Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia

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Abstract

Peer-to-Peer (P2P) electricity markets have been gaining significant attention as a promising model for enabling integration of distributed energy sources by creating consumer-based electricity markets. However, despite the significance of the users in this model, knowledge is still lacking as to who the users interested in P2P electricity markets are and what role they can play in building them. We aim to fill this knowledge gap by providing evidence from the first real-world trial of a P2P electricity market facilitated by the blockchain technology across a regulated electricity network. We apply sustainability transition and innovation thinking to analyse the trial participants as users shaping the P2P-related innovation process . Supported by our empirical results, we found that users joined the P2P market trial with the ambition to learn and co-create the future of prosumer-focused electricity markets. We also found that if P2P is to enter the mainstream market, assistance of other actors such as intermediaries and activists is important to cross the chasm to the majority of users and move from a learning and probing phase to breakthrough and wide diffusion.

Key works: prosumer; consumer role; blockchain; peer to peer electricity markets; sustainability transitions; innovation diffusion;

1 Introduction

In traditional electricity systems, end users only acted as passive consumers and receivers of electricity from centralised generation *via* transmission and distribution grids [1]. However, the traditional model is being challenged as falling prices of small-scale solar photovoltaic (PV) systems and batteries motivate households and commercial properties to instal their own on-site generation capacity. This is transforming traditional end users into an active part of the electricity system [1-3], earning them the title of prosumers – actors that both produce and consume electricity [4-6].

In countries such as Australia, nearly one quarter of households have PV systems installed [7], and prosumers are being remunerated for their excess energy through government sponsored feed-in-tariff (FiT) or buy-back schemes *via* existing electricity retailers. Here, the high level of PV penetration is affecting the technical and economic stability of the centralised electricity system [8] making subsidies and retailers' default purchase of self-generated energy exported to central grids unsustainable [9]. However, as subsidies get reduced and eventually expire, prosumers are left in a post-subsidy era with no alternative revenue model for their excess electricity [4]. There is an increasing interest in post-subsidy market models that could create new value-streams for prosumers [1, 4, 5, 10], better reflect the bidirectional nature of the new electricity system [11], and facilitate the transition to a distributed and clean electricity system [12, 13]. One example of a business model innovation is the Peer-to-Peer (P2P) market model [5, 10, 14-18], that in principle allows prosumers and consumers to trade with each other without the need for an electricity supplier and/or retailer as middlemen. The middleman is replaced by a third-party digital platform, such as a blockchain-based platform, that allows prosumers and consumers to interact directly and negotiate better prices for their electricity in contrast to relying on the offer from a licenced supplier [5, 14]. A P2P market is believed to create a future with users at the heart of the electricity market, democratising local energy provision [15]. In addition, the P2P model has the potential to improve access to affordable clean electricity to those users that do not own renewable energy technologies. This concept has been described as energy and flexibility justice [19-23].

While the concept of P2P electricity trading has recently received an increasing research interest [18, 24-27], it has only existed in the form of conceptual models and experiments in closed environments such as embedded networks [15], university campuses [17, 28] or organised energy communities in islanded micro-grids [5, 16, 26], where P2P sharing and trading occurs in the form of a computational simulation or behind the utility meter in environments shielded from the incumbents and regulations [29]. The P2P case-study described in this paper provides evidence from the first real-world P2P electricity trading trial facilitated by the blockchain technology that allows consumers and prosumers to trade electricity over the regulated electricity network directly impacting their electricity bills.

Existing research into the P2P model is limited by its predominant focus on the technological and pricing aspects of P2P electricity trading. Much less attention has been given to the real-world prosumers and consumers – in this paper collectively refered to as electricity users - individuals or groups that use electricity as well as associated technologies (such as solar panels) to consume, produce and distribute energy[1]. The users in the P2P model are no longer passive consumers of the output (as is the case in traditional business models), instead becoming directly linked in the P2P value exchange and are thus central to its succesful development [31]. Ahl, Yarime, Tanaka and Sagawa [24], reported that the relationship between electricity users and blockchain-based P2P business models (and *vice versa*) is yet to be empirically studied. Further, they also identified that there is no published research into why and how consumers would want to participate in P2P market innovation. This paper aims to fill these gaps and provide knowledge about ways users can contribute to P2P model-related innovation processes that go beyond merely consuming [10, 24, 30]. By doing so, we hope to assist the research community, policy-makers and industry actors in potential implications of this business model [24].

[1] Definition inspired by [30] J. Schot, L. Kanger, G. Verbong, The roles of users in shaping transitions to new energy systems, Nature Energy 1(5) (2016).

We have looked beyond techno-economic literature to better understand and conceptualise the relationship between the users (in this case trial participants) and the development of a business model innovation (i.e. the P2P market trial). We engage with sustainability transition and innovation diffusion literature, which provides us with a conceptualisation of users that goes beyond the one dimensional view of users – playing a role only in consuming the innovation [30]. In this body of literature, scholars emphasise that users are important change agents, enacting agency in all stages of the innovation process from the development of niche market ideas to adopting the niche innovations into their everyday practice [32]. However, former studies have largely focused on the role of users in supporting product innovation, while user contributions to new business model development remains under explored in the transitions literature [12]. The existing business model innovation research is still mainly concerned with the role of a firm, manager, entrepreneur or an advocacy organisation in the process of business model implementation [13, 33]. This paper attempts to fill this gap by conceptualising P2P electricity trading models as a niche business model innovation within a broader transition to sustainable energy systems [4, 32, 35] and by placing users in the focus of our analysis.

The aim of this study is to investigate the motivation and role users play in developing P2P electricity markets. We provide evidence from the first real-world example of P2P electricity trading *via* a blockchain platform, located in Fremantle, Western Australia (WA). The aim is fulfilled by addressing the following research questions:

1. Who are the electricity users that are willing to experiment with P2P electricity trading and what motivates them?
2. What roles do electricity users play in shaping the P2P electricity trading-related innovation?

The paper is structured as follows: In Section 2, we introduce the background for the P2P market model and its potential to support the renewable energy transition. In Section 3, we take a closer look at the way users are conceptualised in transition and innovation literature before we synthesise the existing literature into a conceptual framework for the analysis of our empirical case. Section 4 introduces the research design, methodology and case study, which is followed by the empirical results in Section 5. Results are consequently analysed and discussed using our conceptual framework in Section 6, followed by conclusions in Section 7.

2 Peer-to-Peer electricity trading models

Environmental concerns, technological innovation, and the impacts of prosumers on markets and system operability lead to an increasing interest in distributed renewable electricity systems as alternatives to the dominant centralised model of electricity production and consumption [34, 35]. Growing numbers of scholars and industry actors emphasise that new distributed grids will require marketplace innovation to reflect the decentralised infrastructure and the changing character of users who, by adopting distributed energy technologies, become active market participants that can produce, sell and buy electricity as well as reap benefits of their demand flexibility [4, 11, 15, 19, 20]. Yet many challenges remain, including finding business models that could fairly distribute costs and benefits among a large number of self-interested market participants [24] and facilitate energy and flexibility justice [19, 20]. A number of prosumer-focused solutions are being proposed, with different levels of interaction and levels of dependence on the existing energy system [4, 5]. This paper focused on an autonomous P2P model[2] defined by Parag and Sovacool [5], which in theory allows prosumers and consumers to interconnect and trade directly with each other. This model is perhaps farthest from today's electricity market design [4] and served as a starting point for establishing the P2P trial that is our case study.

The research literature defines the concept of P2P electricity market as an autonomous P2P network of prosumers and consumers and is often compared to the Uber or Airbnb model for the electricity sector [5]. Influenced by ideas of the sharing economy, a software enabled P2P market model allows consumers and prosumers to buy and sell self-generated electricity and other services such as flexibility or demand response, in an open electricity market across the regulated distribution network [10, 18, 24, 36]. Blockchain technology is the software platform that is considered the enabler of the P2P market place [14, 24, 27, 36]. Blockchain is a decentralised internet protocol that could, in theory, enable transactions of monetary and non-monetary digital assets[3] directly between peers without the necessary involvement of a middleman, such as a licensed energy retailer [14, 36]. Due to its ability to create smart contracts and ledgers, the blockchain algorithms could replace the need for a licenced retailer to overlook and verify contractual agreements between peers [27].

Like other new technologies and business models, the P2P model is still unsupported by existing regulatory structures, financial institutions and lacks societal awareness or acceptance [24]. Ruotsalainen, Karjalainen, Child and Heinonen [29] identify the importance of considering that the P2P market model currently only exists as a vision of a desirable future without accounting for existing electricity sector actors and infrastructure. Embedding the P2P model in real-world settings, across the public grid infrastructure, thus face significant caveats and complexities that are yet to be solved if the theoretical benefits are to be realised [4, 5].

An increasing number of scholars and industry actors believe that the P2P model is unlikely to result in a complete collapse of the incumbent electricity sector, instead utilities and public authorities may exist alongside prosumer networks. However, the future roles of different actors in a P2P trading model are not yet known [10, 29]. We do not wish to study actor roles in the

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[2] P2P model is the most radical prosumer-based business model innovation with the prosumers and consumers directly trading with each other in a seamless network without a need for the large grid market. Other prosumer-based models are 'prosumer-to-interconnected or islanded microgrids'; and 'organised prosumer groups market' both including different levels of interaction between the prosumer networks and the large grid market [5] Y. Parag, B.K. Sovacool, Electricity market design for the prosumer era, ibid.(4) 16032..

[3] Digital assets that can be traded on a blockchain are not limited to financial transactions, e.g. payments for electricity. In the energy sector, other non-monetary assets could be traded such as demand-side and flexibility services, energy certificates, carbon offsets and/or storage services. [37] M. Andoni, V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, P. McCallum, A. Peacock, Blockchain technology in the energy sector: A systematic review of challenges and opportunities, Renewable and Sustainable Energy Reviews 100 (2019) 143-174.

future P2P market (assumed as a mature and established system design). Instead, we are interested in the transition and innovation processes leading to this end and the specific role prosumers and consumers can play in the development of P2P markets by studying their motivation, expectations and conduct in a real-world P2P trial. Specific technical details and critique of the blockchain enabled P2P transaction model lay outside of the scope of this study.

3 Achieving transition through business model innovation

As described in the previous section, the P2P model offers a number of potential social and technical benefits for the future of distributed energy systems [5]. Yet, the challenge remains to understand how this niche business model innovation can break through and challenge the dominant electricity market model and what roles users can play in this process. The sustainability transition and innovation literature possess useful frameworks to study the role of niche innovations in system-wide sectoral transitions. The Multi-Level Perspective (MLP) [38] has been one of the most prominent frameworks in this field, studying technological change as an interaction between three analytical levels: the niche, regime and landscape. The socio-technical regime consists of actors, institutions and infrastructure aligned around a dominant design. The regime can be challenged from the niche level, a protected space where radical technological innovations emerge and grow. The regime change can also be affected by external landscape forces, emerging from the broader socioeconomic system (e.g. political agenda). A regime transition is a complex co-evolutionary process that involves fundamental reordering of social and technical components of a socio-technical system. The MLP is described in more detail in seminal papers by Geels and Schot [39] Rip and Kemp [40], Geels [38] and Smith, Voß and Grin [41].

