



Peer-to-peer electricity trading and the sharing economy: social, markets and regulatory perspectives

Alexandra Schneiders, Michael J. Fell & Colin Nolden

To cite this article: Alexandra Schneiders, Michael J. Fell & Colin Nolden (2022): Peer-to-peer electricity trading and the sharing economy: social, markets and regulatory perspectives, Energy Sources, Part B: Economics, Planning, and Policy, DOI: [10.1080/15567249.2022.2050849](https://doi.org/10.1080/15567249.2022.2050849)

To link to this article: <https://doi.org/10.1080/15567249.2022.2050849>



© 2022 The Author(s). Published with license by Taylor & Francis Group, LLC.



Published online: 20 Mar 2022.



Submit your article to this journal [↗](#)



Article views: 160




View related articles [↗](#)



View Crossmark data [↗](#)

Peer-to-peer electricity trading and the sharing economy: social, markets and regulatory perspectives

Alexandra Schneiders^a, Michael J. Fell^a , and Colin Nolden^{b,c}

^aEnergy Institute, University College London, London, UK; ^bSchool of Law, University of Bristol, Bristol, UK;

^cEnvironmental Change Institute, University of Oxford, Oxford, UK

ABSTRACT

Peer-to-peer (P2P) electricity trading is a new data-driven business model currently being trialed within the energy sector. Introducing P2P transactions to an essential service such as energy supply could have far-reaching implications for individuals and the grid. This paper raises considerations and questions from social, market design and regulatory points of view, which should be understood and addressed by societies and policymakers. It does this by considering under what circumstances it is reasonable to conceptualize P2P electricity trading as part of the sharing economy, and drawing parallels to the sharing economy experience in other sectors. In order to reap the full societal benefits, while avoiding considerable risks to infrastructure and individuals, a policy approach promoting dialogue and innovation is necessary. We suggest the regulatory sandbox is the most appropriate tool to achieve this and would help avoid the breakdown of trust between policymakers and platform companies observed in other sectors.

KEYWORDS

Peer-to-peer electricity trading; P2P; sharing economy; collaborative economy

1. Introduction

Peer-to-peer (P2P) electricity trading, which enables energy consumers to buy and sell electricity directly among each other, is a new business model being trialed within the energy sector (Zhang et al. 2017). It is co-evolving with the data-enabled economic transformation process known as the ‘sharing economy,’ exemplified by digital platforms such as Airbnb (Langley and Leyshon 2017).

P2P electricity trading hinges upon distributed energy resources and advances in consumer level communications and control through smart meters and energy management systems which enable consumers to proactively manage consumption, generation and storage of electricity as prosumers (Morstyn et al. 2018). P2P electricity trading enables such prosumers to bid and directly trade electricity with one another through decentralized, autonomous and flexible P2P platforms (Parag and Sovacool 2016). From a technical perspective, commodifying energy and capturing new value from P2P trading through such platforms hinges upon creation, accessibility, interoperability and security of granular generation, consumption and network data (CEER 2019; Kloppenburg and Boekelo 2019). From a practical perspective, P2P trading requires three pillars to function: an adequate pricing mechanism to incentivize supply and demand; a digital transaction loop to reduce transaction costs to the point when transactions become economically viable; and a delivery loop to implement trading decisions contracted among peers and verify such transactions (Glachant 2020).

Due to its experimental nature, however, it is often unclear what P2P electricity exactly implies, what it entails and why it might be important. This is particularly problematic for policymakers, who have to assess the practical implications of this new model when deciding how and whether to regulate it. They will be grappling with some of the same questions as those being tackled by policymakers looking at the wider sharing economy phenomenon. However, as the energy sector is very different in

some important aspects from transport and accommodation, where the most successful and contentious P2P models have emerged (Uber and Airbnb respectively), the sector is facing a unique set of challenges.

This paper, which takes the form of a conceptual piece, aims to explore these challenges by looking at P2P electricity trading in relation to the wider sharing economy phenomenon from a multidisciplinary perspective. We discuss a number of key questions which have not been answered by literature and we believe societies and policymakers will need to understand and answer in order to move forward with electricity sharing approaches in a fully informed way- from social, market design and regulatory perspectives.

We first introduce in [Section II](#) the main drivers and risks associated with P2P electricity trading, before considering how it can be placed within the wider concept of the ‘sharing economy’ and the social benefits that could result from this model ([Section III](#)). This is followed in [Section IV](#) by an analysis of the economic and market implications of P2P electricity trading, particularly focusing on the important role of data in such models. Finally, in [Section V](#) we evaluate questions around the regulation of peer-to-peer electricity and, drawing parallels with the regulation of the wider sharing economy, conclude by providing recommendations on how to approach the regulation of P2P electricity trading.

Methodologically, this paper draws on a wide range of literature to cover social, market and regulatory perspectives on the sharing economy and P2P electricity trading. Analysis was also informed by current debates on the subject, some of which the authors led as workshop hosts or informed as panel members, as well as ongoing exchange among researchers, policymakers and practitioners engaging in the operationalization of P2P electricity trading.

This paper recognizes that P2P electricity trading can provide multiple social benefits, potentially even more far-reaching than those observed so far in other sharing economy sectors. It acknowledges the crucial role played by data in such sharing models, and the risks thereof to energy consumers in particular. Mostly using the UK as an example, but also looking at other countries, our general approach to regulation is precautionary; while we support innovations which can potentially support more decarbonized and democratic approaches to energy service provision, we believe it is important to anticipate the range of possible outcomes so that negative ones can be more easily recognized and protected against (Stirling 2007).

Before we delve into the main questions that this paper focuses on, some background on P2P electricity trading is provided in the next section.

