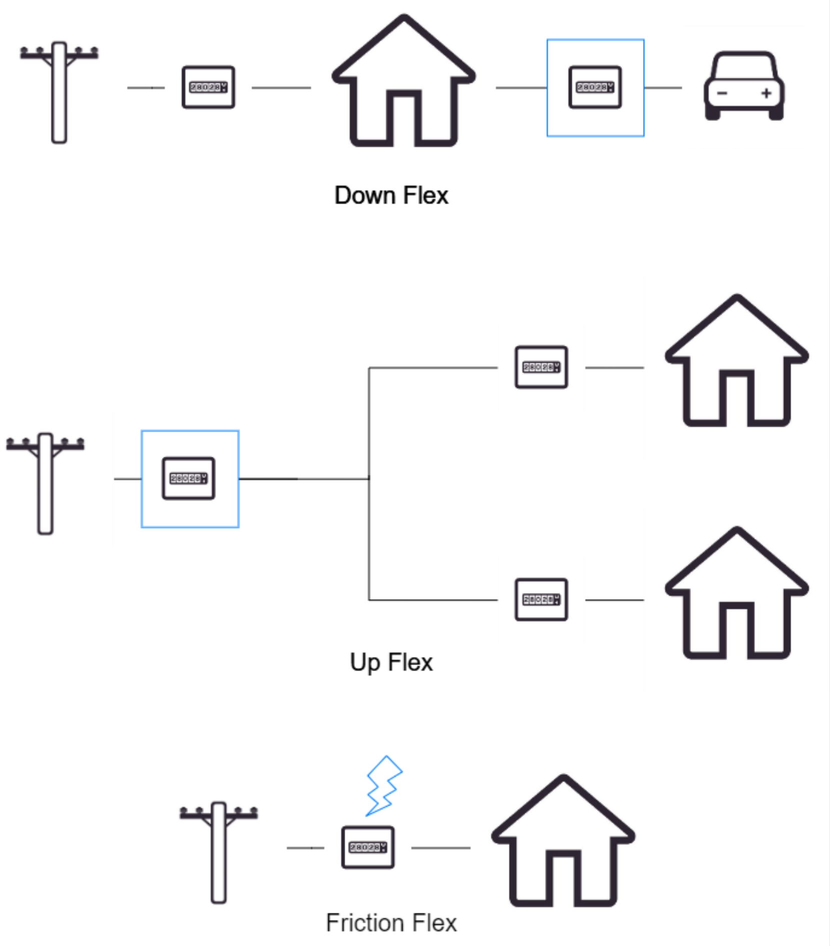

Figure 2 Flex dimensions

These dimensions have allowed the project team to identify and explore aspects of metering that go well beyond Flexible Trading. This has then enabled a deeper consideration of the ways in which societal-energy integration, energy equity and power dynamics can be influence by such changes.

It should be noted that the concept of 'metering' here need not be with reference to a physical meter. Up-flex for example, could include virtual metering approaches that operate by logically summating measurements from deeper meters (a concept used extensively in existing virtual net metering approaches).

4 Meter unbundling models

The project team, supported by several BSGIP experts, elaborated on the principles described in the preceding sections to identify an extensive set of models where novel approaches to metering could be applied. These models collectively describe a wide array of approaches – inspired by, but extending, the meter unbundling paradigm – which could be implemented in ways that vary the technical, economic and social conditions between customer(s) and market actors. These models were then distilled down to a set of case studies described in this section.

These case studies serve as illustrations of factors that were revealed as important in our workshops and subsequent analysis. These are summarised in Table 3.

Table 3 Novel metering approaches – use cases studied

Case	Description
Controlled load	This *down flex* case explores potential meter unbundling impacts on equity. It does this by exploring how capacity to tolerate changing temperature and insulation impacts financial returns of heater flexibility.
Renters	This *down flex* case explores power. It does this by considering how power imbalances between renters and owners could corrupt the beneficial outcomes of meter unbundling if applied to rental properties for solar PV.
Competition in my house	This *down flex* case explores how diverging drivers between flexible assets in a house could lead to poor outcomes. For example, assets might cancel each other's responses out.
Neighbourhood network	This *up flex* case explores how meter unbundling could facilitate community energy or embedded networks.
No meters	This *up flex* case explores the impacts of removing meters entirely from the energy system.
Versatile EV charging	This *friction flex* case explores how meter unbundling could facilitate assets to move more flexibly between locations.
Retailer switching	This *friction flex* case explores the limits of price responsiveness for consumers through the case where consumers can switch retailers every dispatch interval.

4.1 Controlled load

Down Flex

Key takeaways: It is important that reform processes are responsive to the diverse needs of consumers. Without this consideration, even well-intentioned reforms can increase inequity. The example described here indicates how a consumer's physical health could prevent access to the benefits of meter unbundling for some people. This can exacerbate existing inequities. More generally this means that modelling approaches need to be more aware of contextual issues that could challenge reforms form realising their benefits.

Climate control, via reverse cycle air-conditioning is popular in households because it provides thermal comfort for occupants of a household. Heating and cooling, even with an energy efficient reverse cycle air conditioner, is generally quite energy intensive and can significantly impact household electricity expenditure. We know that people have a diversity of tolerances for heat and cold, which can be exacerbated in particular groups of people, such as those with chronic illnesses.

Controlled loads, remotely limited or managed separately to metered household circuits, are one way that energy providers have tried to offer cheaper electricity for certain applications. To date control has been predominantly implemented via turning off, on, or limiting the use time of hot water systems and pool pumps. These devices are only allowed by the energy provider to operate during certain times of the day when the demand for electricity is lowest. This has traditionally been overnight, and more recently during the middle of the day when rooftop solar is contributing large amounts of low cost energy into the grid. A natural question to ask is whether this control approach could be expanded to other devices, such as reverse cycle air conditioning. Generally, these control style offers from providers are in exchange for a lower energy cost to the consumer.

Climate control is a particularly relevant topic to consider in this report because its use varies according to household contexts and is therefore diverse. This provides us with some understanding then of the challenges diversity causes for metering solutions. For some people and in some climates it is necessary to control temperature in their environment to maintain good health. Some people can tolerate wide changes in temperature, while others can only tolerate limited change. Similarly, some houses are well insulated, others are not. In practice, this means that the extent to which heating is flexible depends on who the consumer is, and the thermal properties of their house.

For illustration purposes, consider two people: Gertrude and Josh. Gertrude and Josh are neighbours, who happen to live in identical houses (and thus have identical insulation levels). Gertrude is a retiree with a chronic illness and feels the cold significantly. Josh is a young, energetic athlete who gets chilly from time to time, but the cold really isn't much of a big deal for him. Thus, Gertrude pays a lot more for heating in the winter and cooling in the summer.

Looking at Josh and Gertrude's situations, we can see what they pay for electricity is very different. Gertrude spends a lot more time heating and cooling her house, about 19% of the time compared to Josh's 4% of the time. As a consequence, she uses much more energy for heating and cooling over a year: 4902 kWh versus 611 kWh, and she is paying a lot more to do this: $1357 versus $169.

Meter unbundling as a solution could offer a lower cost supply for some loads, if the loads are "flexible". In other words, unbundled meters can shift consumption in response to some energy system needs. However, not everyone is able to shift their consumption equally flexibly. At face value, Gertrude has much higher heating demand – around 8 times the cost; but it is worthwhile thinking about *why* Gertrude heats. She may have a chronic illness and an energy inefficient house layout, and the link between temperature, wellbeing, and health costs – particularly for those with chronic illnesses – is well established [7]. So even though Gertrude has high demand, the flexible load discount offer may only be feasible for Josh. This means that the benefits of having this offer available mainly accrue to some (those healthy enough to withstand thermal discomfort). Gertrude may not be able to go without heating or cooling for the times required to make the flexible demand (and unbundled meter) offer worthwhile for her. From an equity point of view, this means that a cohort of consumers may miss out on the direct benefits of meter unbundling. And the cohort who misses out may be some of the most disadvantaged today.

It is difficult to design systems that are both equitable and implementable, but it is critical to try. Recognising that people have different needs to be met by electricity, and the degree can vary between person to person, is an important step to being able to build systems to cater to those needs. A large part of the decarbonisation process is acknowledging people are diverse and act differently in their energy consumption and that systems need to be redesigned for people, their needs and values, physical, mental and emotional. Taking steps towards this is paramount for building trust so they can engage in conversations around electricity and decarbonisation more generally.

4.2 Renters

Down Flex

Key takeaways: Down flex meter unbundling could work for the benefit of all here but understanding social 'power' interactions is needed to ensure value is realised in a fair way for all proponents. Proponents of the meter unbundling rule change should explore how the proposed rules may create, reinforce, or dilute social power imbalances in their reforms. This is especially important where some of the relationships being impacted may be outside of the energy system – for example renters and land owners.