While MLP's focus is on new regime building that takes decades, we argue that this perspective can be useful in understanding more recent innovations within a long-term system-wide change. The ability to see the 'context of a transition' can be useful when analysing specific technological novelties. This is evident in most of the single case studies using the MLP, for example the struggle of plant-based milk against entrenched dairy-milk [42] or the niche-regime interaction of solar PV technology in the Netherlands [43]. However, existing transition research has largely focused on the novel technological products from within niches as drivers for change. Scholars have highlighted that new technologies alone will not suffice to achieve a systemic change and pointed to the importance of business model innovation because they connect multiple actors, mediate between production and consumption side and support the introduction of novel technologies into the market. [12, 13, 31, 33].

Business model oriented transition research was established by analysing cases of energy service companies (ESCOs) in the UK [13, 44], new business models for whole-house retrofitting in the Netherlands [12] and distributed business models under the Energiwende in Germany [31]. Similarly, we consider business models being niche innovations in their own right. We therefore use the MLP to position our case study in the broader electricity sector transition, where the centralised energy market is being challenged by innovative electricity market models that are emerging as niche innovations. Whilst this study focusses on the P2P model, we understand that different business model innovations are competing, interacting and complementing each other to gradually develop the future market model for a decarbonised electricity sector [13, 45, 46].

3.1 Users in niche business model innovation

Transition thinking has recently been refined by integrating business model innovation ideas [12, 13]. Existing studies are focused on the role of firms, entrepreneurs, managers and advocacy organisations when implementing new business models in the context of a sector in transition [4, 12, 13, 31, 33]. In transition literature, business models are traditionally integral to a firm, as a means to deliver customer value, with customers seen as passive business model adopters. If the dominant business model logic in the electricity sector is to be broken, more knowledge is needed about the role users can play in business model innovation as they evolve from a sole consumer to a key actor within the electricity market.

Although not specifically focused on business model innovation, the system builders role of users in the energy system transition has been highlighted by Schot, Kanger and Verbong [30], who by using the MLP framework defined a typology of users that support new technologies in different innovation phases along the innovation S-curve [30, 47-49]. In their conceptualisation, user roles include producers, legitimators, intermediaries, citizens and consumers (see Figure 1). While the typology of users is claimed to matter within a system-wide, long-term transition, they provide examples of relatively specific and recent niche developments related to small-scale consumer side renewables. Thus we argue that the user typology can be applied to study early-stage innovations.

This framework offers a user-to-system perspective, where users are one of the system builders breaking down structures of dominant regimes. For example, users-legitimators focus on convincing regulators and users- citizens focus on fighting the incumbents. The users in this framework are important in the alignment of system components for succesful system-wide innovation. Though it provides important insights, this perspective lacks focus on micro-dynamics and emphasis on agency among users themselves, which is important when studying local, small-scale innovation. The diffusion of innovation literature highlights the importance of the user-to-user influence in innovation [50]. In this body of literature, the most widely applied user categorisation was developed by Rogers [50], who divided users into ideal types of adopters along a bell-curve, based on innovativeness, i.e. the point in time in which particular users adopt an innovation and thus have a different influence on its development and diffusion. Here, users range from the most innovative innovators, to early adopters, early majority, late majority and skeptical laggards (see Figure 1).

As Roger's bell-curve is a derivative of the S-curve, we propose that these typologies can be synthesised into the user-role in niche development processes represented in Figure 1. Both of these categorisations support the view that users are not a homogenous group with a single role, rather they are heterogenous actors that play different roles in supporting an innovation. By combining these perspectives, we can highlight that users can play a role in system-level as well-as micro-level (user-to-user) dynamics. Both of these categorisations can be plotted across time, creating foundations for building our framework for analysis (see Figure 2).

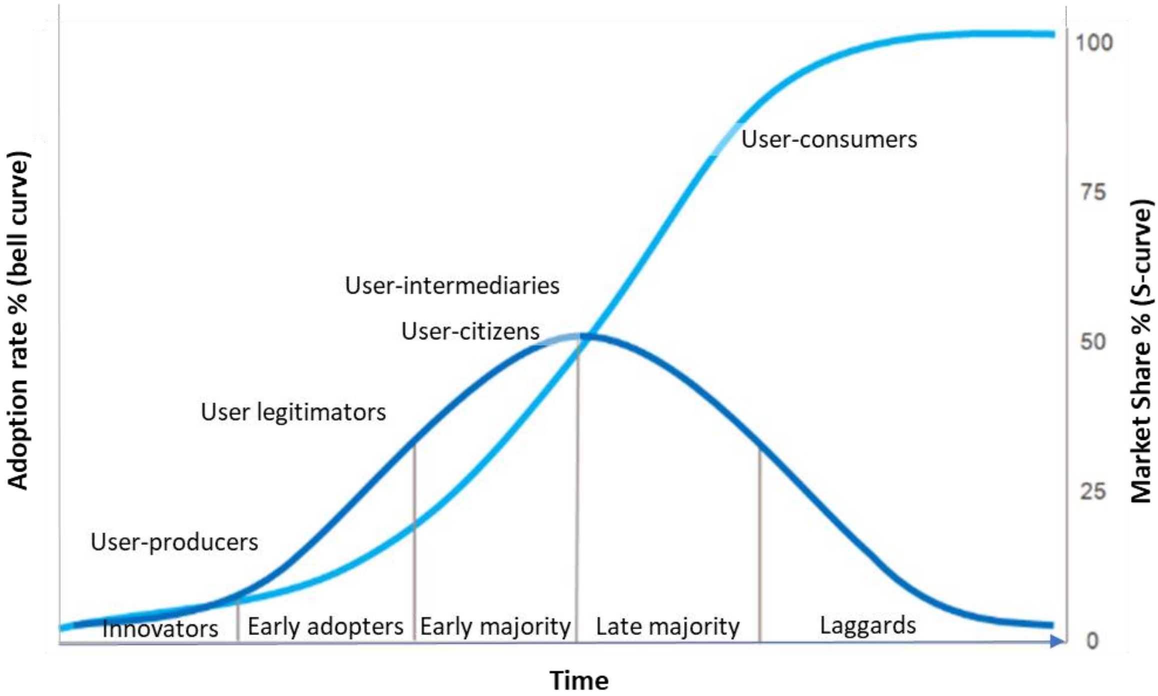

Figure 1. User categorisation along the bell-curve of innovation adoption by Rogers (2003) (x-axis labels) and user typology at different points of the innovation S-curve developed by Schot, Kanger et al. (2016) (graph labels).

As indicated earlier, sustainability transitions and innovation occur through time, conceptualised as phases of system innovation. Various authors have created different but similar descriptions of the technological innovation phases. For our framework we apply the four phase model, developed by Geels [51] (described in Table 1) because it includes the phase of learning and probing as a separate category (Section 3.2).

Table 1: Four phases of system innovation, adapted from Geels (2005).

Phase	Characteristic
Phase 1 Emergence of novelty	Innovation emerges to solve a problem or offer a new alternative to the dominant regime, i.e. sector. It is nurtured by a small actor network (of technology pioneers and innovators) sharing expectation about the future performance of the innovation. To improve the price and performance they experiment to improve the design and figure out user preferences.
Phase 2 Probing & Learning	The supporting network evolves into an established group or community of specialists, producers or consumers. These actors work together to improve the innovation through learning about market preferences and understanding the necessary legislative change.
Phase 3 Breakthrough and wide diffusion	With the help of external pressures and internal momentum, the innovation gains more actor and legislative support, which improves the price/performance ratio, achieves economies of scales and learning. The linkages and co-development of new system elements are increasing, resulting in building new infrastructures, new governmental agencies and professional organisations.
Phase 4 Stabilisation of the new regime	New socio-technical regime is created around the innovation with new infrastructure, new widely adopted user practices, policies and regulations.

3.2 Analytical framework

While the work of Schot, Kanger and Verbong [30] and Rogers [50] emphasises users' contribution to all the innovation phases, other scholars focus on users role in specific phases of the innovation process. Through a literature review, we strengthen the initial framework for analysis shown in Figure 1, by broadening the view on how users have been conceptualised within specific innovation phases. The end result is depicted in Figure 2 and summarised in Table 2.

In the first phase of innovation, when the novelty is emerging, researchers have pointed to the importance of users in inventing and creating novel solutions and routines [30]. They can either be self-propelled, or can be identified by other actors such as a private firm in order to customise their new technology and to improve its quality, performance and user-acceptance before introduction to the mainstream market [52]. They are often cosmopolitan, with connections to a small group of innovators internationally with whom they share a great interest and enthusiasm in novel ideas and technologies [50]. They can understand and apply complex technical knowledge and cope with a high degree of uncertainty. To be able to afford potential losses resulting from supporting an innovation, they usually have substantial financial resources [50]. Alternatively, these users seek and utilise new supportive institutions such as tax reductions or subsidies to support an innovation [30]. Extensive research has long acknowledged the co-creation role that users have and how both systems and technologies are developed, adopted and appropriated by society [53-60]. Existing literature names these users-innovators [50], producers [30], enthusiasts or product designers [56, 59, 61-64]. In our framework, we refer to these users as *innovators* (Figure 2).

In the second innovation phase, users are important in supporting the application of the innovation in a local context, legitimising it. Compared to users in the first phase, these users are locally integrated and have a higher influence on their approximate environment. They adopt innovation soon after launch because they see a compelling reason to use it and are willing to accept the related uncertainties and costs in exchange for future benefits [50]. They embed the innovation locally, reduce the innovation-related uncertainty by learning and probing the innovation, making errors and improving innovation-related knowledge [30]. With local influence, they have the ability to convince and increase the expectations about the relevance and significance of the innovation. They create narratives in order to align opinions about the innovation among their peers and the rest of the actors in the system [30, 50, 65, 66]. These users try to stimulate acceptance of the innovation among their peer networks by encouraging imitation and competitive reactions among the majority of users, thus playing a crucial role in creating conditions for wide diffusion of innovation [66-70]. Existing literature terms them early adopters [50], users-legitimators [30], entrepreneurial users and lead users [57, 71, 72]. We refer to them as *legitimators* (Figure 2).

By considering how the existing literature identifies the way in which users contribute to development in respective innovation phases, we can see how existing categorisations and descriptions overlap. We can also identify some disagreement regarding what it takes to move from one phase to the next. While Rogers' (2003) categorisation suggests that early adopters have the ability to take an innovation from niche to wide diffusion by acting as influential opinion leaders, evidence shows that the diffusion process is not always as linear as this theory predicts [73]. A relevant criticism comes from Moore [73], who claims that in some cases, an innovation that is well received by early adopters is not guaranteed to succeed among the majority of users due to significant differences between their motivations to adopt the innovation, which creates a chasm (see Figure 2) between these two user groups [73]. Moore [73] in his theory explains the issue of crossing the chasm between the early adopters and the early majority of users, pointing out that an early adopter would look to other early adopters for validation, and members of the traditional user group would look to other traditional users for validation that the business model is worth adopting and/or promoting. It is also important to point out that Rodger's (2003) perspective assumes that early adopters have a good position and access to the rest of the social network of peers within a firm or an industry.