2. Background

The energy sector is undergoing a transition driven by decarbonization, decentralization, digitalization and democratization (the ‘four Ds’) (Burger et al. 2020; Institute for Public Policy Research 2018). Consistent with this is a rise in energy consumers producing their own energy (‘prosumers’), thanks to the accessibility of cheaper renewable energy technologies (IRENA 2020). In many countries, the uptake of these technologies has been supported by subsidies such as feed-in tariffs, but these are being ramped down and suspended (Nolden, Barnes, and Nicholls 2020). Other, more market-oriented approaches are being explored to allow prosumers to benefit from their renewable energy generation (Brown, Hall, and Davis 2019, 2020).

The concept of P2P electricity trading, where prosumers/consumers buy and sell electricity directly from and to each other, is receiving a lot of attention in this context (Brown, Hall, and Davis 2019, 2020; Zhang et al. 2017). Using a smart meter, connected to an internet device such as a smart phone or computer, they can trade energy with other consumers at a local, regional and national level (Zhang et al. 2018).

It should be noted that due to a lack of consensus on its definition, the term ‘peer-to-peer electricity trading’ is often used interchangeably with others including ‘transactive energy’ (TE) and ‘community/collective self-consumption’ (CSC). Despite both of these including the trading of energy as an activity, they are different concepts. TE is a term that is mostly used in the United States, with TE pilots focusing on improving grid functioning (e.g. in case of blackouts caused by natural disasters) through

consumer engagement. CSC pilots place the emphasis on the generating and sharing of energy at community level. Peer-to-peer electricity trading, whether within a TE or CSC context, can take place at a local (e.g. Quartierstrom in Switzerland) or national level (e.g. Vandebron in the Netherlands) (Schneiders et al. 2021).

Such models stand in contrast to energy-as-a-service business models, which promise less complexity in energy market interaction and access to renewable energy generation without the need for ownership and demand side response (Britton et al. 2021). While these might be perceived as incremental innovations based on existing business models and supply structures, P2P electricity trading is often perceived as disruptive, as a data enabled business model challenging incumbent market structures (Kloppenburger and Boekelo 2019).

Distributed ledger technologies (DLTs) such as blockchain are sometimes used to enable direct P2P trading between consumers, promising further disruption of existing systems by harboring the potential to guarantee energy provenance (adapted from Kragh-Furbo and Walker 2018). This is facilitated by smart meters (collecting data on produced and consumed energy) being connected to a blockchain-running device. Consumers set their terms for the sale and purchase of energy on the device, which are recorded on the blockchain. Once the blockchain finds matching terms, a (financial) transaction automatically takes place between ‘peers’ on the network (Exergy 2018).

P2P electricity trading could permit prosumers to exploit the gap between selling electricity at wholesale prices and buying electricity from the grid at retail prices, by enabling them to make profits by setting prices below grid supply (Brown, Hall, and Davis 2019, 2020; Hall and Roelich 2016). P2P ‘sharing’ approaches are often portrayed as having wider benefits, such as improved community cohesion and generally a more personal approach (UCL Energy Institute 2019). P2P electricity trading is also perceived by some policymakers as a way to foster decarbonization of the energy sector and increase the share of renewables on the grid (Butenko and Cseres 2015).

However there are potential risks. By enabling direct transactions between peers, depending on the regulatory regime and specific context (such as in private wire arrangements), P2P may allow participants to circumvent certain costs associated with use of the electricity network (Brown, Hall, and Davis 2019, 2020). While these participants may still be substantially reliant on network infrastructure for reliable power, they could end up making relatively little contribution to maintaining it – the costs of which instead weigh more heavily on those who are not part of P2P arrangements (Solar Trade Association 2019). Reviews are underway, in Great Britain for example, to ensure that those who “take action which benefits the electricity system and consumers as a whole pay less” (Ofgem 2018, 5). There are also important questions to consider around making sure that network costs are distributed in an even and fair manner, without discriminating against those consumers who do not have the means nor possibilities to participate in peer-to-peer schemes (CEER 2019).

The energy sector is not alone in seeing rising interest in approaches involving P2P transactions, which are broadly termed the ‘sharing’ or ‘collaborative’ economy. The sharing economy is a new economic model enabled by digital technology and the free flow of data (Langley and Leyshon 2017; Richter and Slowinski 2019; Sundararajan 2016), facilitating the exchange of ‘underutilized assets’ for monetary gain or other benefits by private individuals (‘peers’). As part of the sharing economy, platform companies including Airbnb in accommodation and Uber in transport, allow participants to easily economize assets such as rooms or vehicles by making them available to others (for monetary gain) through online platforms (Böcker and Meelen 2017; Langley and Leyshon 2017).

However, we see the introduction of sharing or P2P models in the energy sector as substantively different from other sectors in two principal ways. Firstly, provision of energy is usually considered to be an essential service, the loss of which could present a “threat to the life, personal safety or health of the whole or part of the population” according to the International Labour Organisation (2006, 119). Similarly, the United Nations considers:

“Energy [...] crucial for achieving almost all of the Sustainable Development Goals, from its role in the eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change.” (United Nations 2020)

To our knowledge, the introduction of P2P trading to the electricity sector stands out alongside shelter (e.g. Airbnb) as the first substantial incursions of a sharing economy model into an essential service sector. This is significant because Airbnb has been linked to rising rents in cities such as Berlin and Barcelona. Rather than economizing assets, Airbnb increases demand, which leads to increases in prices and reduces the availability of affordable shelter for city dwellers (Oltermann 2018).

Secondly, electricity networks are uniquely interdependent forms of infrastructure. In order to operate properly, supply and demand of electricity must be kept in balance at all times. Above a certain magnitude, the actions of any actor on the system have physical implications for the operation of all other actors. There is therefore an acute need for effective common resource governance to coordinate activities and choices, which is usually the remit of the system operator, and to avoid harm to unrepresented vulnerable parties (Gollwitzer et al. 2018).