A conceptual use case for unbundled meters that was suggested in our workshop was to enable access to solar PV for renters. This model is shown in Figure 3. This model is a "down flex" where an additional metering point has been created below an existing point. In this case the meter connects a solar PV array. The aim of this meter is to enable the benefit of solar PV to be measured and shared between the tenant and the property owner. The alternatives available today are either to:

- Create a separate dedicated connection point for the PV array, feeding all energy into the grid. This is the base case in the scenario;
- The land owner installs behind the tenant's existing connection point and pay for the array via increased rent costs. This is in many ways similar to if the tenant had installed themselves via finance, although potentially without the tenant having visibility of how the rent increase relates to the cost of the installed system or any specific mechanism to cease payments once the system is paid off.

Current uptake of PV in rental properties is low, indicating that there are likely barriers. Although those may not be entirely metering related, this scenario illustrates what the impacts of one potential mitigation of barriers could be. The intent is that if there is a way of making the benefits of PV apparent it is more likely that renters can access PV.

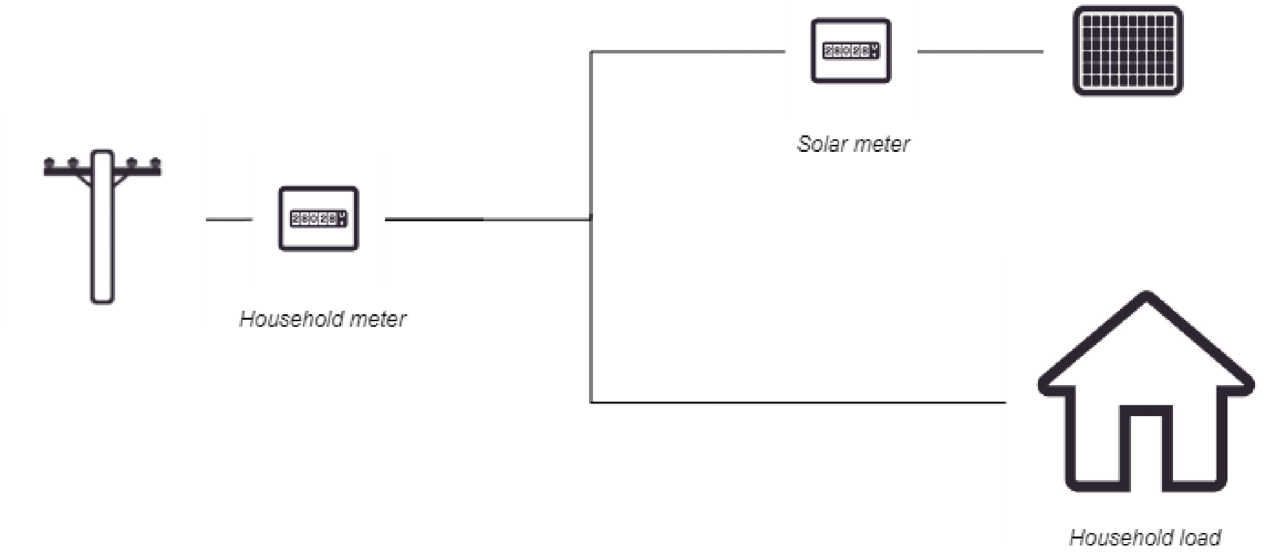

Figure 3 Meter unbundling model: Renter

Initial analysis suggests that there is a benefit to the meter unbundled configuration over the separate connection point scenario. The results are shown in Table 4.

Table 4 Total benefit of "PV renters scenario" (5 kW PV system)

Case	Total financial benefit available (across tenant and land owner)
Separate connection point	$1349
Behind the meter PV	$2082

The additional benefit is generated by the "behind the meter" consumption. This shows what is intuitive: it is best if PV is installed "behind the meter" because of how energy pricing currently works in Australia works.

The social power imbalance between tenants and owners, including the many ways in which owners exert power over tenants, is very well established [8]–[11]. And there is also good understanding of the barrier that split incentives create for improving energy systems in rentals (for the tenant). This begs the question: how could this down flex model exacerbate or remedy this renter to landlord power imbalance? While clearly there is a benefit, the first question is how this benefit is to be shared between the owner and tenant. Three scenarios and the benefit to the owner and tenant are shown in Table 5.

Table 5 Payback scenarios for Renter PV

Case	Payback period on PV array (owner)	Tenant annual benefit
Separate connection point	5.1 years	$0
50/50% tenant owner value split	3.9 years	$366
All value to owner	3.1 years	$0

Clearly the best outcome for the owner is where they can retain maximum benefit, with payback around 10 months sooner than the case where benefit is shared evenly. A 50% split of benefit between the landlord and the tenant reduces the owner's payback period by 14 months. This shows a tension: Owners may push to receive a greater share of benefit to reduce their payback, but doing so reduces the tenant's benefit.

At first glance it appears that the worst case scenario – all value to owner – leaves the tenant no worse off, as the tenant's bills remain the same as the case in which there is no PV. However, this scenario creates an additional driver for the owner: to maximise the tenant's consumption of electricity (at least when the PV is generating). If the tenant's consumption aligns well with PV generation periods, the owner's payback period is reduced to 2.5 years, or an 8 month reduction in payback period over the case where the owner keeps all of the financial benefits of the PV, but the tenant's consumption is unchanged. Owners have capacity to encourage tenant consumption. For example, Garboden and Rosen described how threat of eviction can be used to influence tenants [9]. More simply, avoiding installation of energy efficiency upgrades such as insulation could increase owner returns.

The scenario presented in the paragraph above is not a given outcome of this scenario. There could be ways to avoid this through regulation. The main purpose of this scenario is to show how the landlord's overall social power and diverging drivers (such as those of tenants and owners) could lead to undesirable outcomes. There are other examples where power imbalances could lead to unexpected outcomes, some of which were discussed earlier in this report.

From this work we can see understanding power is important. Proponents of the meter unbundling rule change should explore how the proposed rules may create, reinforce, or dilute social power imbalances in their reforms. This is especially important where some of the relationships being impacted may be outside of the energy system – for example renters and land owners.

4.3 Competition in my house

Down Flex

Key takeaways: Increasing the number of services in a consumer's home means increasing complexity in interactions between the devices those services control. Without coordination, this increases the chances of deleterious outcomes for the consumer and the wider network. Rule makers should consider how these impacts could be mitigated as they define their rules. For example, some coordination between flexible assets behind a common connection point may be necessary to avoid unexpected grid and consumer outcomes.

Introducing Flexible Trading intends to introduce competitive services to operate controllable devices, for the benefit of consumers. Issues can arise when there is no orchestration across multiple controllable devices being operated by different services. The non-alignment of objectives of each service may result in perverse situations where controllable devices are competing against one another. This, in turn, can lead to difficult economic, social or technical outcomes for the consumer.

In this scenario, we introduce competition into a person's home, mediated by two controllable devices with well-intentioned objectives. This home has three key elements, each separately metered;

1. A normal household electrical load, including heating, a washing machine and TVs,
2. A household battery,

3. A vehicle to grid (V2G) enabled electric vehicle (EV)

For clarity, there is no solar PV on this home's rooftop.

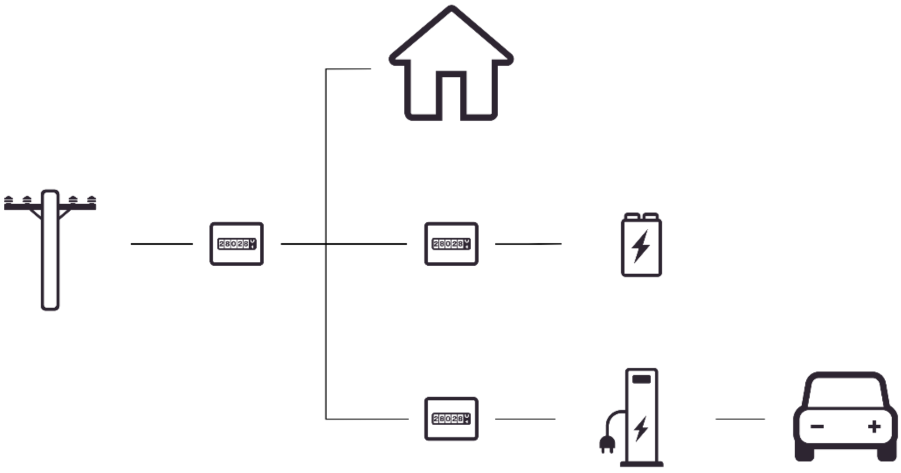

Figure 4 The configuration of the household with a household battery and V2G-enabled EV.