The users importance in crossing the chasm by enabling the breakthrough from experimentation to wide diffusion has been emphasised by Schot, Kanger and Verbong [30]. They label these users *intermediaries*[4] and *activists*, which we decided to adopt in our framework. User-intermediaries represent those users who not only attempt to communicate with other more

[4] A role of an innovation intermediary is not limited to the users. Extensive literature on intermediary actors in sustainability transitions identifies intermediary roles of specialised private and public organisations, government funded agencies, consultancy firms but also individuals such as managers and academics. [74] I. Mignon, W. Kanda, A typology of intermediary organizations and their impact on sustainability transition policies, Environmental Innovation and Societal Transitions 29 (2018) 100-113, [75] M. Hodson, S. Marvin, H. Bulkeley, The intermediary organisation of low carbon cities: a comparative analysis of transitions in Greater London and Greater Manchester, Urban Studies 50(7) (2013) 1403-1422.

skeptical users, but also create space or serve as a bridge for alignment between different actor groups, institutions and technologies to support wide diffusion of the niche innovation. They are active in communicating innovation-related preferences and expectations with the existing regime actors to appropriate and align the existing regulations and standards - thereby promoting the innovation [30]. Another example of user-intermediaries in the literature includes energy user communities [76-79]. Activists play a crucial role in enabling the niche innovation breakthrough by being involved in transition politics. These users are generally dissatisfied with the existing regime, actively lobbying for a reform to overcome the regime resistance and weaken the position of incumbents. These users have previously also been termed activist groups [30, 80] and grassroot movements [17, 76, 81-85].

After a successful breakthrough is achieved, users start playing an important role in the wide diffusion process by adopting the innovation into their everyday practices. This category was emphasised by Rogers [50], who named them early majority, as being crucial for creating a network effect to mainstream the innovation. We therefore call these users based on their role: *mainstreamers* (Figure 2). While they have a strong willingness to adopt, they seldom hold strong opinions or a leadership position and take a longer time to decide to adopt an innovation. These users wait until the other users develop and experiment with an innovation to improve its price and performance, before they adopt (Rogers 2003).

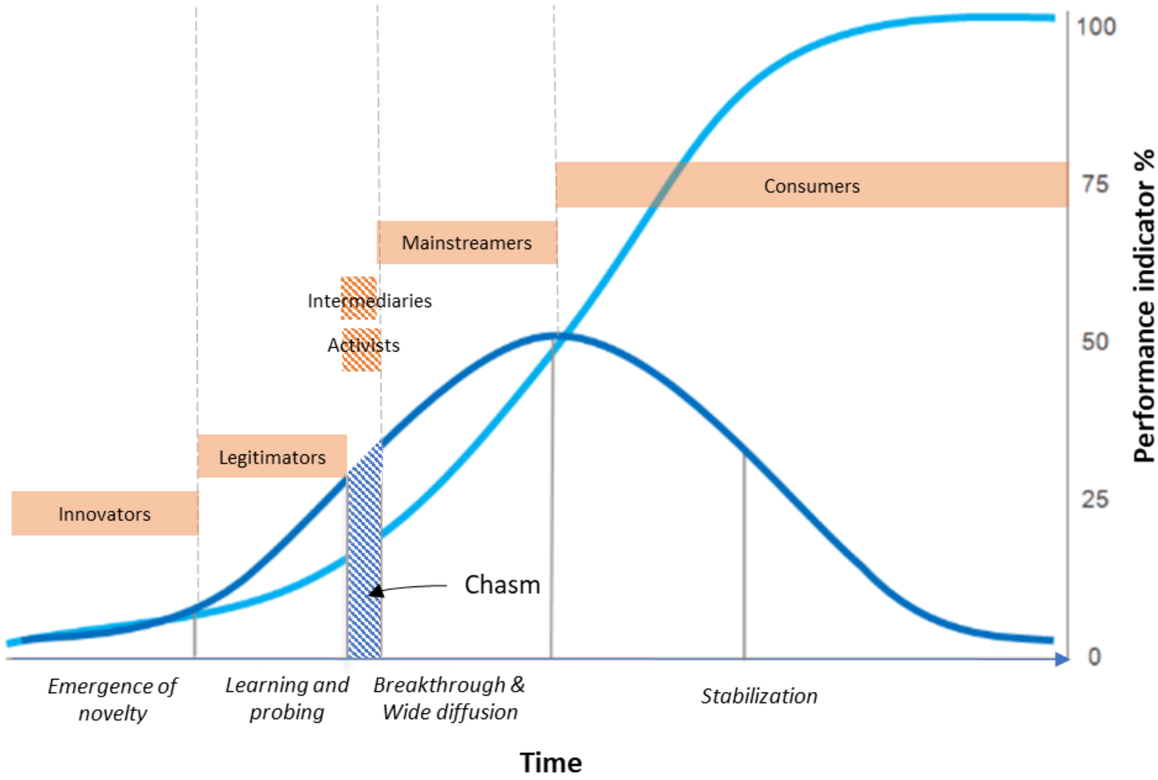

Figure 2. User roles (graph labels) across four phases of innovation (x axis labels). This shows the innovation phase that each user typology is most active within. This includes the chasm that must be crossed to move from learning and probing to breakthrough and wide diffusion with the assistance of user-intermediaries and activists.

After the innovation has achieved wide diffusion, it is followed by the phase of stabilisation. In this phase, users play the most important role in buying products and embed them in their daily practices. In this phase, *consumers*, as we label them in our framework, adopt the innovation just after the average user, once the innovation-related uncertainty is reduced. They do so because it became the dominant choice or because of peer pressure. Existing literature describes these users as late majority and laggards [50], consumers [30, 50, 86, 87], market participants [26] or end-users [88-91].

Table 2. Summary of the user roles across the transition phases with a description of how these users contribute to the innovation and transition process.

Transition phase	User role	User role defined in the existing literature	Contribution to the innovation and transition process
Emergence of novelty	Innovators	• User-producers [30] • Innovators [50] • Product designers [50, 56, 59, 61-63] • Energy enthusiasts [64]	• Invent and create new technical and organisation solutions and routines • Utilise supporting institutions (tax reduction, subsidies) • Enthusiasm towards new ideas understand and apply complex technical knowledge • Looks for ideas outside of the local context • Can cope with high degree of uncertainty • Have substantial financial resources
Probing & Learning	Legitimators	• Users-legitimators [30] • Early adopters [50] • User-entrepreneurs, entrepreneurial lead users [57, 71, 72] • Opinion leaders [65, 66]	• Embed innovation in the local context • Reduce uncertainty by making errors and learning • Convince and increase the expectations about the relevance and significance of the innovation • Stimulate acceptance of the innovation among their peer networks
Breakthrough & Wide diffusion	Intermediaries	• Users- intermediaries [30] • Energy user communities [76-79]	• Create space for alignment of new actors, institutions and technologies • Voice expectations, interpretations and uses of new technologies to the regime actors • Enroll new actors, create networks between them • Cooperate with other actors such as firms, or (non-) governmental organisations
	Activists	• User-citizens [30] • Grassroot movements [76, 81-84] • Activist groups [30, 80]	• Involved in transition politics • Mobilise social movement for a reform • Actively try to overcome resistance of the incumbent actors • Dissatisfied with the current regime
	Mainstreamers	• Early majority [50]	• Important in creating networks effect among users • Adopt just before the average member of a system • Seldom hold an opinion leadership position • They have a strong willingness to adopt but seldom lead
Stabilisation of the new regime	Consumers	• Users-consumers [30] • Late majority [73] • Market product consumers [86, 87] • Market participants [25] • End-users [88-91] • Consumers with preferences, needs, behaviours and practices [92]	• Buy products and embed them in their daily practices • Adopt just after the average user after the innovation-related uncertainty is reduced • User the innovation due to peer pressure or because it became the dominant choice

4 Methodology

4.1 Case study: Western Australia and the case of the RENeW Nexus Project

The Renewable Energy and Water Nexus (RENeW Nexus) project was implemented in Fremantle, Western Australia, and consisted of an early trial of a blockchain-based P2P trading model in real-world conditions, across the regulated electricity network, impacting participants electricity bills. The aim of the RENeW Nexus project was to test both technical and social aspects of P2P trading. Considering the social aspects, which are the focus of this paper, the project aimed to understand why and how participants engage in P2P trading as well as how the P2P model itself affects participants' engagement with the novel trading option.

The project consortium was made up of a City Council, land developer, two universities, a blockchain start-up, electricity network operator, retailer and generator. The retailer is also the largest generator in the state's electricity market. Whilst they are a combined retail and generation organisation, for the purposes of this trial they are retailer alone and are referred to as such. Existing regulations require that residential users must purchase their electricity from the public retailer. Their involvement in the trial was therefore essential to allow payment of the half-hourly P2P trades to be settled *via* the end of month retailer electricity bills.

The retailer provided secondary meters to display real time data to the participants, managed the customer relationship and billing. They also acted as a buyer of last resort for unsold solar exports and a seller of any shortfall electricity that could not be supplied by peers at any point in time. They also ensured consumer protection rules were adhered to. Whilst the active P2P trading component of the RENeW Nexus project is outside the scope of this paper (Figure 3), this information is provided to explain the relevance of the middleman in a trial of an autonomous concept.

The trial was run in the city of Fremantle, which offers a suitable context for sustainability-oriented innovation, given their historical political and civil sustainability leadership. The city's higher number of prosumers and lower energy grid electricity consumption than the state average [93] further adds to its suitability for trialling the P2P electricity trading model.

4.2 Participants in the P2P trial

Voluntary participants for the P2P trial in Fremantle were sought *via* announcements on social media, on the City Council's webpage as well as through word-of-mouth. Fifty participants in total self-nominated for inclusion in the trial: forty prosumers and ten consumers. A participant represents a household rather than the individual. The choice of the household level analysis was influenced by the context of the electricity sector, where households remain the main unit of analysis. Prosumer participants are home owners, which was necessary to allow for the installation of updated metering infrastructure and was typically a precursor to having a solar PV system. As presented in Figure 3, the numbers of participants in the trial reduced to sixteen prosumers and eight consumers following presentation of the P2P trading tariff structures.

Readers are referred to Section 5.4 for reasons why participants chose to withdraw and to Appendix A for details on the specific P2P trading approach and associated pricing structures used in the trial.

4.3 Research design

This paper presents a single case study analysis based on a mixed method research design [94-96]. One benefit of single case studies is that they can be particularly useful for explorative work and in generating new hypotheses [97]. While we are aware that the generalisability of single case study findings can be limited, the case chosen for this study is an exemplary case, reflecting a real-life phenomenon that has not been studied in the past [94] - a case of the world's first P2P electricity trading model across the public electricity grid. Whilst the study size is small, at the time of writing, it represented the only participants globally that were actively P2P trading across a regulated electricity network using blockchain technology. The absence of other real-world case studies precluded the opportunity to employ a comparative case study methodology. Considering these weaknesses, scholars seeking to apply the findings of this research should consider the nature of the community within which the trial has been undertaken [98] (refer to Section 4.1).

An inductive research approach was selected, starting with explorative data collection that would guide us to suitable conceptual perpsepctives, serving as a foundation for our analytical framework [99]. Data was collected in three separate rounds using mixed methods to gain a broader perspective on our research object [100]. These included three surveys and two focus group discussions with the self-nominated participants as detailed in Figure 3. Questions in the first survey and focus group session (Appendix B) were explorative and designed to suit a diverse range of research aims for the broader RENeW Nexus project. The successive survey instruments (Appendix C and D) and focus group were designed to test emergent theories and our evolving analytical framework. The benefit of having used different data collection methods is the possibility to triangulate within our own primary sources [96], especially given that secondary sources relating to users of P2P electricity trading models are still lacking [100]. Figure 3 summarises both the focus of each data collection activity and the numbers of participants within that activity.