This is where the difference between shelter and energy becomes apparent. While Airbnb may have very localized effects on shelter availability, P2P electricity in particular has potentially systemic effects on the entire energy system. While shelter as well as transport certainly display levels of interdependence (e.g. tourism economies and traffic congestion), we believe that no other areas where sharing economy models have been introduced so far have such high interdependence as electricity (this is discussed in more detail in [Section III](#)).

There is currently substantial interest in how the energy sector should be regulated to permit beneficial innovation while minimizing harm (for examples in Great Britain see [Kuzemko et al. 2016] [Ofgem 2018bb] [Sandys, Hardy, and Green 2017] [Willis et al. 2019]). For the reasons described above, we think that special consideration needs to be given to the introduction of sharing and P2P market models in this sector. The next sections will aim to bring some important considerations to the forefront by analyzing the main questions to be asked around P2P electricity trading from social, market design and regulatory perspectives. This will be done through comparison with other sharing economy sectors (e.g. accommodation, transport).

3. Social perspective: Can you share electricity?

Before discussing the relevance of the sharing economy experience in other sectors, it is useful to consider what constitutes ‘sharing,’ and whether (and when) it applies in the context of electricity. It is first worth acknowledging, that the act of ‘sharing’ is not necessarily seen as integral to the concept of the sharing economy at all. For example, Sundararajan (2016) is less concerned with whether the transactions taking place within it can strictly be described as sharing, instead emphasizing factors such as the role of crowd-based networks and blurred lines between private and professional activities. Indeed, he makes the point that he retains the terminology of ‘sharing economy’ more due to its wide recognition than through connection with the idea of sharing itself.

Nevertheless, it is useful to establish the principle of whether and when we can reasonably speak of ‘sharing electricity’ at the outset, and whether sharing between specific entities has any meaning beyond in an accounting sense. This is important because, as we suggest later in this section, the potential to build stories and narratives around P2P electricity trading could be a key part of its allure as a model. Controversy around ‘green tariffs’ (and the extent to which they mean customers are really using renewable electricity) illustrates how it can be difficult to walk a line between conveying an engaging and accessible message, and one that is seen as truthful (e.g. see Shannon and Prestidge 2019). The section then turns to broader considerations widely held to be relevant to the sharing economy concept, such as around (under-)utilization of resources, and the potential for social value creation.

Belk (2007) describes sharing as “the act and process of distributing what is ours to others for their use as well as the act and process of receiving something from others for our use.” The point of sharing here is that ownership is not transferred, but that access is granted for others to some resource –

indeed, Chasin et al. explicitly state that sharing and collaborative consumption models “do not involve ownership transfer” (2018, 297). Other authors take a more liberal view of what may be considered sharing – or at least sufficiently so to form part of the sharing economy. For example, Codagnone, Biagi, and Abadie (2016), among others, admit P2P selling platforms such as eBay and Etsy within their conception of the sharing economy. However, this is again more an acknowledgment of the general features of these (and similar) services than reflective of a view that they actually involve sharing.

The key question is whether P2P electricity trading can be viewed as involving transfer of ownership. In an article considering the concept of sharing in the energy sector more generally, Plewnia treats P2P electricity trading as an example of exchange of goods, saying “it can be considered a very tangible good” and categorizes the energy which is exchanged as a “material” (2019, 7). This suggests that in supply of electricity, a transfer of ownership does occur. However, Plewnia (2019) also goes on to say that in P2P trading “it is rather the PV or wind production facility that is shared economically instead of the energy itself.” Ownership of the generation asset is not transferred. Rather, use of its output is virtually assigned to the owner or any purchasers of that output. Any output not assigned to the owner can be viewed as practically unavailable to them while being available to others and therefore, in effect, shared.

There are existing models of P2P electricity trading that are more consistent with this alternative view. The CommUNITY Project in Brixton, South London (UK), for example, allocates each participant a share of the output of a communal PV array and battery (EDF Energy 2019). Participants are then able to buy or sell this ‘option’ of electricity between each other depending on their needs. In this case the PV and battery are already shared resources, but there is no reason why a similar approach could not be taken for the sharing of privately-owned generation and storage facilities. In this case, what would be shared would be the right to use (for example) a certain amount of output from a PV panel over a certain time – the ownership of the panel itself, and therefore the future flow of electricity – remaining unchanged. Similarly, the solar gardens concept from Australia allows households to purchase or subscribe to a share of a communal PV array (Institute for Sustainable Futures 2018). The Netherlands-based Powerpeers scheme illustrates their offering with the question, “Can I use the energy from your solar panels while you are on holiday?” and also allows users to view “how much electricity they have shared and used” (Powerpeers 2021).

While these examples of sharing are more consistent with Plewnia’s (2019, 7) (“it is rather the PV or wind production facility that is shared economically instead of the energy itself”), we go further to maintain that it would also be legitimate to claim that people can meaningfully share in an output of electricity in a way that goes beyond just ‘virtual’ or ‘balance sheet’ representations. Due to the extreme interconnectedness of the electricity system, every generating asset plays a role in setting up the instantaneous state of the overall network. The ability of system users to derive energy services from it is determined in part by this state. What is shared is the option to benefit from this state which, as just suggested, can be attributed proportionally to all generators – if a generator owner/controller is sharing its contribution to a useful state of network, they cannot benefit from it themselves (i.e. by self-consuming it). It is a ‘service’-based, rather than a ‘good’-based, conceptualization of P2P trading. Such a discussion is of more than simply theoretical interest, but to explore this further it is useful to briefly consider another frequently cited tenet of sharing – that of underutilization of assets.