The battery is operated by one service to absorb cheap solar energy during the middle of the day. The V2G-enabled EV is operated by another service, which aggregates controllable devices and bids them into the frequency control ancillary services (FCAS) markets. The FCAS markets pay the service to maintain grid stability.

In practical terms, the household battery will want to charge during the middle of day when electricity prices are low, and then discharge over the evening and night when prices are higher. The V2G-enabled EV will bid into the FCAS markets as and when the service controlling it decides. In this example, it is bidding into all the contingency raise and lower FCAS markets. In these markets, if your bid is accepted, you are paid even if not called upon to provide energy. However, if you are called upon to provide energy and you do not, you are heavily penalised.

Soaking up solar for later usage and providing stability to the grid are both positive objectives. However, unless these devices have knowledge of each other and are orchestrated across services, they can behave at odds. The graph below (Figure 5) provides an example of one such day where things go wrong.

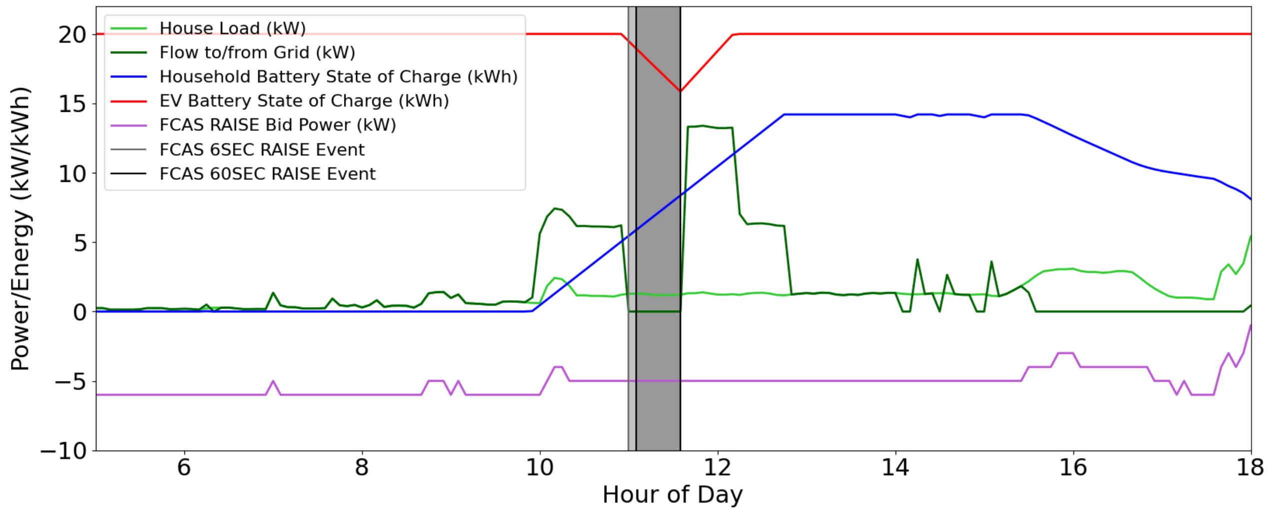

Figure 5: A V2G-enabled, market participating EV not fulfilling market obligations due to incompatibility of objectives with the household battery.

In Figure 5 –

- Light green represents the power being consumed by the household.
- Dark green represents the power flowing to and from the grid.
- Blue represents how much energy is in the household battery.
- Red represents how much energy is in the V2G-enabled EV.
- Purple represents the power being bid into the market by the service controlling EV charging.
- Grey and black regions represent the market events.

The day starts out normally. The people in the home start their morning slowly; it's a weekend and the weather is fine so there is no need for heating or cooling (light green line is flat). Around 10am the household battery decides it's time to start absorbing solar energy for the day (blue line increasing) as the price of solar has dropped to a reasonable level. The EV is parked and connected with its battery half-full (red line), so it can bid into all raise and lower FCAS markets (purple line shows power available for raise). At 11am, far away in Queensland, a turbine in a coal-fired power station explodes, and frequency drops, causing two FCAS raise events to occur (grey and black shaded regions). The EV responds to these events by exporting energy (red line lowering), as it should. However, as the household battery is trying to charge from solar, most of the power from the EV flows into the household battery, and only a small amount makes it to the grid. From a grid perspective this counters the value of the raise service. This could cause penalties for the FCAS service provider (and thus the household), but more fundamentally the "grid side good" of the service has been negated.

This scenario was generated assuming that the services involved are acting in good faith. It would not be difficult to show a scenario in which a service acting in bad faith deliberately scuttles the ability of another device in the household to operate.

One of the downsides of increased competition is that it increases the complexity of the objectives needed to be satisfied. At some point, a situation is reached where there is no solution that will satisfy the objectives of all devices, and coordination of these devices is required for stability. This is not only true in a home, but on distribution networks, electrical grids (such as the NEM) and microgrids.

4.4 Neighbourhood network

Up Flex

Key takeaways: Up flex metering is an option for neighbourhoods. The main concerns for the decarbonisation effort of the electricity network are the increased demand from electrification of gas appliances and EV uptake, and increased generation from rooftop solar which will require incredibly expensive network upgrades. Operating a section of network as a neighbourhood network with an appropriately sized neighbourhood battery and neighbourhood solar could be sufficient to negate or postpone these costly network upgrades. Feasibility and costs could be further improved by demand management, using smart hot water systems and smart EV charging. Up flex metering can introduce new mechanisms to reduce costs and inequity for consumers, therefore it is worthwhile for rule makers to broaden the scope of meter unbundling discussions to consider additional use cases.

A meter is a point of mediation between consumers and energy providers. Currently, this occurs between each household, often and individual or handful of people, and the entities that compose the electricity system. This gives a large degree of personal freedom in how each consumer interacts with the energy system, if they have the means to do so. In reality, most consumers are disengaged with this conversation and often implement ‘set and forget’ strategies.

In this case study, we consider what it would look like if we moved the point at which this conversation between consumers and providers occurs further up the network to the neighbourhood level. This point could be at the distribution transformer, which would encompass a couple of dozen households, or at a feeder level, which could span a suburb or two. In investigating this we need to consider aspects like:

- What are the implications for care, community and engagement?
- Would this increase or decrease costs for the consumer?
- What technical issues could this create, and what technical issues could it alleviate?

As we undertake efforts to decarbonise Australia, more and more strain will be put on the electricity grid through the electrification of gas appliances and the uptake of EVs. Concurrently, the amount of installed rooftop solar will continue to increase. In many areas, the current network infrastructure is insufficient to meet this increase in both import (electrification and EVs) and export (rooftop solar), necessitating costly infrastructure upgrades. Could neighbourhood networks provide an alternative that minimises the impact of this increase import and export to the electricity network, negating the need for costly infrastructure upgrades?

- How would the role of energy providers change in a system with neighbourhood networks?
- What is the financial impact for energy providers?
- Would neighbourhood networks solve these technical issues the grid will face in the future?

To investigate this, we create a neighbourhood composing of:

- 38 households
- 34 of these households have rooftop solar
- 5 of these households have household batteries

In the current network, a meter is place between each household and the grid (Figure 6 left) In a neighbourhood network, the meter is placed between the collection of households and the grid (Figure 6 right).

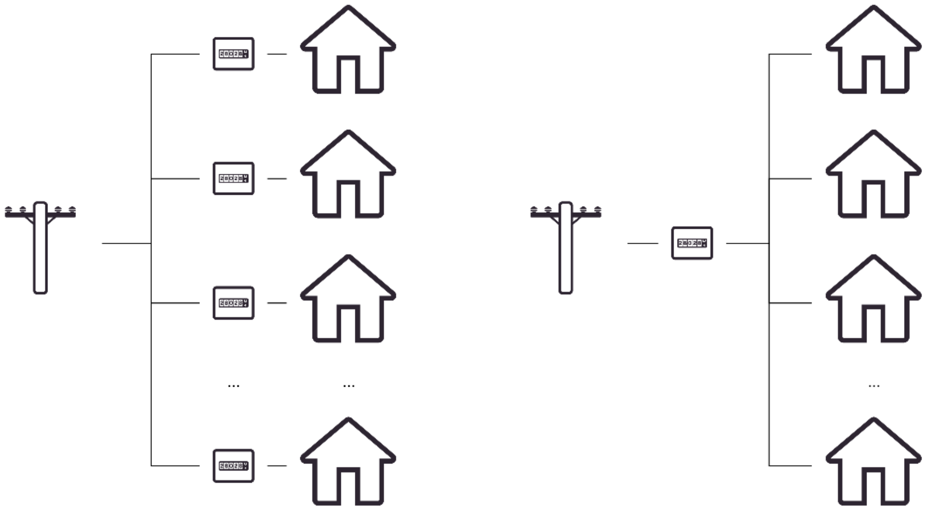

Figure 6 The current metering configuration (left) and a neighbourhood metering configuration (right) of a neighbourhood.