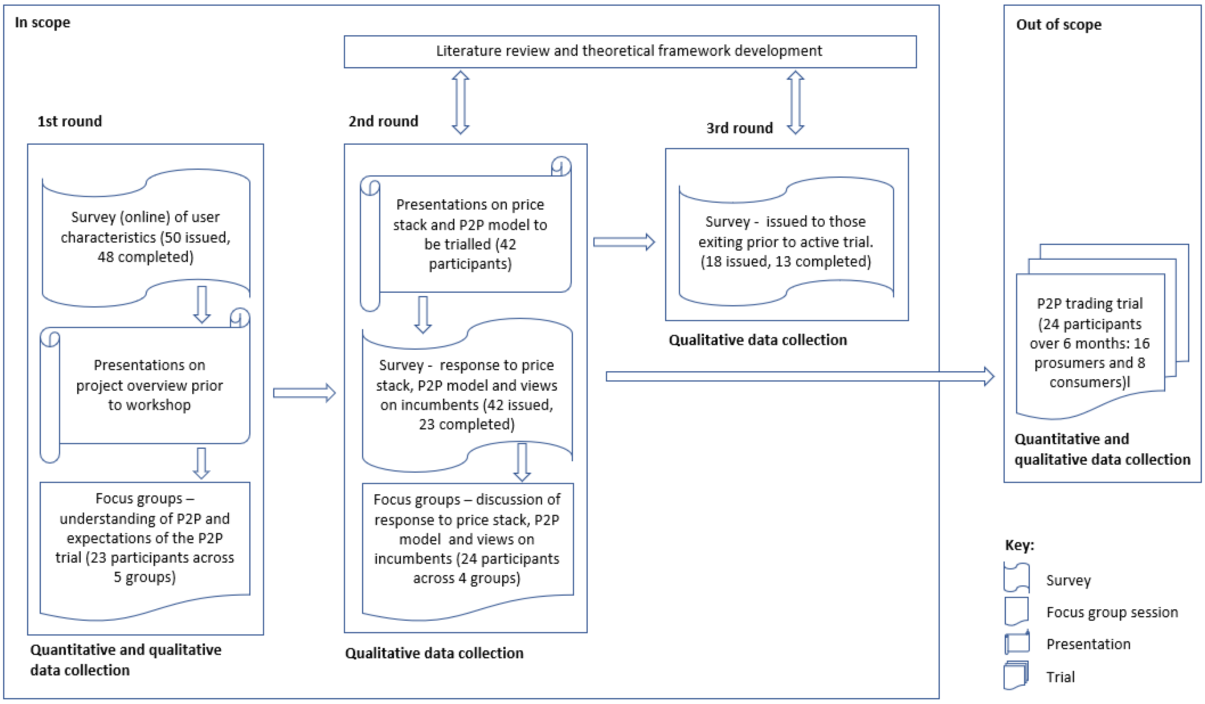

Figure 3. Stages of qualitative and quantitative data collection up to the commencement of the live P2P trial. This paper focuses on research findigs stemming from the data collected in the in scope box. The P2P trading trial results are out of scope for the current paper.

While surveys were conducted with individuals representing a household, the focus group sessions were conducted with individuals in groups of 4-5 people with an independent facilitator allocated to each table. At the first workshop, each participant provided independent written response to the two questions (*i.e.* participants' understanding of P2P and their motivations to participate) on post-it-notes. Each note was then discussed within each table to identify common themes and areas for extrapolation. All written notes were later themed and coded within the qualitative analysis software NVIVO 12. At both workshops, audio recordings of the discussions at each table were transcribed verbatim into NVIVO 12. The same coding categories used for the written responses were then applied to each transcript. Coded themes from the written responses can be considered as more representative of individual thoughts whereas those mentioned during discussion drew out issues more important to the collective groups.

5 Results

5.1 The first P2P electricity trading users

According to the survey, the participants had a median household income of over AUD$156,000 per year. This is 48% greater than the median household income for Fremantle residents [101], indicating that the users involved in the trial are relatively financially secure households.

Eight prosumers had acquired their PV systems in 2009 or earlier, while over 50% of all prosumers had installed rooftop PV systems between 2016 and 2018 (Figure 4).

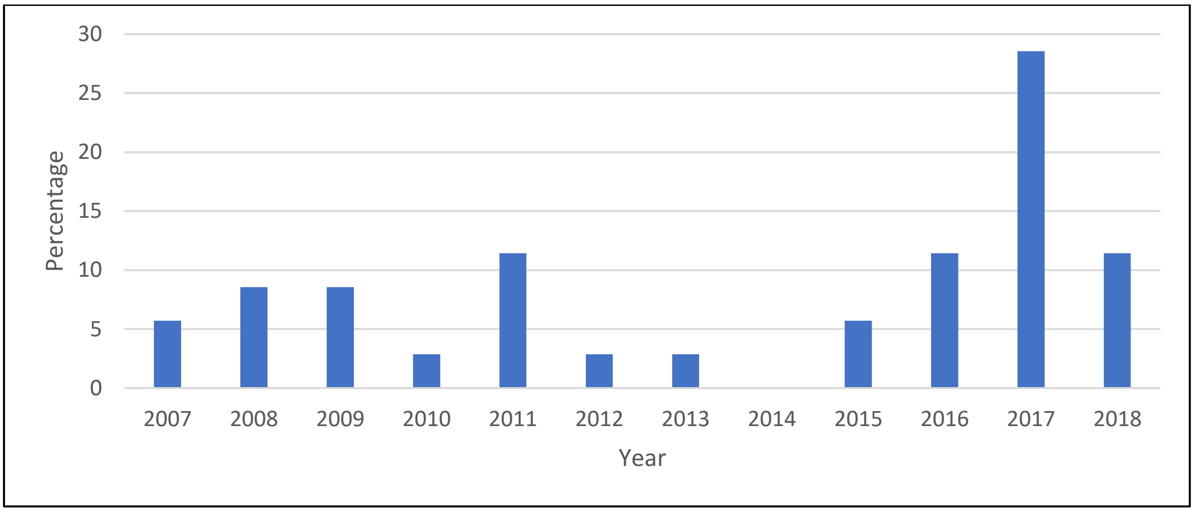

Figure 4. PV installation year of the prosumer households.

The survey revealed that the participating prosumers perceive themselves as having a good understanding of the PV technology and how to make the most of their self-generated electricity. In fact, 67% of prosumer households revealed that they often or very often adjust their consumption patterns to use more electricity during the daytime. 55% claimed to set their appliances on a timer to increase consumption of self-generated electricity.

5.2 Motives to trial P2P electricity trading

The initial survey asked participants about their attitudes towards the incumbent electricity sector in WA in order to explore whether it was a part of their motivation to join the trial. The results show that 58% of the participants are dissatisfied with the existing electricity retailer, while prosumers are generally less satisfied than consumers (Figure 5). The most common reason for dissatisfaction is financial, related to high grid electricity prices (AUD$0.28/kWh) and low financial compensation for their renewable energy generation (the FiT is AUD$0.07/kWh). For a full breakdown on the tariffs relevant to the P2P trial in the local electricity market refer to Appendix A.

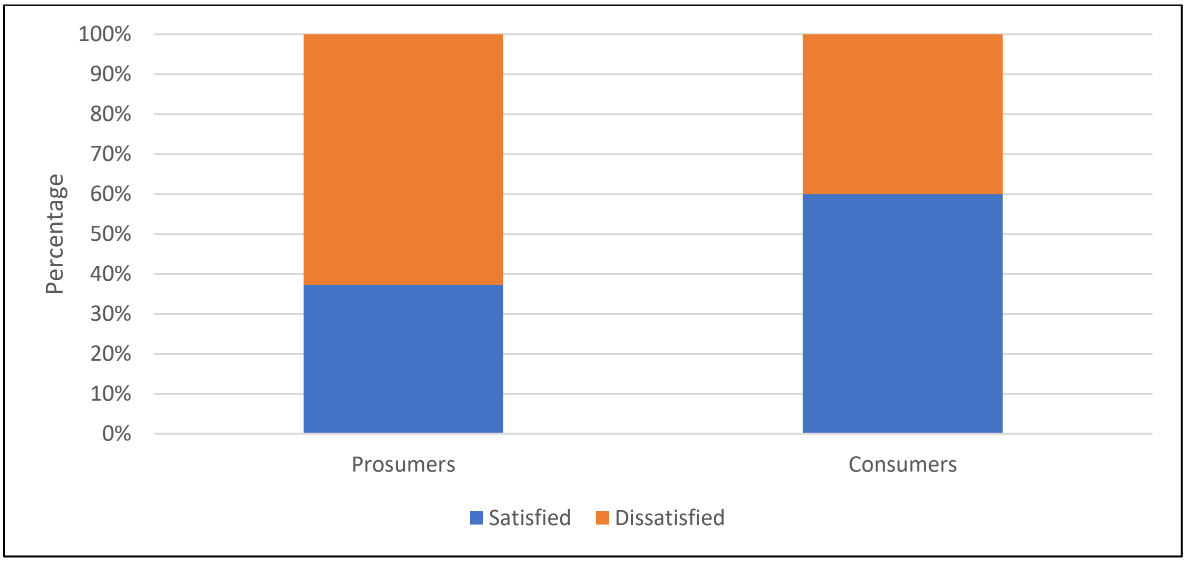

Figure 5. Participants' satisfaction with the current electricity retailer.

A significant number of respondents also mentioned dissatisfaction with the network grid operator's supply charges. Concerns were raised that the supply charges were passing through transmission costs that participants perceived to be unnecessary in the context of the high levels of local renewable energy generation.

Other less frequent reasons for dissatisfaction with the electricity retailer related to the lack of detailed electricity usage information in electricity bills; lack of incentives for saving electricity; and a perception that the retailer/generator does not invest enough in renewable energy production (Figure 6).

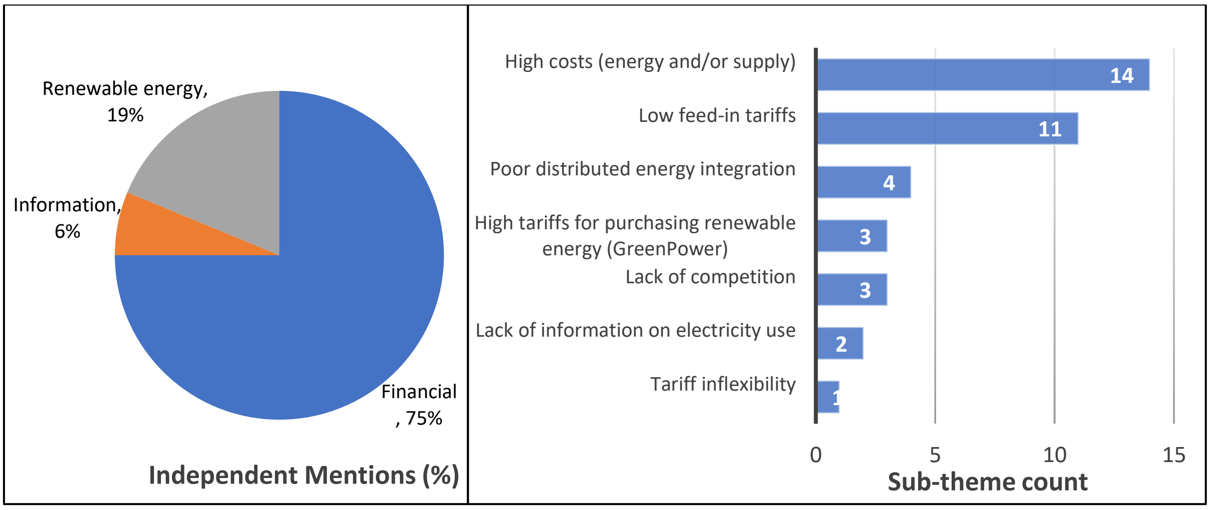

Figure 6. Reasons for participant dissatisfaction with the electricity retailer. Key themes (left pie chart) and broken down into sub-themes (right bar chart).