3.1. Sharing and (social) optimization

A commonly cited argument in support of sharing models is that they make better use of an underutilized resource (e.g. Cusumano 2015; Parente, Geleilate, and Rong 2018). In the context of energy, we must therefore ask whether energy assets such as PV panels or batteries can be considered underutilized. Let us consider the example of a PV panel. On the face of it, so long as the panel is grid-connected, any generation that is not used on-site is automatically exported and used elsewhere. Utilization may therefore be considered to be 100% – which is hardly a case of underutilization.

However, viewed another way, arguments can be made for underutilization, or at least sub-optimization, of PV panels. Firstly, there are grid management challenges associated with unmanaged exports from assets such as PV panels on distribution networks. In areas with higher prevalence of PV, substations can become overloaded and there may be other power management issues (Luthander, Lingfors, and Widén 2017). So, while it can be said that the output of the panel is indeed used in full, it also causes negative externalities that amount to sub-optimal utilization. However, this sub-optimality has the potential to be managed through (for example) location-specific direct load control, time-varying tariffs or more flexible use of shared batteries that are not explicitly based around the idea of sharing or direct P2P trading. So why introduce these ideas of sharing at all?

In a straightforward economic sense, there may be appetite to pay more for electricity with a known provenance, such as local energy (e.g. in the Brooklyn Microgrid (Dnv 2017), or Energy Local schemes (see Octopus Energy 2021)), suggesting the full value of supplying electricity from known sources may not otherwise be realized. However, evidence for this is mixed, with studies finding either slight but inconsistent (Mengelkamp et al. 2019) or no (Wilkinson et al. 2020; Wörner et al. 2019) willingness to pay more for local electricity.

Beyond this, consider that electricity systems are socio-technical in nature. The technical components exist to service social needs and desires, are created and operated by people, and operate more or less effectively depending on factors related to the beliefs, activities, and practices performed by people. In such a context, might we consider a PV panel that is exporting indiscriminately to the grid, even in a context where there is local load management, as being used optimally in service of the social benefits that the electricity system aims to provide?

Advocates of sharing might argue that creating direct links between specific prosumers/consumers, or at least within societies, has benefits and meanings (e.g. energy saving and community cohesion) that could not be realized through simple exporting. That these benefits are not realized represents an underutilization of the social potential of the PV panel. It could be said that a kind of ‘social exergy’ – the level of social-energy benefits that are available to be used – is higher in this configuration than without such direct relationships. It could be in this way that P2P sharing of PV output can be most usefully conceptualized as reducing underutilization.

Put simply, P2P trading or sharing has the potential to open the door to more compelling narratives that could be more effective in helping realize good societal outcomes than other more purely technical approaches. There is certainly evidence of some enthusiasm for energy platform projects that aim to drive benefits for, and links within, the wider community (Ableitner et al. 2020; Hackbarth and Löbbe 2020; Smale and Kloppenburg 2020; Wilkinson et al. 2020). This could extend beyond straightforward financial contributions. For example, in-kind returns for sharing may be preferred, or even intangible recognition such as gratitude whose value may primarily be in reinforcing social bonds (Singh et al. 2018). There is also the prospect that sharing schemes could help promote wider changes in energy-related activity. For example, could the knowledge that you are using electricity from your local school, or your community, or your parents motivate engagement with energy efficiency schemes, or even result in you using electricity differently (such as at different times)? The power of narrative and storytelling in energy has been demonstrated (Moezzi, Janda, and Rotmann 2017), but further research on its role in this context would be required to test this hypothesis.

In light of the arguments above, it can be said that P2P electricity trading does not have to be treated as the sale of electrons between peers. It can be conceptualized as the sharing of a useful state of the electricity network set up by the combination of all electricity generation or storage installations. The provision of access to (a share of) this flow by individuals can then be viewed as a service-based transaction. Crucially, through the sharing of energy generated by assets such as solar panels, P2P electricity trading could fulfil important social functions such as strengthening community cohesion and fulfilling a common (policy) goal such as increasing energy self-sufficiency, although such benefits are largely still to be empirically demonstrated. It could be argued that these are more far-reaching social implications than those extolled by other P2P sectors. However, it is by no means certain that the potential social benefits of energy sharing will be realized. Indeed, this is likely to be strongly

dependent on the way in which sharing platforms are owned and operated. And experience in other sectors raises a number of causes for concern. The implications of this for consumers and for the wider electricity sector are the focus of the next section.

4. Market design perspective: The emergence of data-enabled platforms

This section analyses the institutional arrangements and market implications of P2P electricity trading within the context of socio-technical change toward sustainability, how societal and individual value are captured, tensions between incumbents and P2P trading platform providers, and (data) governance. Its starting point is that P2P constitutes an element of change which is putting into question the role of all market stakeholders, including energy suppliers and the State itself.

The decentralization trend which enables P2P trading is part of a series of overall transitions in energy system governance. The first transition, associated with economic liberalization policies of the 1980s and 1990s, saw governance and responsibility shift from the public sector toward highly regulated, competitive markets (Mitchell 2008). Some argue that we are now witnessing a second transition which is shifting governance and responsibility toward civil networks, households and individuals (Heldeweg 2017). An increasing range of grid-edge innovations is fueling this transformation, with sharing economy models promising scalable market platforms capable of redeveloping the energy grid from the bottom up (Burger et al. 2020; Kloppenburg and Boekelo 2019).

How do these transformative forces shape and reshape the energy system and where does market governance responsibility lie? P2P electricity trading is a consequence, and potentially a driver, of the privatization of energy provisioning at multiple scales which challenges the “public character of energy infrastructures” (Kloppenburg and Boekelo 2019, 69). By enabling autarky and grid defection at the ‘grid edge,’ it has the potential to disrupt established and centralized structures (Smale and Kloppenburg 2020). For others, the emergence of the prosumer and P2P provides opportunities for energy democracy, participatory governance and grid integration (Szulecki 2018).