In the current network, the cost for each household is calculated at the household meter. In a neighbourhood network, the cost is calculated at the neighbourhood meter, and divided amongst the households by some means. At this point there is a decision to be made about *how* cost is divided. There are numerous ways to do this, and it is here we can start to see how people in these neighbourhoods could have input into how costs are divided. A more in-depth discussion about this is presented in Section 4.5.

In this case study, we modelled 35 different combinations of network (current or neighbourhood), infrastructure (additional batteries and solar) and objectives (minimise cost, minimise energy flow to/from the network) using a multi-commodity optimisation tool called Echo developed by BSGIP. For brevity, we have only presented a handful of combinations here. We modelled each combination for one week in summer and one week in winter of 2022, corresponding to the extremes in energy consumption and production in Australia. Household consumption and solar generation data is real data collected by Wattwatchers.

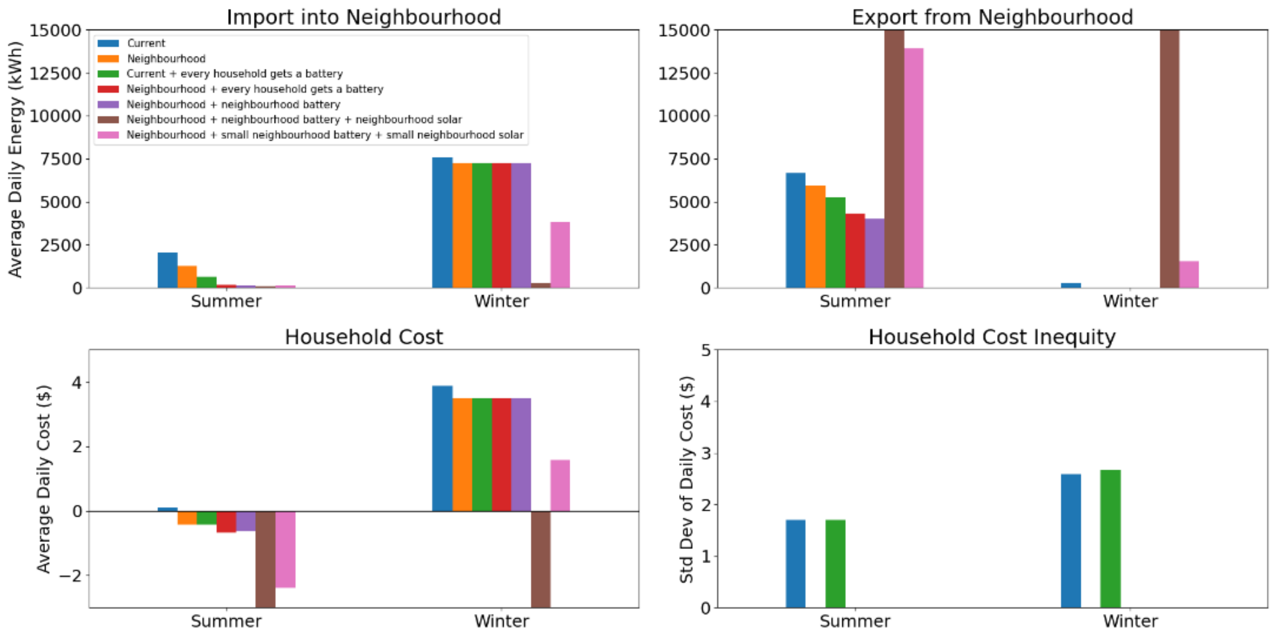

Figure 7: Energy imported into (upper left) and exported from (upper right) a neighbourhood with associated costs to consumers (lower left) and inequity of those costs (lower right) for seven different network configurations.

In Figure 7 –

- Blue represents the current network configuration where each household is metered individually.
- Orange represents a neighbourhood where the neighbourhood is metered by a single meter.
- Green represents the current network where each household is given a household battery.
- Red represents a neighbourhood network where each household is given a household battery.
- Purple represents a neighbourhood network with a neighbourhood battery.
- Brown represents a neighbourhood network with a neighbourhood battery and neighbourhood solar PV.
- Pink represents a neighbourhood network with a neighbourhood battery and neighbourhood solar that are both sized to reduce capital expenditure so that winter imports are half, and summer imports are negligible, compared to the current network configuration (blue).

Here we have measured the import and export of energy to the grid, the average cost to households and the standard deviation of cost to households. We include the standard deviation of cost as it allows us to probe how increased economic value flows onto the households; a measure of inequity. We chose to divide costs equally across households in neighbourhood networks. Costs are reflective of operating costs only, not capital costs, and do not include supply tariffs, only usage tariffs.

Current Network vs Neighbourhood Network

First, we can investigate the impact of operating a network as it is currently (blue) versus a neighbourhood network (orange). The amount of energy imported and exported in both seasons decreases for the neighbourhood network due to greater utilisation of solar generated by households with rooftop solar, rather than selling it to the grid. This results in a decrease in average cost to households, as solar consumed by a household is much more valuable than solar exported to the grid (four times more under the tariff conditions used in this case study). This additionally generated value helps to decrease costs to households, but importantly, the benefits are shared amongst all households in the neighbourhood, as shown by the decrease in standard deviation of cost (orange is zero).

Battery Storage

We can also compare the impact of introducing various configurations of battery storage. Household batteries can be given to each household that doesn't currently have one (current - green and neighbourhood - red) or adding one neighbourhood battery (purple). The neighbourhood battery has the same capacity as all the household batteries combined. All three perform as good or better for energy imported, energy exported and cost than the same networks without batteries. Adding batteries to all households to the current network maintains the inequity of value flow of the current network, whereas the neighbourhood networks maintain more equitable situations.

Additional Solar PV

34 of the 38 houses in this case study already have rooftop solar, so there isn't much rooftop space left to add more. Adding neighbourhood solar into the neighbourhood network with a neighbourhood battery (brown) reduces both summer and winter imports close to zero. Exports are increased significantly, particularly in summer – the bar in the upper right plot extends way beyond the limit shown here. This does earn the households a substantial amount of money (lower left, the bars are beyond the limits shown here), given the tariff structure implemented here.

Considering Capital Expenditure

All combinations containing additional battery and solar devices so far test the limits of what is achievable if we ignore capital expenditure. The pink bars represent a more modestly sized neighbourhood battery and neighbourhood solar to reduce capital expenditure, while maintaining the major benefits The sizes of these devices were selected to reduce winter import by half from the current state, and to reduce summer import down to negligible amounts. Exports in summer and winter do increase from the current state, but integration of smart devices such as smart hot water heating and smart EV charging will be able to utilise this excess energy to derive further benefits for consumers (not modelled here). The operational costs to consumers is decreased compared with all other combinations, besides the larger neighbourhood battery and larger neighbourhood solar (brown).

This section explored what could happen if the point at which the conversation between consumers and energy providers shifts 'up' toward the network. Empowering consumers to act together and share resources can unlock a raft of new opportunities to aid the decarbonisation pathway, while providing mechanisms for reducing costs for energy providers, and cost and inequity for consumers.

4.5 No meters

Up Flex

> **Key takeaways**: The main proposal from this section is to consider how energy use and revenue generation could be restructured if the current metering configuration (i.e. everyone has a meter) were removed or reframed (if meters were 'up flexed' into the energy system).

This scenario is posed as a "up flex" model where meters are moved as far as possible from individual consumers. The main value of this scenario is to analyse the concept of metering from a consumer point of view in more detail.

In today's energy system a meter is a key mediator of relationships between consumers and various energy system providers. It quantifies and controls a specific quantity (energy) and acts as a vehicle of responsibilisation (through initiatives such as cost-reflective tariffs). Adding additional meters can be seen as adding additional mediation points. However largely they use the same tool (energy flow) to mediate this relationship. Unmetered supplies exist today (such as for street lights) however these have predictable behaviour (such as expected time the light will be on) and known properties (such as wattage of light) as analogues to meters. Residential energy use is not that predictable.

This no meter scenario enables broader consideration of what a different relationship could be like. For example:

- How would costs and benefits be shared in a more just way if metering were removed or redefined?
- What are the affordances of energy in people's daily lives?
- What is "reasonable consumption" and how does it differ between people?