The results from the first workshop revealed that the largest single motivation to join the trial is related to participants' interest in knowledge acquisition, including the opportunity to learn about their personal electricity use and the electricity system in general; what will happen after the FiTs expire; and the potential solution P2P trading can offer (see Figure 7). The second strongest motivation is the chance to be ahead of the curve and trial a cutting-edge technology. Interactions between participants during workshop discussions reflected a sense of excitement at being part of a cutting edge innovation. There was also a collegial tone as many participants were early adopters of rooftop solar technology and shared an enthusiasm for renewable energy and sustainability, with the P2P trial seen as an embodiment of these principles. This is shown from the following quotes taken from each of the workshop tables:

> *"light a fire that could go global quickly, … and have a rapid transition to a clean energy future"*

> *"I feel good that Fremantle is starting this and we can say, you know, that you are proud of this."*

> *"In 30 years time when it is common practice. Knowing that you were at the beginning"*

> *"sends a very clear message to the government that people are interested in sustainability and they want better policy"*

> *"..love being involved in stimulating renewable uptake."*

They were motivated by the potential to influence the sustainability transition towards a more socially equal and clean energy system by being able to demonstrate the successful utilisation of a P2P trading model. Around half of the participants were motivated by efficiency improvements, described both in terms of financial efficiency, which might be achieved by eliminating the retailer/middlemen; and in terms of energy transfer efficiency with more local solutions and less need for long distance transmission. Notably, during the focus group discusison only 25% of respondents stated that they were motivated to join the trial to save money or with an expectation of being financially better off, and this was mentioned apologetically:

> *"This is going to sound really terrible but one of my motivations was to get cheaper power"*

Despite this apparent irreverence to the financial implications of the P2P model, many follow-up questions at the end of the session were related to potential financial implications of the trial.

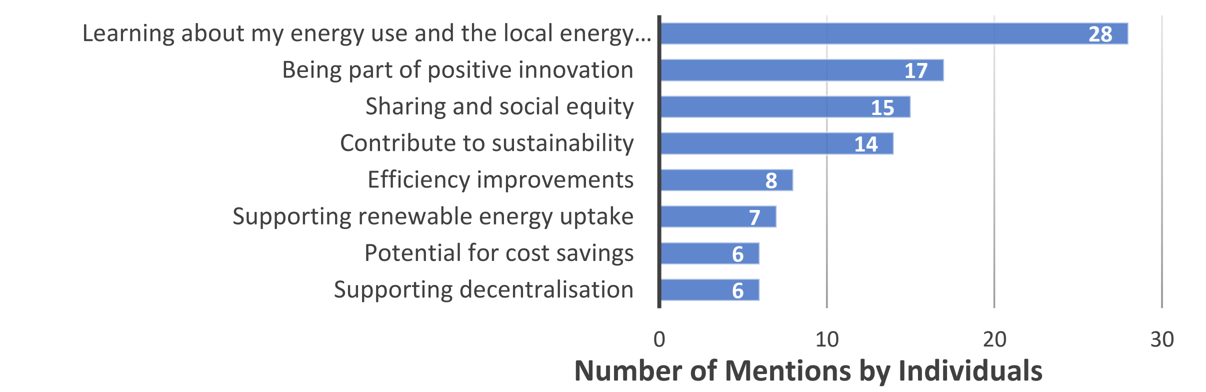

Figure 7: Motivations for participating in P2P trial showing the number of times that individual participants mentioned the theme during independent note taking at the first workshop.

5.3 User expectations of P2P electricity trading

Asking participants about their expectations revealed that they had a good knowledge of P2P trading and clear expectations about the future potential and performance of this new trading model. The most frequently voiced expectations related to local community trading, flexible and lower prices and improved system efficiency. Eight participants independently noted that they expected it would reduce the need for involvement of the existing retailer. This view was then generally agreed during focus group discussions, with the quote below being indicative of the expectations raised during discussion:

> *"So you're providing your neighbours with some of the electricity you acquire through your PV panels, and not necessarily going through the retailer and the main energy companies. So I don't understand the software involved with it, but I understand it is about sending power from your PV panels to your neighbours and cutting out the middleman."*

Seven participants independently noted expectations related to decentralisation and localisation of the market, improved use of the local distributed network and the possibility for local electricity sharing:

> *"this way of working means that you're not beholden to the big picture of power. It's really very local."*

Six of the participants related P2P trading to the specific use of the blockchain technology and crypto currencies (Figure 8). Fewer expectations related to the P2P trading potential to increase the use of the distribution grid infrastructure, increased adoption of renewable energy production and batteries and secure trading platform, among others.

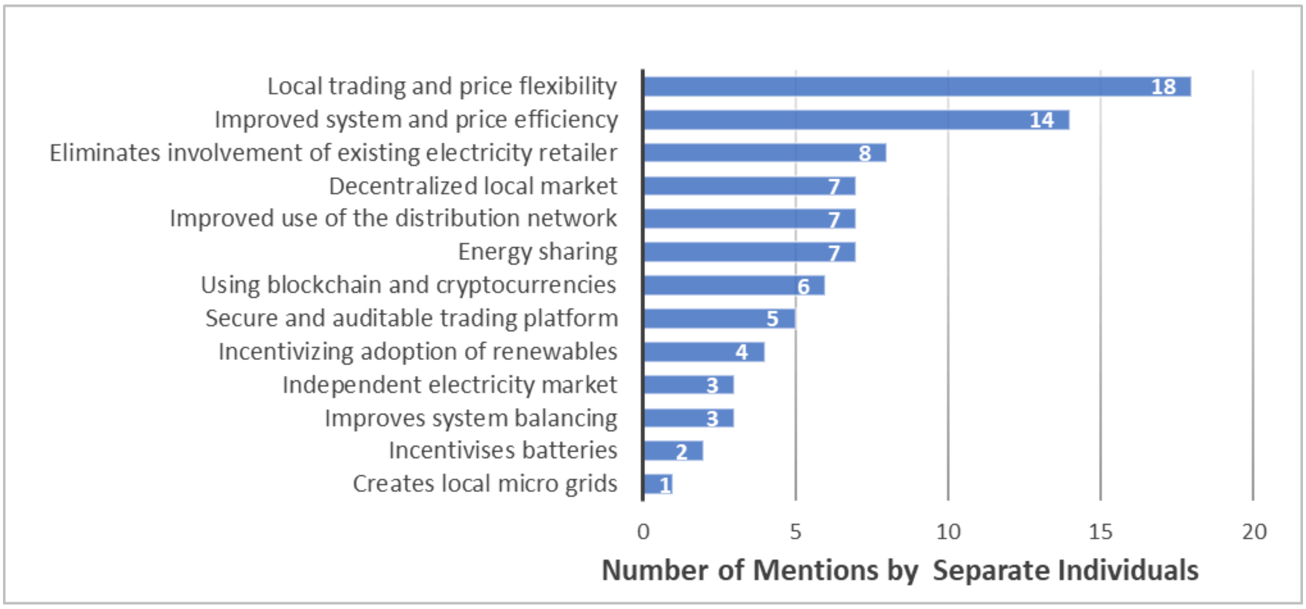

Figure 8: Participant expectations from P2P electricity trading based on the number of times that separate individuals mentioned the theme during independent note- taking during the workshop.

5.4 User reaction to the design of the P2P electricity trading model

Following the first participant workshop, the design of the P2P electricity trading system in the project was negotiated and developed by the project consortium and later introduced to the participants during the second workshop. A notable shift in user willingness to participate occurred when they received detailed information about the final design of the P2P trading model. Appendix A details the pre-existing tariff structure and a comparison with the P2P pricing design that was trialed.

The consortium developed tariff design adopted in the trial created concerns among the trial participants, particularly in terms of the impact this would have on any remaining FiTs they were entitled to. This was mostly the case of small electricity users and those that were in receipt of the legacy AUD$0.4/kWh FiT, which they would have to forfeit if they proceeded to the trial. A price forecast model presented at the workshop showed that with the new fixed daily charges, participants that were large electricity users would benefit, whereas households that currently purchased and sold small amounts of electricity, and thus use the grid less, would be disadvantaged by participating in the trial.

Responses to the survey that was issued immediately after the presentation demonstrated that attendees understood the justification for the new daily charges embedded in the P2P model, as being important for the maintenance of the distribution system and for ensuring adequate generation capacity. The general acceptance of the P2P trading charges to support the broader electricity system was matched to a near unanimous agreement that electricity should be made available to everyone in the community at reasonable prices.

Despite understanding the basis for higher prices, the participants expressed concerns that the trial would reward big electricity users and penalised small ones. Many of these participants expressed that the design benefited the incumbents, lacking an appropriate compensation for small residential electricity producers and consumers. Many of them thought that P2P trading should be subsidised to encourage uptake, as occurred previously with solar PV.

The mood of participants was less positive in the second workshop in comparison to the first. This was expressed during the focus groups as the final P2P model not aligning with participants initial expectations. The misalignment is visible in Table 3, which contains contrasting quotes taken from the first and second workshops. Discussion amongst the focus groups indicated a continued enthusiasm for P2P trading as a concept, but people were unsure of it's benefits to themselves. Many stated that they would need time to review the information before further committing to participate in the active trial.

Table 3: Quotes from the first and second workshops showing the divergence from initial expectations (first workshop) versus the realities of the P2P market model to be trialled (as understood by participants at the second workshop).

First Focus Group Session	**Second Focus Group Session**
"I feel strongly about the sharing economy and this is another way of sharing."	"we're looking at something that's competitive with one another. And it-- to me, it just doesn't actually sit right to have that, the spirit of it doesn't gel".
"I love the idea of hooking into the shared community battery, … and just the actual value of sharing for a common cause. Yeah, we all have these systems. If we can share our energy and water, it makes so much more sense than having all these individual unique systems that we've got to pay for, look after, so it's a common cause."	"it is very market-driven. "
	"It's a lot like… stock trading."
So, people who want to buy electricity can trade online, and ideally get slightly below the wholesale price, and ideally we get paid more than what the retailer, the monopoly, offers.	"Because for all my good intentions, I'm working full-time, I've got two children to look after and there's a lot of things to do in the day-- I don't-- can't guarantee I'm going to get the time to sit down, look at-- open the platform and compare the platform with the current buy and sell price for what I'm producing and change the price."

Many participants joined on the basis of supporting local community trading and positive societal change. However, there was a mismatch between the trading design and participants' expectations. The trading was considered overly market driven, based purely on demand and supply but with no ability to selectively support and sell to selected individuals within the community. Other concerns related to the inappropriate design for the actual participants, not reflecting the local movement of electricity and presenting a high risk for the prosumers involved in the trial. Concerns about the design are summarised into themes in Table 4.

Table 4: Key themes emerging from the workshop where the P2P trading model and associated tariff structure was revealed to trial participants.