This raises questions about where value associated with decarbonization, energy security and the provision of energy as an essential service materializes. Energy governance is thus confronted with the need to simultaneously ‘keep the lights on,’ while shifting from a prescriptively regulated fit-for-purpose system based on fossil fuel supply toward a facilitatory system where responsibilities are diffuse yet risk-taking needs to be encouraged. A new fit-for-purpose system consequently needs to maintain security of supply while facilitating necessary socio-technical and socio-ecological innovations (Sandys, Hardy, and Green 2017; Willis et al. 2019).

The main innovation underlying P2P electricity trading is the possibility of establishing marketplaces based on platforms. Such platforms coordinate multisided markets which enable peers to interact and transact through the use of data (Fuentes et al. 2019). The ‘platformization’ of network industries (e.g., energy and transport) and other sectors such as finance is part of this socio-technical transition toward decentralization (Fuentes et al. 2019; Judson et al. 2020; Montero and Finger 2021). In theory, such platforms support the “transition towards decarbonized, decentralized and digitized energy systems” (Smale and Kloppenburg 2020, 1).

If reintermediation through P2P electricity trading platforms follows similar patterns to accommodation and transport services, however, it is in danger of producing platform capitalism in the energy sector (Langley and Leyshon 2017; Srnicek 2016). Under such a scenario, platform providers seek to extract monopoly rents by concentrating market governance through reintermediation, while trading concentrates the benefits of prosumerism among peer traders (Filipović, Radovanović, and Lior 2019). While the sharing economy characteristics of such platforms in theory enable the capitalization of surplus capacity (as discussed in Section III), their underlying profit-driven business model may have a tendency to crowd out socially and environmentally beneficial outcomes that are economically unfavorable (Smale and Kloppenburg 2020).

Such platforms are nevertheless considered essential to provide the trading space which enables prosumers (actors) to engage in P2P electricity trading (act of trading). Prosumer-to-grid integration or prosumer community group arrangements, on the other hand, are less dependent on platforms (Parag and Sovacool 2016; Smale and Kloppenburg 2020). In fact, research among prosuming households in the Netherlands suggests a preference of prosumer-to-grid integration because this arrangement does not require platforms which were not considered suitable for achieving social justice (Smale and Kloppenburg 2020).

Alongside the question of where and how value is created, accumulated and ‘shared,’ ‘re-intermediation’ through platforms therefore also raises questions about the potential of P2P electricity trading to contribute to social justice priorities, and what degree of (de-)centralization might be possible or appropriate (Fuentes et al. 2019; Kloppenburg and Boekelo 2019; Parag and Sovacool 2016). If value is only created by reducing grid use and the reduction of associated charges, there is a danger of reducing network use. Assuming full cost recovery by regulated network companies, this leads to higher charges for those who remain, which in turn encourages them to reduce usage, while concentrating associated data in the hands of platform providers (CEER 2019). One of the key pillars to support the functioning of P2P trading platforms is therefore the pricing mechanism (Glachant 2020). This can also be concluded from the determinants of market integration, as well as social and economic acceptability of P2P electricity trading, identified in Great Britain:

- 1) how users of P2P trading platforms are allocated network charges,
- 2) the contractual arrangements which determine how P2P ‘exchange’ transactions are governed,
- 3) how P2P trading sits alongside ancillary services arising from the (platform-enabled) management of generation, consumption and storage.

Regarding point 1, the British regulator Ofgem has been engaging in its Targeted Charging Review since 2017 to ensure that residual charging arrangements meet the interest of current and future consumers while reducing distortions and maintaining fairness in relation to ‘embedded benefits’ (Ofgem 2018a, 2019).

Regarding point 2, ‘re-intermediation’ through P2P platforms entails new contractual arrangements between new market participants, between such participants and trading platforms, and between such participants or the trading platform and existing market participants, at which point the need to balance social costs and private benefits becomes an issue (CEER 2019).

Regarding point 3, alternative value creation opportunities through ancillary services, such as flexibility, balancing and congestion management could be unlocked alongside P2P electricity trading if the marketplace provided appropriate price signals (CEER 2019).

In theory, a transactive energy market might enable such ancillary services to be built into transactions among peers at the ‘grid-edge.’ Rather than distorting energy markets, valuable ‘grid services’ could be provided from the bottom-up (Energy Web Foundation 2020). In practice, however, legacy market structures make it more likely for such services to be provided by professional intermediaries managing demand response service rather than P2P trading (Ofgem 2019). This is supported by large-scale trials in Great Britain, such as the Cornwall Energy Market (Judson et al. 2020).

Led by energy supplier Centrica, this trial demonstrated the possibility of buying “flexibility simultaneously and in a coordinated fashion via a single third-party platform” (Centrica 2020, 3). Although P2P was not an element of this trial, it suggests that P2P can be an element of local energy markets if it succeeds in balancing local supply and demand and some form of centralization is maintained (Judson et al. 2020).

This suggests that alongside important similarities, there are also significant differences to Airbnb and Uber, whose platforms connecting accommodation and transport customers with car owners and landlords are upending traditional business models in both markets. A key factor they have in common is their reliance on data. In contrast to Airbnb and Uber, however, energy market data is core to the functioning of the overall system while lacking the time and space granularity as well as compatibility for P2P trading (Centrica 2020; IRENA 2020). To ensure full energy system integration,

P2P trading parties need to fulfil prevailing obligations of balancing and cost bearing (CEER 2019). However, a lack of data regarding congestion and constraint forecasting, power-flow relationships between grid nodes and customer-to-network mapping represents a barrier to such integration (Centrica 2020).