In 2022 the NEM and the SWIS generated 227,292 GWh of electricity, of which approximately 26% is for residential consumption. Assuming standard usage and supply tariffs, this equates to approximately $20.2 billion total energy cost today. Clearly the cost of energy needs to be funded somehow. Currently cost is captured through meters. The question for now is: What alternate models exist? And what (if any) metering is needed to achieve this?

A criticism of the current method of funding the energy system is that it is blind to consumer capability to pay and the intersectional disadvantage that may lead to a particular consumption patterns. Energy subsidies exist for some people, however these are outside electricity provision pricing model(s) and are instead funded by governments through taxation. A potential new model may be to flip this orthodoxy and fund energy (either partially or wholly) through taxation. The simplest model would have all consumers share the cost equally. Equal costs could be orchestrated through the taxation system, for example. We understand this has its challenges too but see the benefit in thinking it through at the extreme. Table 6 presents an indication of what could happen if this were the case. There are three scenarios: if cost were applied per Australian, only to those who pay tax, or to each household.

Table 6 Dividing energy cost evenly

	Cost ($/day)	Cost ($/year)
Per person	$2.10	$768
Per taxpayer	$3.68	$1343
Per household	$5.47	$1997

However, this model is afflicted by the same issues as metering today: other than (potentially) not applying to those who don't pay tax, it is blind to people's capacity to pay and difficulties in their contexts (such as varying quality of housing). An alternate frame may be to use income tax brackets to divide by ability to pay. An indicative model is shown in Table 7.

Table 7 Dividing cost by tax bracket

Tax Bracket	Cost ($/day)	Cost ($/year)
0 - $18,200	0	0
$18,201 – $45,000	$0.41	$148

Tax Bracket	Cost ($/day)	Cost ($/year)
$45,001 – $120,000	$3.43	$1253
$120,001 – $180,000	$9.64	$3519
$180,001 and over	$31.79	$11603

This model removes direct financial impacts on consumers to modulate their consumption. In this model consumers are exposed only to the *total* cost of the energy system. This potentially changes the drivers for consumers. For example, under the current consumption cost paradigm high consumption applies a proportional cost directly to the consumer who is using the energy. If the consumer can afford the energy, it may imply that energy is infinitely available therefore any use is acceptable. If energy was paid for as a social cost, individual consumption levels impact social costs. Clearly this means that there is still an incentive for people to manage their consumption, it just applies differently. As described in 4.2, there are several avenues that are not directly related to price (both constructive and otherwise). But fundamentally the aim of this exploration is to raise the questions *"What consumption is sufficient?"* and *"are there aspects of consumption that don't need to be mediated through a meter?".* The second question is discussed below. But for the first question: currently energy is priced as if it is costly but infinite. Climate science is revealing that this is incorrect. There is a maximum sustainable energy consumption which should be considered from the perspective of the entire energy system. Therefore, it is likely a broader discussion around consumption is required, although this discussion transcends energy and metering.

These models still largely answer the question *"How do you split a given a cost for a commodity?"*. The aim is to make the distribution of these costs related to capacity to pay, rather than how much people use. This frame assumes that as a whole people use energy responsibly, which would require a larger discussion (such as what responsible energy use is in the first place).

A taxation model could be considered as a collectivist approach. It proposes a system where people are trusted to use a collective asset more carefully. Electrical energy is used for a variety of purposes. These purposes are not equal. For example, a pool pump may be considered as a lesser use for energy than lighting or heating. And within heating, an unwell person's heating may be seen as more important than a well person (see 4.1). We can see these value judgements in the meter unbundling rule change itself where "discretionary" load could be separately metered. Although the proposal is largely to make this demand *less* expensive to supply even though the premise is that it is less important due to its ability to be shifted. A useful frame is to consider the purpose energy consumption (through some kind of device). Electricity enables comfort or wellness [7] when used through a heater, for example. Or, it enables a pool that can be used for leisure when used with a pool pump. It enables visibility at night when used through a bulb, and many other things. Potentially a more just model would price what electricity enables differently. These use cases are not captured in the consumption dataset we have. Similarly, it is not clear how they would be captured. However, the data used in this study is disaggregated to a level. We can consider some types of use have more valuable use cases (such as heating and lighting) therefore should attract a lower cost. Other use cases (such as pool pumps and EVs) could be considered low value and thus attract a higher price. This can be considered as introducing a "just" cross subsidy between those who consume energy for less valuable purposes to those who consume for more valuable purposes. For the cohort of data that was analysed in this study, the change in cost (normalised) is shown in Figure 8.

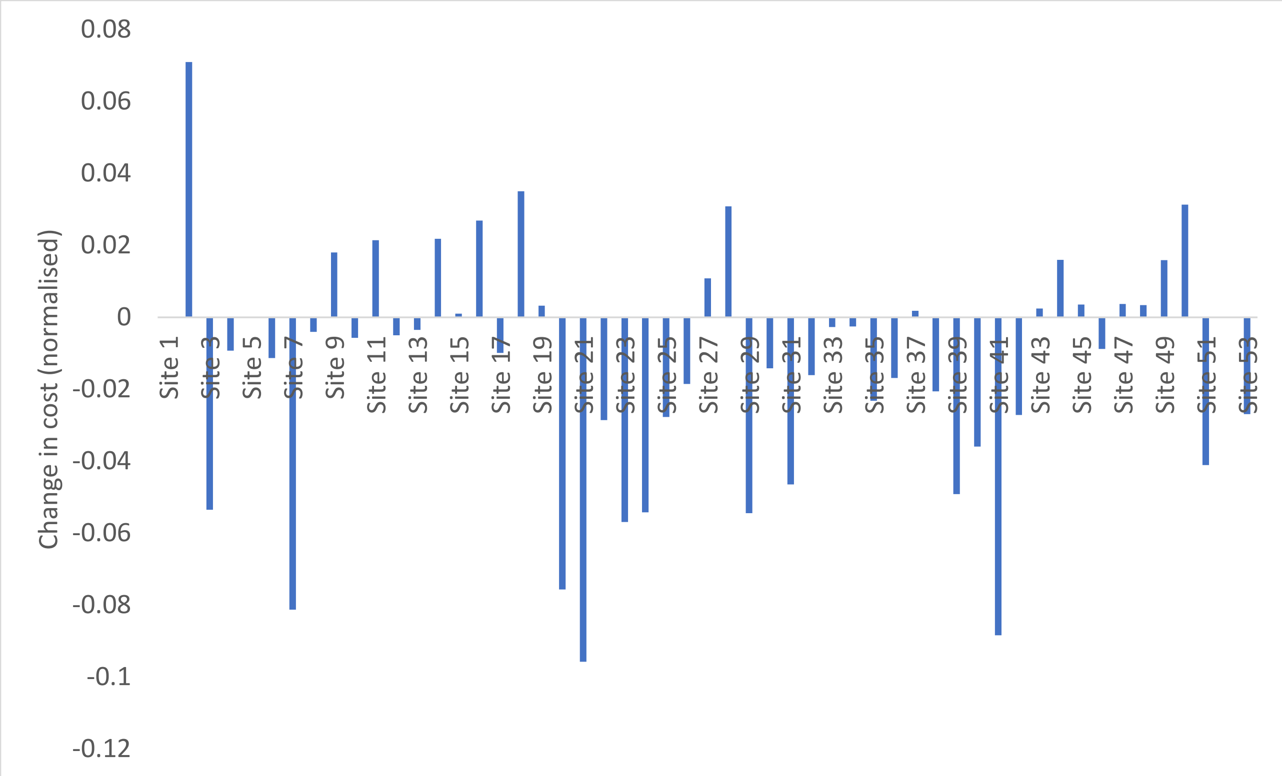

Figure 8 Change in cost when priced by value

The models suggested here can be considered as “alternate frames”. The main proposal from this section is to consider alternate frames that enable potentially more just distribution of cost and benefit. Some of these frames may change or entirely remove metering compared to today.

4.6 Versatile EV charging

Friction Flex

Key takeaways: Electric vehicle charging can be made simpler and easier with small extensions to meter unbundling principles. This can create fairer and more equitable outcomes for consumers. Focus should be placed on benefits to consumers separate to any benefit to the wider network.

In this scenario we have attempted to consider how the Flexible Trading approach to metering could be extended to simplify how EV charging is financially reconciled, in ways that reduce management complexity. The principle is straightforward – if an EV charger is separately metered (whether this is done at the EV supply equipment or within the EV itself) and has an awareness of its normal operating tariff (i.e. the tariff that its owner typically pays when charging at home) then this tariff could also be applied when charging away from home (either as-is or with some variation dependent on the new location).