Theme	Summary
Financial incentives matter	*Worse Off:* If people are going to be worse off financially, then they would be less likely to participate. Fixed charges were understood but discouraged participation. *Subsidies Required:* All groups thought that P2P trading should be subsidised to encourage uptake as occurred with solar PV.
Alignment with community values	*Design is too market driven or not community oriented enough:* Many participants joined on the basis of supporting local community and broader social equity issues. The design is too market driven with no ability to trade with individuals of their choice. *Social equity:* The design is similar to the stock market and the uneducated or disadvantaged will be less able to trade effectively so will be further disadvantaged. *Need to support community trading:* Participants were willing to accept small additional costs of P2P in the trial in order to demonstrate the benefits of P2P for community sharing of electricity in the expectation that it would lead to lower costs in the longer term should the P2P network scales up.
The P2P market design	*Different design required:* Participants liked the concept of P2P but thought it would be better suited to either closed networks such as trading within apartment blocks, or for the benefit of those that have batteries and can sell their excess electricity during peak times. *Reflect local movement of electricity:* Some wanted design to reflect cost savings from reduced electricity transmission, and others wanted the fixed capacity charge to be scaled to encourage energy efficiency outcomes. *Risk too high for prosumers*: Some expressed that prosumers were taking on too much risk by offering their own electricity production and selling into an unknown market with limited number of consumers, which could lead to reduced returns on their investment.

After the P2P trial design was presented, almost half of the initial participants decided to leave the trial. An exit survey was completed by 13 of the original participants who elected to leave. Ten said they would have stayed in the trial if they weren't financially worse-off as compared to continuing with their existing tariffs. Of those who decided to proceed with the P2P trading trial, 10 were estimated to be approximately AUD$200 per year worse off, 2 were expected to break even and the reminder was expected to benefit. Only the households with large PV systems were expected to financially benefit from the P2P trading model.

The various opinions related to the pricing design of the trial expressed by focus groups during the second workshop were mirrored by responses obtained in the exit surveys. The strongest reason for participants withdrawing from the trial was the design for P2P trading being too expensive and/or not aligned with participants' initial expectations about the future potential of the innovation (refer to Figure 9 for a summary).

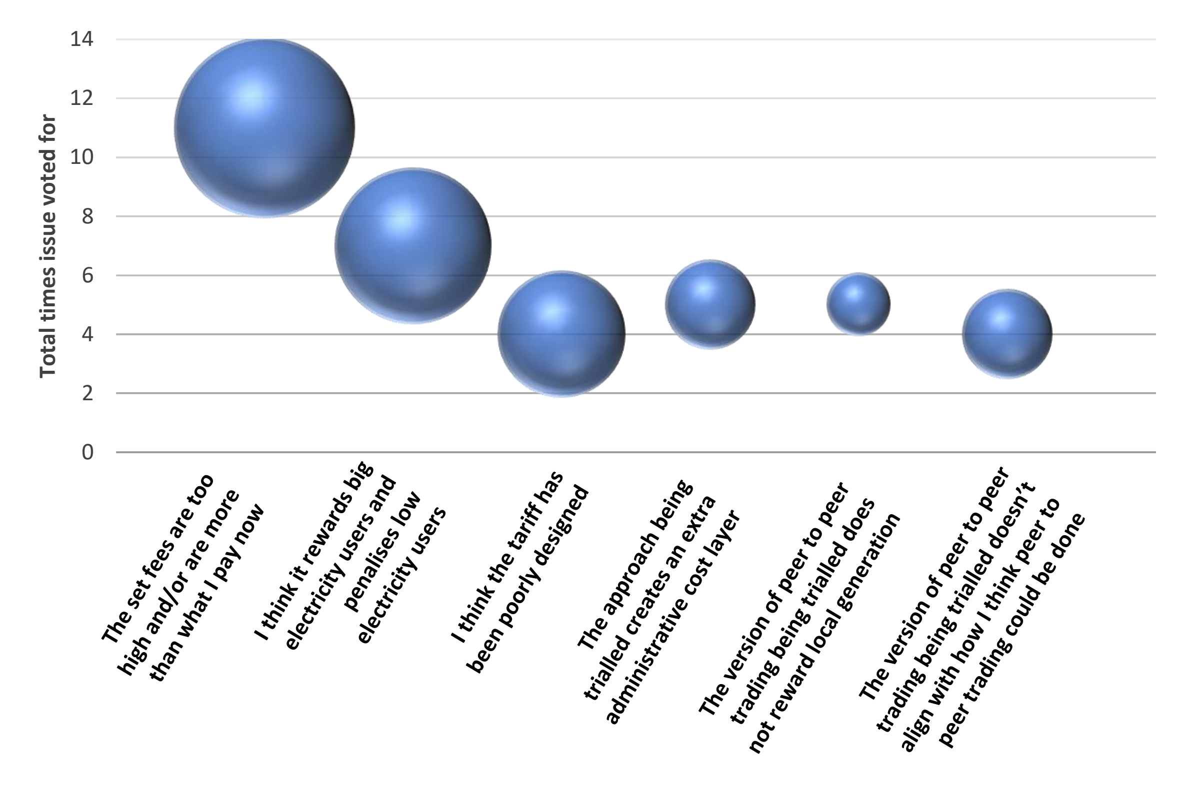

Figure 9: Survey results defining reasons people dropped out of the trial. Respondents were able to select multiple reasons why they did not want to participate in the trial and then rate these reasons in order of priority. The position of the bubble on the y-axis indicates the number of times the reason was voted for, whereas the size of the bubble represents how often the reason featured as one of the top four reasons for each respondent withdrawing from the trial.

6 Analysis and discussion

In the following section, we analyse the results and discuss these within the context of our analytical framework (Figure 2).

6.1 Roles of P2P trial participant in innovation processes

Our findings show that users in the P2P trading trial are financially secure households with a high interest in social equity and transitioning to decarbonised energy systems. They have good knowledge about their local context and the issues that they would like to help resolve. An important attribute of the trial participants is their good understanding of renewable energy technologies and their consumption and production patterns. They are also strongly motivated to learn about their own electricity use and broader innovations in the electricity sector, without being discouraged by initial complexities and financial losses. They also want to be ahead of the curve and have a first-hand experience with a cutting-edge technology. These findings indicate that they aspire to be *innovators* (Figure 2).

However, while they are interested in supporting the emergence of the niche P2P market and are self-motivated to do so, they are neither independent inventors nor creators. Instead, they show greater interest in learning about the innovation and in embedding it in the local context. This points to the trial participants being *legitimators* (Figure 2) as described in Table 2. They strongly believe their participation could increase outside expectations and therefore support the transition towards more socially equal and local renewable energy systems through demonstration of the P2P model.

According to the results, most of the trial participants share a degree of dissatisfaction in the incumbent electricity companies, whom they perceive to control and undervalue the price of self-generated renewable electricity. Although this finding indicates a role of *activists* (Figure 2), users actively speaking out against the *status quo* and incumbents, the dissatisfaction is strongest among prosumers and mostly related to low financial reward for self-generated electricity. They differ from grassroot movements or activist groups in that they are not a self-organised group of consumers defining their identity through fighting the establishment to allow for the future of P2P trading. The participants are not stubbornly acting against the incumbents, instead they prefer acting with the incumbents *via* the project consortium to improve the quality, performance and user-acceptance of the model before its potential introduction to the mainstream market. However, as the initial design of the P2P trading model was developed with little consideration of user's input, the co-production process was weak, resulting in user critique of poor design with inapproariate pricing. These factors contributed to a high number of dropouts from the project. This result supports existing literature that points to the importance of collaborating with *users-innovators* to help co-create the innovation design and improve user acceptance [56, 59, 64].

Although initially all the trial participants appeared to be *legitimators* of P2P trading, the willingness to participate shifted after the introduction of the P2P tariff structure that indicated likely financial losses. Less than half of the participants remained in the trial, with those that exited being less prepared to adopt the new approach until financial uncertanties and risks improve. While these users do not wish to legitimize the innovation, they can play an important role as *mainstreamers* (Figure 2) - users creating network effects for wider diffusion in a later stage of innovation, after the legitimacy has been improved and a better price-performance ratio has been achieved.

Our analysis uncovers important findings in relation to the hypothesis of the chasm (see Figure 2) with a gap between the experimentation phase and wide diffusion [73]. We found that the two groups of trial participants seem to have different motivations to adopt the innovation, being on the opposite sides of the chasm. However, none of the trial participants expressed interest in assisting to bridge the chasm by aligning other actors or assiting to recruit other users in the community. This role needs to be filled by an (another/external) *intermediary actor* [12, 102], which in our case could be the project consortium, primarily the retailer and network operator due to their direct access to the majority of customers. They could bridge the chasm by taking the lessons from the *innovators* to the *mainstreamers* and *consumers*.

However, the chasm will not be bridged until the project consortium acknowledges the roles the trial participants wish to play. Our findings point to a misalignment between the way consortium members perceive the participants involvement and how participants wish to be involved. While the trial participants view themselves as an active part of creating the niche by contributing to learning and probing as *innovators* and *legitimators*, the project consortium views the participants merely as *consumers*, playing a role in consuming the new market product. Incumbents, such as the utilities in the consortium, will often seek to get users to fit-and-conform to their view of the evolving niche rather than working with the users in a co-creation process [103]. It is likely that the discrepancy in the perception of the user's role was one of the main reasons behind high dropout rates and the perception of the weak trial design. While at first glance, high prices seemed to have been the biggest reason for losing almost half of the initial trial participants, our analytical framework assisted us in understanding that high drop-out rates could also have been a consequence of lack of user-role consideration on the consortium-side.

In terms of the concepts used, our analysis confirms the importance of viewing electricity users as agents shaping the sustainability transition process as proposed by Schot, Kanger and Verbong [30]. However, their user role conceptualisation comes with a number of limitations. First, they assume that users involved in innovation always seek to have a specific system-level influence as an organised groups with clear identity related to the innovation [30, 50, 63]. Our results show that users can contribute to the transition efforts without necessarily being instigators or drivers of a transition. Instead, users can also support the transition by adopting the innovation and collaborating with other project actors, provided it appears to align with their idealised vision for the future and/or is financially beneficial to them. They need not be part of a collective movement, but rather, can be organised and assisted by another intermediary actor in the system [48, 102, 104]. Second, their conceptualisation views users in idealised categories that are exhaustive and often mutually exclusive. Based on our results, we observe that the participants of the P2P trading trial do not belong to a certain group or conform to a user category with a single role, but instead they take on multiple key roles in the innovation process, often as individuals [32]. Our findings support the recent conclusion made by Sopjani, Stier, Ritzén, Hesselgren and Georén [32], indicating that users can take on multiple roles simultaneously within transition processes.

In addition, the user typology developed by Schot, Kanger and Verbong [30] is useful for analysis the user-to-system dynamics, yet lacking the micro-level agency and user-to-user interaction in innovation along different innovation phases (see Section 3.2). We therefore complement this typology with existing user-related research to highlight that trial participants can both shape the wider socio-technical system change as well as have influence on other participants and users in the process of innovation.

Perhaps the biggest contribution to existing user focused transition literature is the application of our analytical framework on a case of business model innovation. While an increasing number of studies analyse the role of managers, private firms and entrepreneurs in business model innovation processes, we have been able to show that succesful business model innovation requires attention to users as explicit transition shaping agents.

6.2 Policy implications and areas for further research

The findings in this paper point to a number of policy and industry related implications. Firstly, our theoretical framework suggests that in innovation trials, it is important to consider the innovation phase when designing a project and recruiting trial participants. Very early stage projects may be best served by targeting users wishing to co-create and legitimise and who are specifically interested in learning and probing an innovation. It is also essential for the recruiters to realise the important roles of these users, which is to facilitate learning processes, embed the innovation locally and raise expectations directly related to the local issues. The actor consortium could have involved participants in the initial design processes to increase the success of the trial, which directly depends on the consumer's image of what a P2P market design should look like. For the Fremantle trial community, this included aspects of social equity, and sharing of energy within the community; aspects that the eventual market design failed to deliver.