4.1. Data governance implications

Fundamentally, the scope and depth of P2P electricity trading platforms is a function of available energy data (Zhang et al. 2018). Specifically, it requires spatiotemporally granular electricity data capturing capabilities which add the dimension of provenance beyond the property-boundary (International Energy Agency 2017; Kragh-Furbo and Walker 2018). Smart meters create visibility at increasingly short intervals, in some cases approximating ‘real time data’ by timestamping generation and outflow (International Energy Agency 2017). This provides the basis for subsequent trading and sharing and associated value creation by creating digital provenance (Burger et al. 2020; Kragh-Furbo and Walker 2018).

In principle, the increasing penetration of smart meters, sensors and the Internet of Things (IoT), enables energy data to be captured at increasingly granular levels down to individual energy demanding devices. Machine learning and Artificial Intelligence (AI) facilitate big data analytics and the creation of provenance (Kragh-Furbo and Walker 2018; Nolden 2019). Distributed ledger innovations allow ownership of energy production, consumption and demand-side response derived from smart meters to be transparently authenticated and tracked, which provides the basis for value and accounting chains (Andoni et al. 2019).

As it stands, however, consumer data is held by energy suppliers while flexibility and balancing data relating to congestion and constraint forecasting, network topology changes, the power-flow relationship between grid-nodes, and customer-to-network mapping is held by Distribution Network Operators (DNOs) (Centrica 2020; CEER 2019). As long as data availability, analytics and connectivity are limited to such organizations, the transaction costs of platform ‘re-intermediation’ are likely to outweigh the reduction of such costs through a better coordination of network systems and industries (CEER 2019).

As P2P is enabled through digitalization, P2P related data governance is inseparable from the governance of energy system digitalization. Such governance will determine the granularity, accessibility and interoperability of data alongside the balance between enabling innovation and ensuring that the whole system benefits from such innovation (CEER 2019).

Given the novelty of P2P, and uncertainties regarding points 1–3 above (in the first part of Section IV), such trading in the UK is confined to experimental settings in regulatory sandboxes (see Section V.). However, P2P trading, by enabling peers to balance energy supply and demand with any imbalance dealt with by the wholesale market, requires marketplaces which act as facilitators rather than energy suppliers. To establish P2P trading, data will need to be made more accessible, possibly as a public good. This in turn has privacy implications, especially with regards to General Data Protection Regulation (GDPR) which puts energy service providers such as P2P trading platforms under legal obligations regarding the processing of data (Vigurs et al. 2021).

New entrants, such as P2P electricity trading platform providers, are therefore reliant on the provision of GDPR-compliant aggregated and anonymized data which is currently held by incumbents. There is a strong argument for such data to serve incumbents such as energy suppliers and DNOs ahead of P2P marketplaces, given the need for “all parties involved to fulfil prevailing obligations for balancing, cost bearing etc. and are not separated from but integrated in existing markets” mentioned above (Council of European Energy Regulators (CEER) 2019, 23). Under such conditions, the allocation and activation of flexibility in emergent flexibility marketplaces by DNOs would take precedence over the facilitation of platforms for P2P electricity trading as it is easier to manage contracts among electricity and distribution network operators at a national level to avoid local power cuts (see Cornwall Energy Market, Centrica 2020; Judson et al. 2020).

There is nevertheless scope for P2P trading in such market arrangements if price signals are clear and data exchange requirements precisely defined to reduce transaction costs and implement trading decisions (Glachant 2020). In this case minimum size and administrative requirements could be overcome through P2P platform aggregation (Szulecki 2018). However, governing data and platforms to ensure both data transparency and the protection of consumer rights has not been the remit of energy regulators. The Council of European Energy Regulators (CEER 2019) calls for close cooperation with consumer organizations to help separate key information from ‘noise.’ As data will become cheaper and more widely available, they suggest that current asymmetries between regulators and regulated and unregulated entities will be reduced. This could lead to a shift in market power to platforms (CEER 2019).

Governance needs to be aligned accordingly to ensure that opportunities for market abuse and power accumulation are minimized (Montero and Finger 2017). Energy data governance thus hinges on the generation of the “right sort of data” (CEER 2019, 49). It needs to be granular in space and time and accessible and useful in terms of availability, while ensuring interoperability and, above all, security (CEER 2019; IRENA 2020; Kragh-Furbo and Walker 2018).

From the perspective of the sharing economy, data and platform-facilitated local energy markets would severely disrupt the business models of energy suppliers, potentially also DNOs/DSOs, the companies which currently hold much of the data necessary to enable P2P electricity trading. Current market arrangements which established energy suppliers as core intermediaries between customers and the energy system, on the other hand, evolved with a centralized configuration (Judson et al. 2020).

This centralized configuration is entrenched in legal frameworks, licensing arrangements, and industry codes, regulation and rules. As customers can only contract with one licensed supplier at a time, trading between peers is impossible to enact independently, although a derogation from the need for an energy supply license is made for supply under 2.5 MW in the UK (Hall et al. 2020; Judson et al. 2020). Given limited support for smaller scales and active local participation in the UK (evident in the Government’s 10 Point Plan which prioritizes electricity generation at a large scale, BEIS 2020), it appears likely that institutional change, especially in relation to decentralized innovations challenging existing and functioning centralized business models will only progress incrementally (Judson et al. 2020).

Policymakers should ensure that potential social benefits accruing from the services provided and value gained by energy-producing peers to the P2P community are distributed fairly and do not distort the market. How the regulator approaches both incumbents and platform providers will define whether and how potential social benefits of P2P electricity trading will be maximized, as suggested by the next section on regulation.

5. Regulatory perspective: How to manage risk while innovating?

Peer-to-peer electricity trading is currently at an experimental and pre-competitive phase. The regulatory approaches adopted by countries around this model will define its future success. They will also shape the social and market repercussions set out in the previous sections. This section assesses existing regulatory approaches to P2P electricity trading, the legislative and sandbox approaches, and makes a case for looking closely at the lessons learned from other sharing economy sectors.