Such an approach could have a number of advantages over the counter-factual approaches to charging. The owner can charge at friends’ houses or their workplace without creating a cross-subsidy from the connection owner to the EV owner. The EV owner can have confidence in what their charge will cost (at least in per-unit terms), without having to manage repayments or other financial arrangements between entities. This approach could also be used for public charging, although it is likely that the owner of the charging infrastructure would expect to amend the tariff in order to fund the infrastructure and make a profit.

From an analytical standpoint this model is relatively straightforward – we simply calculate the energy supplied to the EV across the charging period, and apply both the connection owner's and EV owner's energy tariffs to determine the money saved by one and paid by the other. If the tariffs happened to be the same for both, this would represent a direct transfer of value from the EV owner to the connection owner (i.e. a net-zero-sum gain). If the house and EV owners were on different tariffs then these amounts may be different (and whether the overall benefit is positive will depend on the details of the tariffs in question). A simple example of this is when one has a higher energy price than the other. We should also consider whether the EV owner will share in a portion of any fixed costs associated with the connection (e.g. daily service charge in the case of residential tariffs) as not accounting for such fixed costs would represent an inherent cross-subsidy from the connection to the EV owner. A simple way to do this is to split the connection's daily fixed costs across each payment interval (e.g. 30 minutes for a typical home smart meter), and then apportion the costs at each interval between the connection and EV owners' tariffs based on their proportion of the total load at that time.

Figure 9 below indicates the daily cost for charging an EV on a range of residential tariffs, both including and omitting the daily service charge:

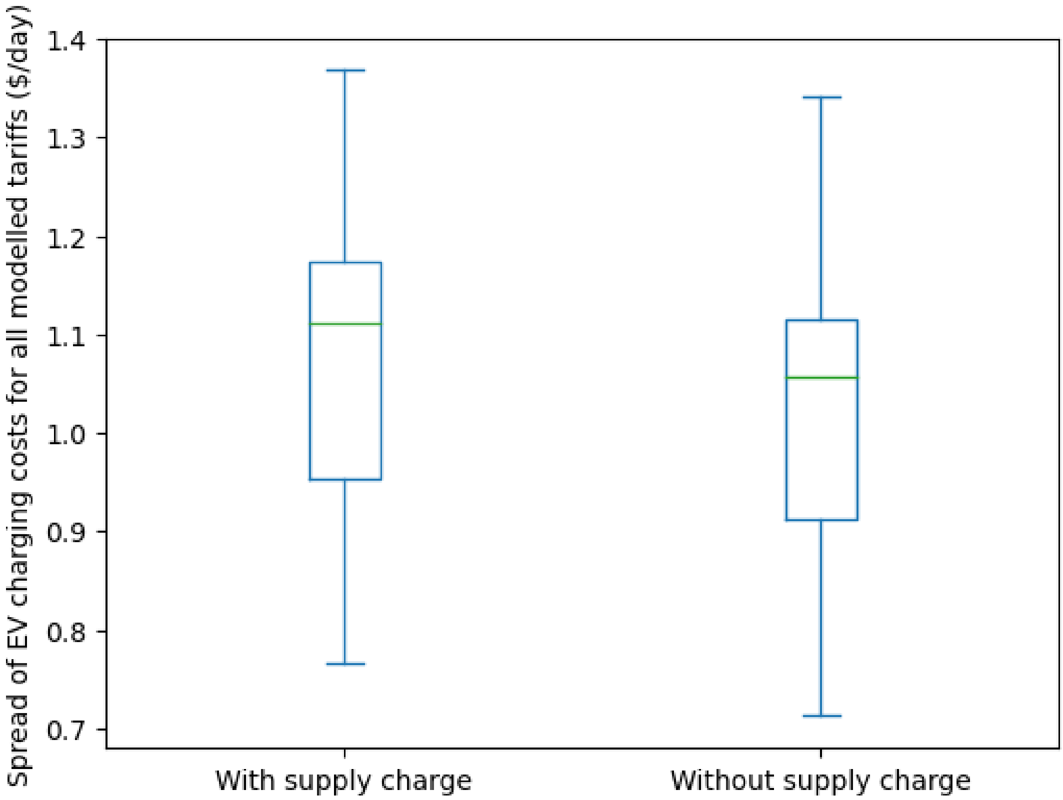

Figure 9 Average daily costs of EV charging for various tariffs (with and without supply charge)

By basing this model in existing tariff structures, social considerations are largely bounded to a comparison between the participating actors (that is, the EV and connection owners). This model likely represents a more 'fair' approach to managing EV charging, as the EV owner becomes primarily responsible for the costs associated with the benefits they are accumulating. This is particularly pertinent while EVs are still largely a luxury asset, with low-income households unlikely to benefit from the cross-subsidisation this model is intended to address. However, there may be negative consequences with making such an approach available; for example, workplaces may have less reason to offer free or discounted EV charging to their employees if an easy alternative is available to allow convenience charging during the day (the role on-site solar may play here could add further complexity).

There are of course a number of technical and regulatory considerations that would need to be addressed for this approach to be feasible. For example:

- How such a system may operate differently across distribution network service providers (DNSP) and jurisdictional boundaries;
- Whether there would need to be dynamic negotiating between the site main meter and EV sub-meter; and
- Whether, and how, import-side dynamic operating envelopes (DOEs) might apply to the EV charger.

These are all topics that would need to be considered in the implementation of such a system.

As a starting point, we have considered how DOEs could be applied to an EV charging at a residence other than its owner's (and particularly one without existing controllable loads, so import DOEs would not otherwise be applicable). Figure 10 below shows how a DOE (based on a simple diurnal limit aligned with one DNSP's peak and off-peak periods) might impact the charging of the 'new' EV on a high-charging day:

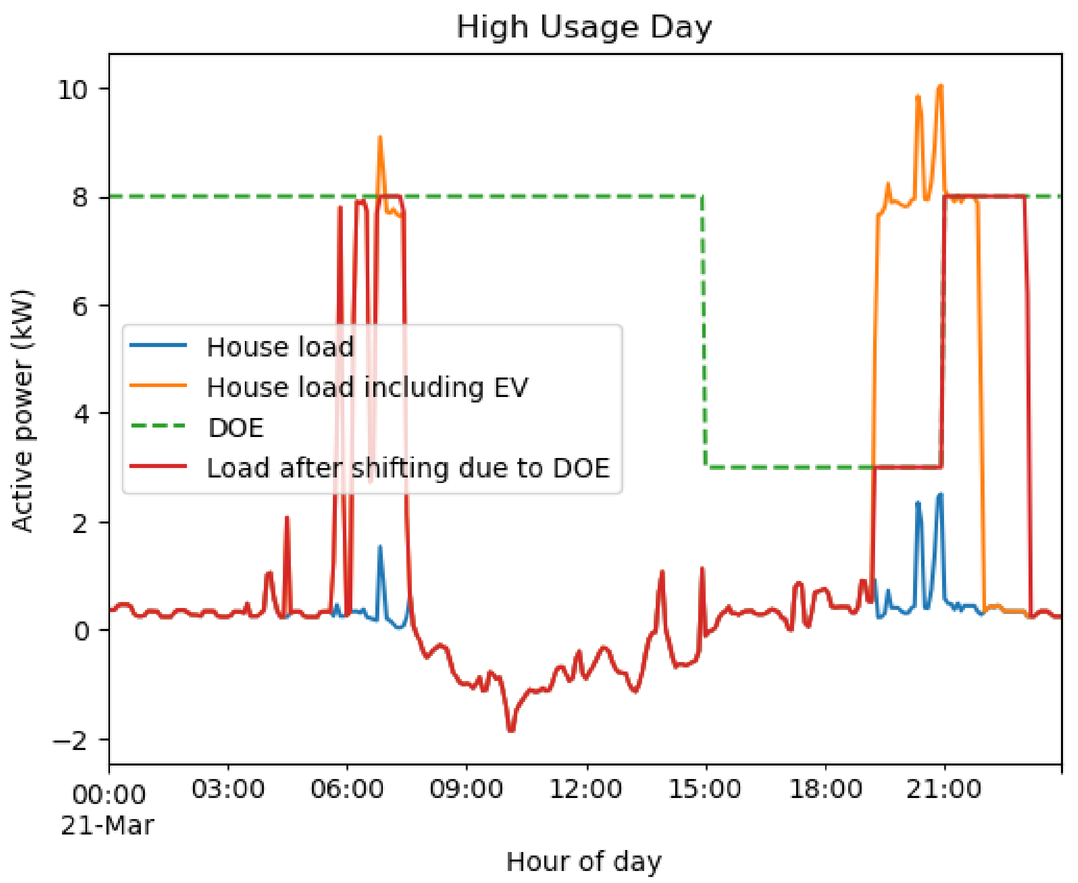

Figure 10 Potential impact of dynamic operating envelope on EV charging

The total charging energy required by the EV across this day is 30.75 kWh, and of this 9.23 kWh causes the site to exceed its DOE. The shifting of this energy later in the day allows the site to maintain its DOE, however this extends the evening charge out by 70 minutes.