As the high rate of drop-outs from the project demonstrated, finding users that are interested in supporting early innovation processes is not easy as the majority of users tend to get discouraged by high levels of uncertainty and/or lack of alignment with their underlying values and expectations. While this is not a surprising finding, it emphasises the need for including trial participants in the tariff design process to minimise their disappointment and reduce the number of participants leaving the project.

Furthermore, early efforts should be made to target recruitment of local opinion leaders – those whose views future customers will value and listen to. In addition, an effort should be made to actively recruit users who wish to intermediate and lobby for the innovation. These represent the users essential for taking the innovation into the breakthrough and wide diffusion phases. This could include recruitment of institutionalised user communities that are already committed to the transition, such as energy communities recognised in the United Kingdom [82, 105], Netherlands and Germany [106]. More effort could have been made to include a public participant, such as the City of Fremantle and its facilities as a prosumer in the trial given they have local influence and could act as intermediary and would also have balanced the residential participants with complimentary load profiles.

When it comes to areas of future research, future trials of P2P market models should seek to accommodate a range of users and load profiles, thereby demostrating a closer to real-world marketplace. The fact that this was not done within the trial was in part due to the inflexibility of the inherent regulatory environment, but also a by-product of the tight project timelines. The tight timelines precluded resolution of constraints, collaborative design and strategic recruitment of participants. Future projects should allow sufficient time to work through and resolve these issues. Another area that should be analysed is the choice of technology employed – in this case blockchain - and the ability to fulfil the specific needs of the participants in P2P markets. We believe a more careful study should be made of whether the blockchain ledger is well suited to users intentions to bring about local benefits and create a local community electricity market. It is important to consider as the blockchain technologies have evolved to suit adversarial contexts where trading is verified by a computer code rather than as a social agreement, which is potentially at odds with the underlying values of the trial participants.

Future studies could also address aspects that are outside of the scope of this study. Analysing users involved in prosumer-based electricity markets elsewhere in the world, both in local and broader regional electricity markets across different geographical regions could strengthen the findings in this study. Positioning these studies within the analytical framework outlined in this paper could assist in a better understanding of user interest and adoption of the P2P model but also allow for further testing of the relationships between user roles and transition phases.

Whilst this study has provided important insights into the roles of first users in transition processes, it has not been possible to demonstrate the system effects nor the broader benefits that may exist from the scaling up of P2P electricity markets. Empirical studies of this nature must wait until there has been greater uptake of the P2P markets. Conclusive results will require substantially longer time horizons that are more consistent with broader transitions.

7 Conclusions

This paper provides new insights into the role the electricity users can play in innovation, paving the way towards a fossil-free electricity system. Using the empirical case of P2P electricity trading innovation trial in Western Australia, we bring new findings about what motivates users to participate in this novel trading model and their role in its development and diffusion. We thus contribute to the limited knowledge about the users interested in P2P electricity trading, as pointed out by Ahl, Yarime, Tanaka and Sagawa [24]. Our findings show that users that joined the P2P trial in WA are typically financially secure households with a high interest in social equity and transitioning to environmentally cleaner energy systems. They have good knowledge about their local context and the issues that they would like to help in resolving.

In addition, through the innovation and transition literature about energy users, we were able to synthesise existing user categorisations and point to specific roles that users can play in different innovation phases: from idea creation to integration of novelty into everyday practices. We found that the users that joined the P2P trial wished to play a role in co-creating local community-based electricity markets, legitimatising the innovation by using a cutting-edge technology and actively challenging the incumbent sector, which they were dissatisfied with. These participants remain dedicated, despite the innovation-related complexities of price and performance. While these users are crucial for the learning phase of innovation, our analytical framework indicates that they are unlikely to cross the chasm to the more hesitant mainstream users. Here, we suggest that the project consortium can potentially act as intermediaries where users cannot. The consortium could bridge the chasm between different users and thereby assist with taking new innovations into the mainstream. However, the chasm can only be bridged if the consortium acknowledges the diverse roles users can play, instead of viewing them solely as consumers.

The conceptual contribution in this paper stems from the synthesis of concepts from the existing literature that allows the role of both individual and institutionalised users to be analysed both in term of user-to-user [50] and user-to-the-rest of the socio-technical system [30] in all stages of the sustainability transition process. This study has demonstrated that users' diverse roles should be considered in business model innovation, through which new value from sustainability innovations is created [13].

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Appendix A: P2P Tariffs

Pre-existing tariffs included a subsidized renewable energy buyback rate, a daily supply charge and a charge based on the kilowatt hours of usage. The daily supply charge included a State Government subsidized network supply fee, whilst the electricity charge included a bundle of both energy and non-energy related expenses. The largest non-energy expense related to recovering costs associated with capacity payments made to all generators on the network. These are part of the local capacity market, designed to ensure that there is sufficient generation capacity within the market to meet the peak demand periods that exist for only a limited number of hours each year, typically on the very hottest summer days.

As summarized in Table A1, the trial introduced time of use tariffs (9.09 cents/kWh Peak and 5.72 cents/kWh Off-peak), which had substantially lower per unit costs than was payable by non-trial electricity users (28.33 cents/kWh). This was balanced by fixed daily charges ($3.30/day), introduced for the trial to separate out the real energy from the service and capacity related costs of energy supply. This tariff design allowed for trading of the energy only component. The daily network and capacity charges were also designed to reflect the pricing model that both the network and gentailer considered likely to be introduced prior to any P2P trading schemes being enabled within the jurisdiction. Notwithstanding this, it is acknowledged as a potential limitation on the study that trial participants were required to pay a AUS$3.30 daily fee as compared to those not on the trial, who paid AUD$1.015 per day. This tariff structure rewards the higher energy using participants and would have resulted in cost increases for low energy using households. Many of the initial trial participants were on the lower energy use end of the Western Australian spectrum, as could be expected within the conservation minded community.

Table A1: Pre-Existing and Trialed Peer to Peer Tariffs

Existing Tariff Items	**Rate ($AUS)**	**P2P Trial Tariff Item**	**Rate ($AUS)**
Supply Charge	$1.015/day	Network Supply Charge	$2.20/day
		Capacity Charge	$1.10/day
Electricity Charge	$0.2833/kWh	Peak (3pm-9pm)	$0.0909/kWh
		Off-peak	$0.0572/kWh
Renewable energy buy back rate (no feed in tariff)	$0.07135/kWh	Renewable energy buy back rate	$0.04/kWh
Renewable energy buy back rate (with feed in tariff)	$0.4/kWh		
		P2P Trading Platform Operator's Charge (paid by buyer)	$0.005/kWh
		P2P Sale price	Set by participants

Participants were able to set their own rates for the energy they intended to buy or sell in the P2P trading platform. Any excess energy not sold on the platform was bought by the retailer at the buyback rate of 4 cents/kWh. The buyback rate was set low to incentivize P2P trades. Participants were able to amend their buy and sell rates at any point for current and/or future half hour trading periods.

Prosumers with the lowest sell prices had first priority for trading. Where there was more supply in the trading environment than demand, the lowest sell prices were sold and those with higher sell prices leftover were bought by the gentailer, who was the buyer of last resort. Consumers with higher buy prices had first priority for buying energy. Where there was more demand in the trading environment than supply, the highest buy prices were met first and those with lower buy prices leftover were met by the gentailer. Sellers were charged the transaction cost of 0.5 cents/kWh by the P2P platform operator.

Appendix B: Initial User Characteristics Survey Instrument

Implied consent

☐ I have received information regarding this research and had an opportunity to ask questions. I believe I understand the purpose, extent and possible risks of my involvement in this project and I voluntarily consent to take part.

Introduction

As part of the RENeW Nexus project, we are interested in getting a better understanding of your house design and daily energy and water consumption. Please help us by completing this 10 minutes survey.

Demographics

1. What is your property address? ________

2. How many people live in your house?
   - Adults ________
   - Children (under 15 years old) ________
   - Children (15 and above) ________

3. What is your total annual household income (before tax)? *(drop down list)*
   - I prefer not to say
   - Up to $10,399
   - $10,400-$15,599
   - $15,600-$20,799
   - $20,800-$31,199
   - $31,200-$41,599
   - $41,600-$51,999
   - $52,000-$64,999
   - $65,000-$77,999
   - $78,000-$103,999
   - $104,000-$129,999
   - $130,000-$155,999
   - $156,000-$181,999
   - $182,000-$207,999
   - $208,000 or more

House design

4. Please select your dwelling type *(drop down list)*
   - Separate house
   - Semi-detached, terrace house or townhouse
   - Apartment → Q6

5. How many storeys is your dwelling? *(drop down list)*
   - One storey
   - Two or more storeys

6. How many bedrooms, bathrooms and living areas do you have?
   - Bedrooms _______
   - Bathrooms _______
   - Living areas _______

7. In which year was your house built or last renovated?
   - _______
   - I don't know

8. What is the NatHERS Star rating of your house?
   - _______
   - I don't know

9. Does your house have insulation in the following locations:

	Yes	No	I don't know
Ceiling	☐	☐	☐
Roof	☐	☐	☐
Walls	☐	☐	☐
Floor	☐	☐	☐

10. What is the size (kW) of your PV system?
    - _______ → Q12
    - I don't know
    - I don't have one → Q13

11. Which year were you solar panels installed? _______

12. How often do you maintain your solar panels?
    - Never
    - Every few months
    - Every few years
    - My solar panels are new
    - Other: please specify

13. What is the volume (L) of your rainwater system?
    - _______
    - I don't have one → Q14

14. What is the approximate area (m^2) of your roof?

- ________
- I don't know

15. What is the approximate area (m^2) of your outdoor irrigated garden?
- ________
- I don't know

Fixtures and appliances

16. How many of these electric heating and cooling devices are present on your property?

Electric heating and cooling devices	0	1	2	3	4	5
Reverse cycle air conditioner (split system)	☐	☐	☐	☐	☐	☐
Ducted reverse cycle air conditioner	☐	☐	☐	☐	☐	☐
Ducted evaporative air conditioner	☐	☐	☐	☐	☐	☐
Ceiling and/or pedestal fans	☐	☐	☐	☐	☐	☐
Portable air conditioner	☐	☐	☐	☐	☐	☐
Portable electric heater	☐	☐	☐	☐	☐	☐
Portable oil heater	☐	☐	☐	☐	☐	☐
Floor heater	☐	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐	☐

17. How many of these electric appliances are present on your property?

Appliances	0	1	2	3	4	5
Fridge/freezer	☐	☐	☐	☐	☐	☐
Electric oven	☐	☐	☐	☐	☐	☐
Microwave	☐	☐	☐	☐	☐	☐
TV	☐	☐	☐	☐	☐	☐
Home entertainment system	☐	☐	☐	☐	☐	☐
Computers	☐	☐	☐	☐	☐	☐
Clothes dryer	☐	☐	☐	☐	☐	☐
Washing machine	☐	☐	☐	☐	☐	☐
Dishwasher	☐	☐	☐	☐	☐	☐
Pool pump	☐	☐	☐	☐	☐	☐

18. How many of these fixtures are present on your property?

Fixtures	0	1	2	3	4	5
Pool	☐	☐	☐	☐	☐	☐
Spa	☐	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐	☐
Shower	☐	☐	☐	☐	☐	☐
Bathtub	☐	☐	☐	☐	☐	☐
Sink/basin	☐	☐	☐	☐	☐	☐

19. What is your water heating system? *(drop-down menu)*
- Gas – instantaneous or storage
- Electric storage
- Instantaneous electric
- Solar, electric boosted
- Heat pump

20. What type of lighting do you have in your house? Please select all that apply
- LED
- Halogen
- Fluorescent
- Incandescent

Routines and lifestyle

21. What does a normal weekday look like for you and other members of your household? Please check the boxes that apply for you and each of your household members.