We first look into the legislative approach. The European Union’s recently revised Renewable Energy Directive (2018/2001/EU) defines peer-to-peer energy trading as “the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant” (Art. 2(18)). This is supported by other provisions in the Directive stipulating the conditions under which P2P energy trading may take place. For instance, consumers participating in trading will continue to be protected, provided such an activity does not constitute their “primary commercial or professional activity” (Arts. 2(14), 22).

The European Union's approach of setting conditions in legislation around P2P energy trading is comparable to that taken by individual European countries such as France and Spain, where laws have been formulated (mostly before the EU finished revising its Directive) to enable the collective self-consumption (CSC) of energy at small scale (as made clear in the introduction, P2P electricity trading is one of the activities that can take place within a CSC contexts), subject to strict conditions. For instance, the original French law requires individuals to be part of one legal entity and connected to the same low-voltage substation (Art. L. 315–2) (Legifrance 2018). The latter condition is similar to that imposed by the original Spanish law, which recognizes “self-consumption by one or several consumers” of electricity originating from production installations that are “connected to the internal network of associated consumers,” either through direct links or the same low-voltage substation (Art. 9) (Jefatura Del Estado 2013).

Despite such legislation making small-scale P2P pilots possible, limits such as the geographic proximity between residents have proven to be stifling for those running pilots in France, who in addition to this are not able to become fully operational without government subsidies (UCL Energy Institute 2018). It should be noted that, likely due to these concerns, the French law has been changed in November 2019 to widen the perimeter within which collective self-consumption can take place to 2 km (Legifrance 2019). The same can be observed in Spain, where the law was broadened in April 2019, making it possible to share energy at residential scale (Molina 2019).

On the other hand, an increasing number of countries such as Great Britain and the Netherlands are opting for the ‘regulatory sandbox’ approach. This enables organizations to trial innovative ideas which are not foreseen in regulation, in a real-world environment with a small number of domestic customers during a limited amount of time, without some of the usual rules applying. The aim is for the learnings and results of pilots to be taken on board by the government and regulators when revising the applicable rules and legislation, potentially enabling pilots to operate at a wider scale post-sandbox. P2P electricity trading trials (mostly using blockchain technology) are currently taking place under the British and Dutch sandboxes.

Ofgem, the energy regulator of Great Britain, has stated that its sandbox (‘Innovation Link’) is crucial at a time when regulation must evolve to facilitate the “deep and wide-ranging transformation” the energy system is undergoing. Its view is that a “flexible approach that relies ... on learning over time” is necessary in a situation of “regulating for uncertainty.” The protection of consumers’ interests is crucial in this transition. The sandbox, launched in 2017, allows pilots to run for up to two years. Trial participants must partner up with a licensed supplier/distributor (Ofgem 2021).

The Dutch sandbox (‘Experimenteerregeling’) was launched in 2015. Its declared intention is to assess whether current legislation presents a barrier to enhanced renewable energy generation at a local level, as well as the efficient use of available energy infrastructure. These aims are part of the government’s programme to meet its renewable energy targets. Trials have a duration of up to 10 years and can deviate from a wider regulatory framework as compared to the British sandbox (RVO 2018).

5.1. What can previous attempts at regulating the sharing economy teach us?

It is clear so far that there are two regulatory approaches when it comes to P2P electricity trading: legislation and sandboxes. As the European Union starts to formally recognize the right to trade energy in its legislation, EU Member States will need to align their national legislation (and fill gaps in EU legislation around the practicalities of trading energy), while being careful not to stifle innovation. Recent attempts to regulate other sharing economy sectors can provide valuable lessons for the regulation of P2P electricity trading. Which approach is preferable to achieve this? This is the question which this section seeks to answer.

The sharing economy model does not fit within any existing legal framework. It is not only a disruptive innovation, but also a 'regulatory disruption' (Cortez 2014, 175–177). This is because it represents a move away from 'two-party relationships' between consumers and service providers, by creating 'three-party relationships' between consumers, platforms and service providers. This new type of relationship requires a different allocation of liability in order to protect consumers efficiently (Katz 2015).

There is consensus between legal scholars that regulating sharing economy companies through existing regulatory tools is not sustainable in the long-term. Regulators have so far largely tried to apply 'legal tools for equivalent commercial practices,' e.g. regulate Airbnb using rules targeted at hotels. These rules are not only outdated in terms of not recognizing the three-party relationship, but they are also based on 'command-and-control' regulatory responses dating from a time when innovation moved at a slower pace (Armstrong, Gorst, and Rae 2019). Back then regulators had more time to 'get their facts in order' before they made a regulatory intervention (Fenwick, Kaal, and Vermeulen 2018).

Innovation is moving at a much faster speed today, with regulators unable to catch up. Regulation needs to evolve into a flexible and iterative process, continuously informed by data enabling regulators to fully understand these constantly evolving models (Allen 2019). This is however inhibited by 'information asymmetries' caused by a lack of available data for regulators; data which is collected by platforms and held by companies (Cohen and Sundararajan 2015). Sharing economy companies such as Uber and Airbnb have taken advantage of this asymmetry by engaging in 'regulatory entrepreneurship,' i.e. carrying out their business under the assumption that they can 'change the law to accommodate that business' through political pressure (Allen 2019).

This is particularly risky in the energy sector, as it is an essential service and the infrastructure used (i.e. energy grid) is of critical national importance. Energy regulators will be faced with additional questions such as how to determine liability in the face of increased risks presented by consumers selling self-produced energy to other consumers. Since a 'reliable electricity supply' to various retail customers needs to be ensured, individual prosumers could become 'responsible for the management of the production units that they own' (De Almeida et al. 2021, 22). It is also difficult to imagine how safety-enhancing systems found in P2P platforms such as Uber/Airbnb, for instance user and provider ratings, can work in a P2P electricity trading context (it would be impractical due to a large volume of small trades). P2P platforms operating in the energy sector are therefore likely to need to be monitored more heavily than those in non-utility sectors.