4.7 Retailer switching

Friction Flex

Key takeaways: Consumers are intended to be responsive to market signals and able to change behaviour to reflect system needs. In its extreme this price-responsiveness could have strong positive outcomes for consumers but to the detriment of other market actors. Rule makers should consider the limits of the behaviour they request of consumers.

This model presents an unrealistic but thought-provoking mental experiment, intended to explore the extremes of price-responsiveness and 'consumer-centric' neoliberalism.

Amongst the discussions relating to Flexible Trading has been the potential for sub-metered devices to be capable of being reconciled against multiple other devices based on specific criteria. For example, a home may include both an EV charger and a home battery that are taking advantage of FTM2 by being managed by different retailers (e.g. an EV charge management specialist and an FCAS-targeting battery VPP); if such a home also had solar, having the solar able to be reconciled against each depending on certain circumstances (e.g. time, presence of an EV) would make sense. To facilitate this would mean the ability for meters to change between retailers, possibly arbitrarily.

Additionally, it is frequently suggested that consumers could be considered to be price-responsive entities, capable of adjusting their personal behaviour and the operation of their devices. This model describes a thought experiment that takes this to a logical extreme – what if meters (including potentially main meters) were able to respond dynamically to the different tariffs being offered in the market, by switching between retailers at every operational interval (e.g. every 30 minutes)?

To explore the potential for consumer savings (at retailer expense) under current tariffs, we calculated the half-hourly costs of a representative household, based on a set of both fixed-price and time-of-use tariffs operating within CitiPower's network. We additionally modelled the Amber residential tariff, which reflects the wholesale half-hourly market price with an additional $15/month fixed fee. Finally daily service charges were included by distributing each tariff's daily charge equally across all 48 half-hourly periods in a day.

This dataset was then analysed for a number of interesting metrics. The first is arguably the most important – how does this "meter-switching" system perform when compared against the source tariffs? The results are shown in Figure 11.

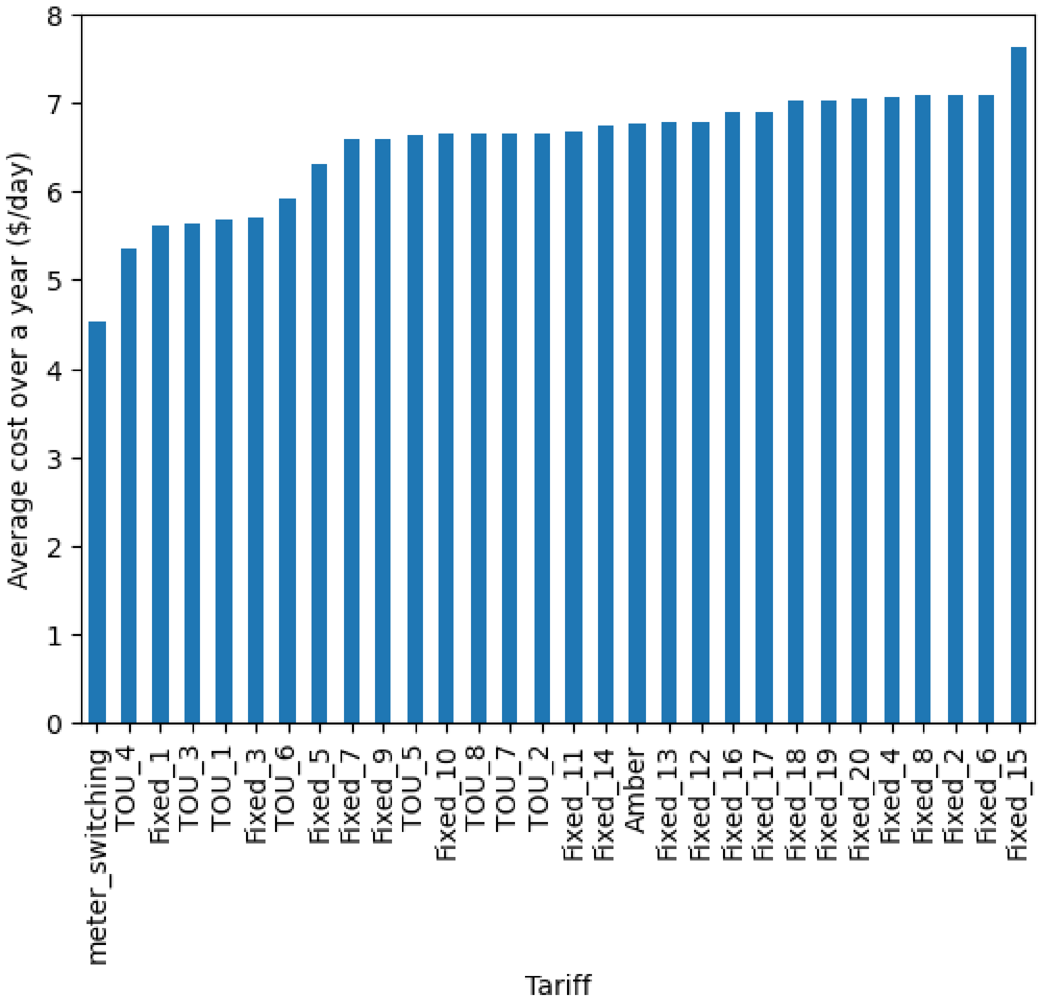

Figure 11 Performance of analysed tariffs against the "meter switching" approach

This demonstrates that the meter switching outperforms all tariffs (which should not surprise as it is optimised to do so), however individual tariffs, and in particular certain time of use tariffs, can come within 15-20% of the meter-switching approach across the year. However other tariffs, including the majority of fixed tariffs, (perhaps less-surprisingly) perform quite poorly when compared with the meter-switching approach. Interestingly for this dataset Amber performs approximately at the middle of the pack; this makes a certain amount of sense, as Amber's business model is predicated on enabling consumers to change their habits based on the wholesale price, which this consumer is not otherwise incentivised to do. The reduced costs here represent a direct transfer of value from retailers to consumers.

We then chose to investigate at what times of the day different tariffs were dominant. Figure 12 summarises this by identifying which tariff is selected by the meter for each half-hourly interval, and then summed across all 365 days of the year.