	Off-site full-time worker	Off-site part-time worker	Work from home	Shift worker	I work varying hours	At home	Pre-schooler at home	Full-time student/day care	Part-time at day care
You	☐	☐	☐	☐	☐	☐	☐	☐	☐
Member 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Member 2	☐	☐	☐	☐	☐	☐	☐	☐	☐
Member 3	☐	☐	☐	☐	☐	☐	☐	☐	☐
Member 4	☐	☐	☐	☐	☐	☐	☐	☐	☐
Member 5	☐	☐	☐	☐	☐	☐	☐	☐	☐

22. How strongly do you agree with the following statements?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Comfort at home in summer is important to me even if it means spending more on energy	☐	☐	☐	☐	☐
Comfort at home in winter is important to me even if it means spending more on energy	☐	☐	☐	☐	☐
I value money over comfort	☐	☐	☐	☐	☐
It is important for me to reduce my energy costs	☐	☐	☐	☐	☐
It is important for me to reduce my water costs	☐	☐	☐	☐	☐

Electricity practices

23. How do you and your household keep warm in winter? Please rank from what you do with more frequency to what you do the least

- We put warm clothes on
- We cover ourselves with blankets
- We close the windows and curtains
- We take advantage of the sun to heat the house during the day
- We take a warm shower or bath
- We turn the heater on
- We use a fireplace
- We have hot drinks/food
- Other: please specify

24. How do you and your household keep cool in summer? Please rank from what you do with more frequency to what you do the least

- We put lighter clothes on
- We open the windows at night for natural ventilation
- We shade our house during the summer
- We spray ourselves with water
- We turn on the fans
- We turn on the air conditioner
- We have a cold shower
- Other: please specify

25. How often do you/your household use the air conditioner in summer?

Very often	Often	Sometimes	Rarely	Very rarely
☐	☐	☐	☐	☐

26. When you use your air conditioner, what time of the day do you usually do it? Please select all that apply

- Mornings
- Afternoons
- Evenings
- Night
- All day

27. How often do you/your household use the heater in winter?

Very often	Often	Sometimes	Rarely	Very rarely
☐	☐	☐	☐	☐

28. When you use your heater, what time of the day do you usually do it? Please select all that apply
- Mornings
- Afternoons
- Evenings
- Night
- All day

29. [for prosumers] Are any of your appliances programmed to work on a timer? If so, please select which ones
- I don't have any appliances set on a timer
- Irrigation
- Pool pump
- Dishwasher
- Washing machine
- Heater or air conditioner
- Standby power
- Other: please specify

30. [for prosumers] Are you familiar with the solar panel technology and how it works?
- Yes
- No

31. [for prosumers] How often do you try to use appliances during the day when your solar panels are generating electricity?

Very often	Often	Sometimes	Rarely	Very rarely
☐	☐	☐	☐	☐

Water practices

32. On average, how many showers are taken in your house per day? ________

33. On average, how many washing loads do you do per week? ________

34. On average, how many times per week do you turn on the dishwasher? ________

Energy App

35. Would you be interested to see your electricity consumption in real-time?
- Yes
- No → Q39
- I don't know → Q39

36. Assuming you had the energy usage app on a mobile device, please order the following features in order of priority, from most important to least important.
    - Energy usage/consumption today
    - Energy traded this week
    - Energy traded this week versus last week
    - Savings this week/month OR season
    - My current balance ($$)
    - “How am I doing today?” (in terms of my energy usage goals)
    - “How am I tracking?” (against similar households)
    - Alerts/Notifications

37. How would you use the information about your electricity consumption if you could access it in real-time? Please select all that apply
    - I would keep an eye on it out of curiosity
    - I would change the way I use certain appliances to reduce my bills
    - I would try to identify where the electricity is coming from
    - I don’t think I would use it, I’m too busy
    - I don’t know
    - Other: please specify

Service providers

38. Are you satisfied with the current electricity services provided by Synergy (e.g. tariffs, service, model)?
    - Yes
    - No → Why not? _______

39. Are you satisfied with the current water services provided by WaterCorp (e.g. tariffs, service, model)?
    - Yes
    - No → Why not? _______

Appendix C: Second Survey Instrument – Testing how the P2P pricing design aligned with expectations and values and how this influenced perception of the incumbent utilities

Please circle the relevant options for questions 1 to 3:

1) I am currently registered as a:

   A. Prosumer
   B. Consumer: or
   C. Not yet registered in the trial.

2) I attended the August RENew Nexus trial workshop: **Yes / No**

3) Would you be prepared to pay more for energy if you knew it was produced within your local community from renewable sources? **Yes / No**

4) If you answered yes to question 3, then please indicate how much more you would be prepared to pay for renewable energy produced within your local community:
   $____________

On a scale from 1 to 5, please circle the number that best corresponds to your thoughts in response to the following questions.

5) I think that peer to peer energy trading will result in more solar PV being installed on domestic rooftops than if peer to peer trading wasn't available.

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe your reasons?

6) I think the Western Power grid charge* proposed for the RENew Nexus trial is fair and reasonable.
   (*The grid charge is to cover Western Power's costs in providing and maintaining the poles and wires that transport electricity to each dwelling/business).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

7) I think the capacity charge* proposed for the RENew Nexus trial is fair and reasonable.
(*The Government makes a capacity payment to all electricity generators on the grid to ensure that there is enough generation capacity to meet the peak grid demand (usually on very hot summer days). This payment is to ensure the financial viability of some generators that may only be required on a few very hot days every year or two. Synergy's purchase costs of renewable energy certificates is also being covered by the Capacity Charge. In the trial's electricity bill, these costs are being spread across all electricity users and recovered on an equitable basis).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

8) I think the Synergy Everyday off peak and Everyday peak tariffs* proposed for the RENew Nexus trial are fair and reasonable.
(*The Synergy Everyday tariffs relates to what you pay Synergy for the actual kilowatts of electricity that you consume that are in addition to those supplied by trial participants. These kilowatts are produced by the mixture of all generators on the grid. Energy will be charged at 9.9 cents per kilowatt hour during peak times and 5.72 cents during off peak hours.)

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

9) I think the default Synergy Buyback Rate* proposed for the RENew Nexus trial is fair and reasonable.
(*The default buyback rate is the price that Synergy will pay you for the excess solar PV from your system if you don't find a buyer from within the trial at your preferred sale price. This is expected to be 4 cents per kilowatt hour).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

10) I think the transaction charge* as proposed for the trial is fair and reasonable.
(*This is the fee that Power Ledger will charge for hosting the trading platform that allows you to trade energy with your community peers).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

11) I think that we shouldn't be charged the capacity charge* as part of our electricity bill if we're doing peer to peer trading.
(*As for question 7, above, the Government makes a capacity payment to all electricity generators on the grid to ensure that there is enough generation capacity to meet the peak grid demand (usually on very hot summer days). This payment is to ensure the financial viability of some generators that may only be required on a few very hot days every year or two. Synergy's purchase costs of renewable energy certificates is also being covered by the Capacity Charge. In the trial's electricity bill, these costs are being spread across all electricity users and recovered on an equitable basis).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

12) I think that we shouldn't have to pay Western Power grid charges as part of our electricity bill if we're doing peer to peer trading.
(*As for Question 6, above, the grid charges is to cover Western Power's costs in providing and maintaining the poles and wires that transport electricity to each dwelling/business).

Strongly agree **Strongly disagree**

1	2	3	4	5

13) I think that electricity should be charged based on the time of use (such as cheaper in the middle of the night but more expensive at peak times) rather than a flat energy charge.

Strongly agree **Strongly disagree**

1	2	3	4	5

14) I think it's important that energy can be provided at a reasonable price to everyone in our community, including the poor and disadvantaged.

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

15) I think that the billing approach proposed in the RenewNexus trial closely aligns with my expectations of peer to peer trading.

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe your response?

16) I think it's important that I can go to my retailer or biller when I've got a problem with my bill to have my issue investigated/resolved (e.g. when I feel I've been charged too much; I haven't been paid enough for my PV exports; or I can't afford to pay my bill just now).

Strongly agree **Strongly disagree**

1	2	3	4	5

Can you briefly describe why you gave it this rating?

Appendix D: Third Survey Instrument – Testing reasons for households exiting the trial.

Consent tick box

As part of the RENeW Nexus project, we are interested in gaining a better understanding of why householders have decided not to participate in the RENeW Nexus Plan peer to peer energy trading trial. If you would like to participate in the RENeW Nexus Plan trial but have not yet registered please do so via the Synergy link that was sent to you on the 31st October. Thank you for your participation in the trial up to this point. If you maintain your decision not to participate in the RENeW Nexus Plan peer to peer energy trading trial, we encourage you to remain engaged with the project as it progresses. You are still able to monitor your generation and usage via the energyOS platform.

Property address (so we can match their results from the first survey)
Did you fill out the Survey Monkey questionnaire in August?

- If so, skip
- If not, do you have solar PV system? Y/N

I attended the August RENeW Nexus trial workshop and information session/s on 3rd August and/or 19th October (tick attendance)
Are you satisfied with the service provided by Synergy (e.g. tariffs, service, model)? - Y/N, open ended response
Are you satisfied with the service provided by Western Power- Y/N, (open ended response)
I would have participated in the RENeW Nexus Plan trial if: (open ended response)

Why are you choosing to not participate in the RENeW Nexus Plan trial (choose as many options as apply to you and then number your top 5 from 1 (biggest reason) to 5):

- I do not produce enough excess solar PV energy to trade
- I do not require additional energy than what I currently generate
- I do not wish to virtually purchase energy from other participants
- It looks like too much extra work for the potential savings
- The version of peer to peer trading being trialled doesn't align with how I think peer to peer trading could be done
- I thought peer to peer trading would be more community oriented, but this is very impersonal and "free-market", kind of like the stock exchange
- The approach being trialled creates an extra administrative cost layer rather than removing one
- Using the peer to peer trading platform looks too difficult
- The peer to peer trading platform does not show me what I want to see
- The version of peer to peer trading being trialled does not reward local generation over transmission from further sources
- It doesn't allow me to trade with the person/people of my choice
- I think it rewards big energy users and penalises low energy users
- I think the tariff has been poorly designed
- I think the set fees are too high
- The set fees are more than what I pay now

- The set fees are outside of my household budget
- There isn't scope for me to change my energy use patterns, so I wouldn't get much value out of the peer to peer trading
- I cannot see how this will help the transition to a cleaner energy future

Answer strongly agree, agree, neutral, disagree or strongly disagree to the following:

- Comfort at home in summer is important to me even if it means spending more on energy
- Comfort at home in winter is important to me even if it means spending more on energy
- I value monetary savings over comfort
- It is important for me to reduce my energy costs
- It is important for me to reduce my water costs

Have you looked at the energyOS platform to view your energy usage patterns over the past couple of months? Yes/No
If yes, did using the energyOS platform influence your energy use at home? (open ended response)