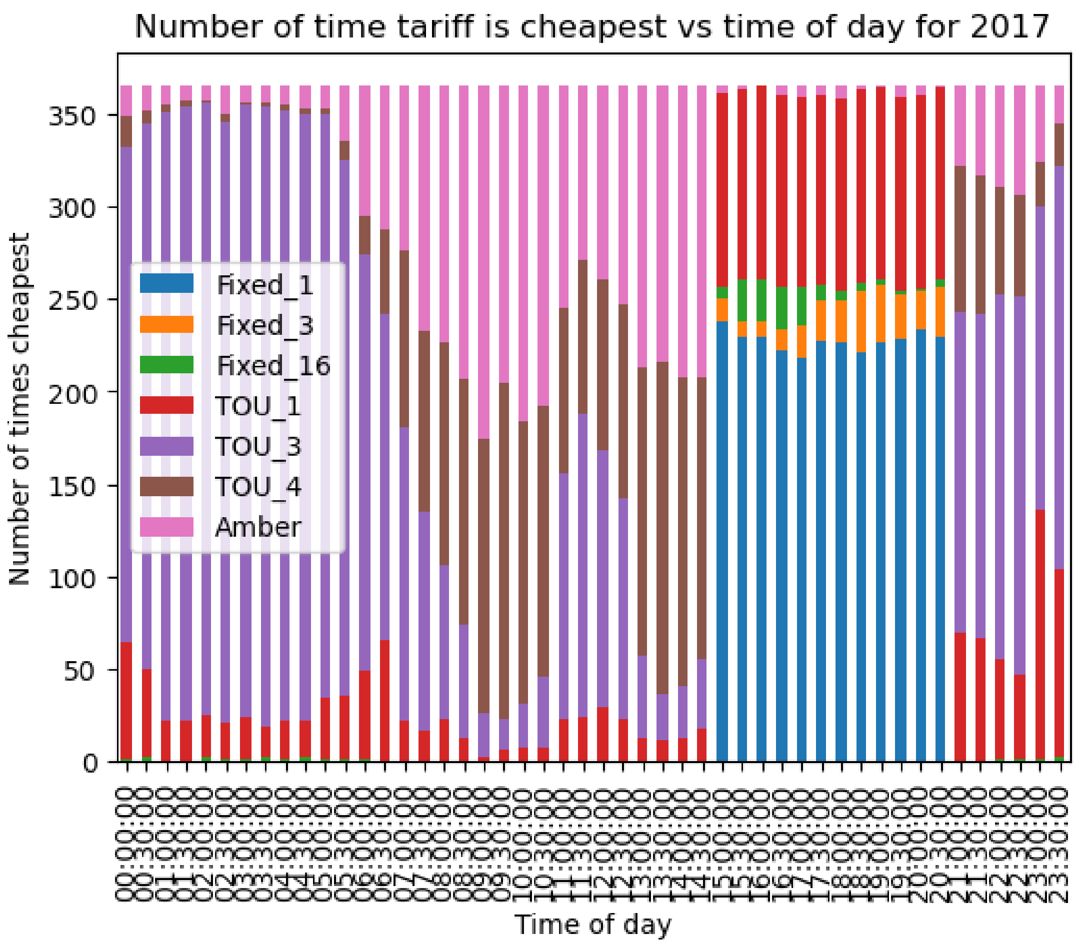

Figure 12 Performance of each tariff across the day

A key point to note here is that only a handful of the modelled tariffs (7 out of 29) are high-performing tariffs at *any* time in the modelled dataset; this is a finding which should encourage consumers to shop around! As can be seen Amber performs most strongly in the middle of the day, when solar generation is likely to push spot market prices lower. Similarly time of use tariffs tend to perform poorly during peak periods (primarily 3-9pm), except notably for TOU_1, largely driven by its unusually-low daily service and peak charges which make it competitive with fixed tariffs even in peak periods. This is offset by its poor performance against other time of use tariffs in off-peak periods. The overall best-performing tariff (shown in Figure 11) was TOU_4, which in this case was driven by a low off-peak tariff causing strong performance during the periods immediately pre and post the peak. Although TOU_3 clearly dominated overnight, the low amount of energy consumed in these periods made this a relatively small contributor to its overall performance.

A final point to note on this experiment relates to the prevalence of switching between tariffs. Although there were relatively few leading tariffs, the complexity of time of use tariffs and the role of Amber created situations where the optimal tariff changed frequently. The total number of tariff-switches across the year was 4384, or an average of just over 12 times per day (i.e. more than a quarter of the 30-minute intervals saw a change in optimal tariff). These switches occur most frequently at the border between peak and off-peak periods as shown in Figure 13, although there are substantial numbers of switching events outside of these spikes.

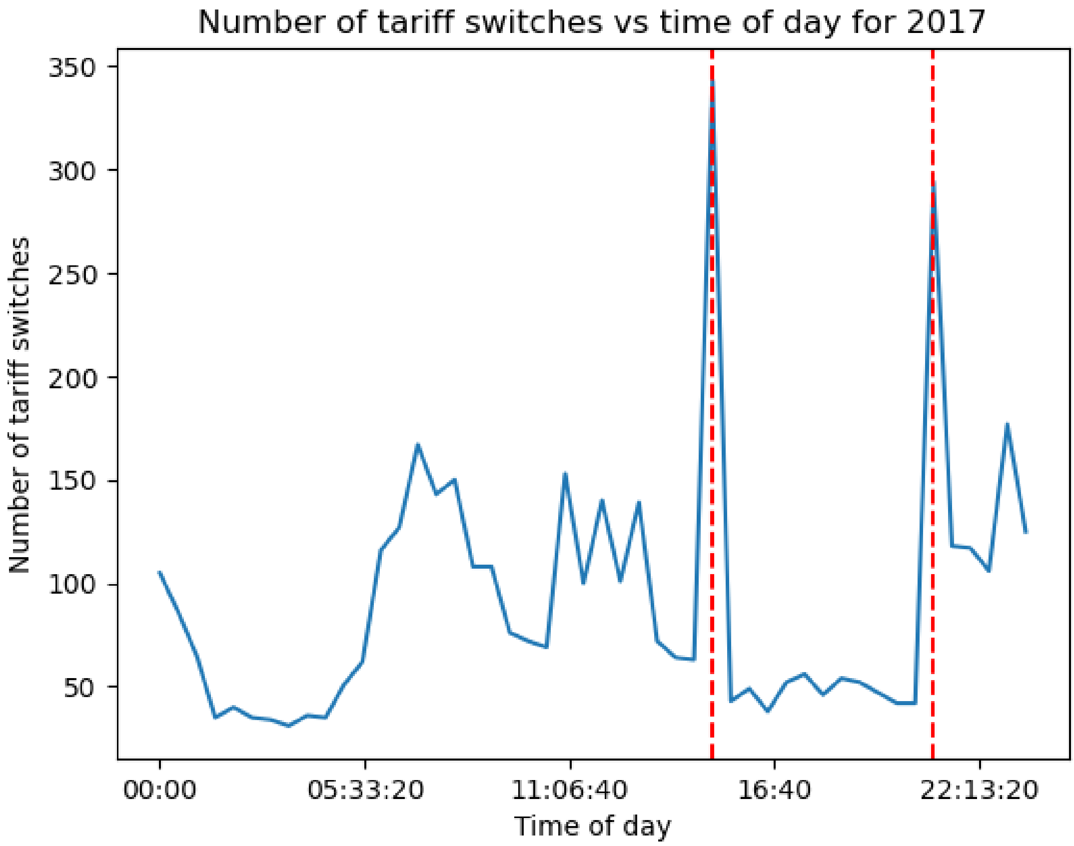

Figure 13 Number of meter-switching events across the day for a year (peak borders highlighted)

It should of course be recognised that an approach such as the one defined here could not occur in a vacuum. Retailers use extensive hedging mechanisms to ensure they remain profitable despite variable spot-market pricing and fixed/steady retail tariffs, which could be significantly compromised by the approached discussed here. Were consumers able to respond to tariffs in this way retailers would no-doubt redesign their charges to ensure they remained consistently profitable, likely reducing the opportunity for consumers to benefit from this approach. Regardless this exploration provides a useful insight into how retailers use their dominant position in the energy market to provide themselves a reliable income, and the potential for new approaches to undermine this to the benefit on consumers (in contrast to some historical approaches which have had the opposite effect).

5 Conclusion

The recent AEMO proposed rule change on Flexible Trading aims to enable increased flexibility for DER, and to unlock a variety of new ways for consumers to engage with the energy system and market. Meter unbundling is a key opportunity of this rule change proposal, which AEMO proposes will be a vehicle to simplify and make understandable ways of integrating DER.

In this report, BSGIP considered this change as essentially a way to increase *flexibility* in metering. If done well, increasing metering flexibility could represent a paradigm shift in improving household activity within the energy system. However, historic attempts at consumer-centric change have demonstrated the challenges with ensuring good and equitable outcomes for consumers.

Our goal in undertaking this work was to explore the limits and impacts of increasing metering flexibility, including social, financial, and commercial impacts. Our exploration delved into areas such as:

- The role that meters play in intermediating the relationship between households and the market;
- The potential for optimised systems to lead to heavily sub-optimal outcomes;
- How opportunities that involve multiple consumers have the potential to improve or substantially worsen equality; and
- How smarter metering could reimagine how local energy systems are formed and operate.

To support this investigation we developed a social analysis framework, building on the Responsible Research and Innovation concepts developed by Stilgoe et. al. We incorporated this framework into our existing expertise in techno-economic analysis, to create a new methodology for performing socio-techno-economic analysis of change. This framework will form part of BSGIP's socio-techno-economic analysis toolkit going forward, and we look forward to using this capability to support rule makers improve their own understanding of the impacts of major change.

In undertaking this work, we found several issues that should be explored further by the AEMC and rule proponents to ensure changes genuinely result in consumer benefit:

- A broader view on consumer's ability to uptake flexible products can mean reforms reinforce existing inequities; and
- Power imbalances can subvert positive outcomes from reform.

The analysis also revealed several possibilities or positive outcomes that could be enabled by metering reform:

- Potential to reduce the effort required to implement new energy sharing and trading models such as community energy schemes;
- A more explicit way to resolve key issues in adjacent sectors such as charging work vehicles at home; and
- The potential to break normative assumptions around metering and its use cases could enable a fairer and more just energy system.

Clearly, increasing flexibility in metering does not predetermine a good or bad outcome. If implemented carefully it can create benefits for all. But if not, it can reinforce inequity, exacerbate power imbalances, or create bad financial outcomes for consumers. This work can act as a flag to decision makers to analyse reform more expansively. A socio-techno-economic and critical lens can reveal issues that we have not observed be discussed in regulatory discourse but are key determinants of the outcomes of change. We hope our findings will inform the energy market reform process and lead to better outcomes for all participants, and will assist in achieving our collective goals of greatly-improved household electrification.

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