There is consensus in the legal literature on the sharing economy that the regulatory sandbox is the ideal tool to allow regulators to have access to the data they need in order to regulate efficiently and protect consumers. It not only allows them to learn about new business models at pace, but also avoids the 'regulatory entrepreneurship' scenario (Allen 2019), since companies work together with regulators in a sandbox. This makes way for a 'collaborative data-empowerment supervisory regime' that is more fitting for today's circumstances (Tsang 2019). The first ever sandbox, launched for financial services applications by the UK Financial Conduct Authority (FCA), reportedly helped reduce the time and cost of 'getting innovations to market' (FCA 2017).

However, there have been criticisms of the way sandboxes (the bulk of which are in financial services) have been designed and run so far. First of all, there is a problem of 'transparency and replicability,' with dispensations given to companies and learnings from trials often not being openly disclosed by regulators. Furthermore, participation is not open to all actors active in the sector, for instance smaller unlicensed parties (which are of particular importance in the sharing economy) (Zetzsche et al. 2017). In order to fully understand innovation in the sector, regulators need to engage with smaller actors. Furthermore, these small actors would benefit from the sandbox since they have a more limited understanding of the regulatory environment and need more guidance than large companies (Allen 2019).

These lessons will need to be borne in mind by regulators designing and running energy sandboxes. Due to their limited scope (e.g. in the British energy sandbox only certain rules can be deviated from) and timeframes so far, it is not certain to what extent they can warn energy regulators about wider

market impacts such as network effects and the existence of (data) monopolies. They should be designed so that they can represent, as accurately as possible, the impacts of such new business models on energy consumers and the role that will be played by existing and new market actors when rolling these out.

There might be a need for a continuous sandbox to inform regulation on a continuous basis. Sandboxes and regulation are not mutually exclusive and could run in parallel. Provided rules are not drafted in a too prescriptive manner, they could provide space for further experimentation within a regulatory sandbox environment. France is an example of a country keeping both options open (Commission de régulation de l'énergie 2020). The sandbox approach might end up being more important after all, since it would be an essential tool to draft evidence-based regulation. Efforts so far of countries such as Spain and France (set out at the beginning of this section) show that drafting legislation on the matter is premature, and they would benefit from a sandbox showing the practical realities of how P2P electricity models are being rolled out.

6. Discussion and conclusions

Peer-to-peer electricity trading, currently at a pre-competitive stage, could become an important part of the future energy system. Proponents argue that it is a promising way of meeting renewable energy and climate targets, supporting energy democracy and participatory governance and a means to help balance supply and demand in an increasingly decentralized energy grid.

More cautionary voices point toward the concentration of value accruing through sharing economy approaches, primarily among sharing platform providers through value monopolization, and secondly among platform users through cost socialization. This is a consequence of P2P electricity trading being enabled by digital technology and increasing data generation and capture abilities, as with other sharing economy sectors. If P2P electricity trading can be regulated appropriately, it may represent one of the building blocks that make up the decarbonized energy systems we require. If it is not, P2P is in danger of amplifying both social costs and private benefits.

In this paper, we raise important questions- from a social, market design and regulatory point of view that we think should be considered and answered by policymakers and societies before they move forward with the wider rollout of this new business model.

From a social perspective, we first consider whether it is reasonable to conceptualize P2P electricity trading as a form of sharing economy activity, and under what circumstances. We conclude that this is more legitimate if electricity is treated as a service rather than a good. Similarly to other sharing economy sectors, consumers would be able to sell energy services through online P2P platforms.

We further argue that a sharing conceptualization of P2P electricity highlights its higher societal potential than alternative approaches which have similar grid management goals (such as direct load control and time-varying tariffs), but which do not have a sharing element. This is because electricity trading could allow more compelling stories to be told around ideas of community, neighborhood, family, etc. – although research would be needed to test this. The potential for P2P electricity trading to benefit the wider community also highlights its more far-reaching societal impact as compared to other sharing economy sectors.

From a market design perspective the emergence of P2P electricity trading poses questions regarding market and data governance. Historically, the evolution of energy systems, distribution networks and security responsibilities has created one-sided value creation and cost recovery structures. Platform capitalist market models undermine these structures through the concentration of transactive, consumption and behavioral data. If P2P electricity trading evolves along similar lines, re-intermediation through such platforms might facilitate monopoly rent extraction through the gate-keeping of data infrastructures overlaying electricity infrastructures. Energy governance thus needs to interlink with data governance to maximize the benefits of such data overlays while minimizing the risks. Regulators currently evaluating the strengths and weaknesses alongside drivers and barriers to

P2P electricity trading should bear in mind the results of present P2P platforms in accommodation and transport, creating monopolistic entities benefiting consumers while making society in general worse off in some cases.

Striking the right balance in the electricity sector depends on choosing the right regulatory tools. Following a review of existing regulatory approaches, this paper concludes that regulatory sandboxes (providing regulatory exemptions) are an appropriate tool to assess and eventually modify regulation to maximize benefits for all stakeholders involved. This is because they provide a platform for regulators to learn from innovators on new business models and their implications for consumer wellbeing, as well as facilitate evidence-based policymaking.

However, policymakers should ensure that an energy regulatory sandbox is properly designed, in order to provide a complete picture of the impacts of P2P electricity trading on all stakeholders involved. This is particularly necessary to gauge consumer appetite, as ultimately consumer desirability will be more crucial to the success of this model than technical and economic viability.

Regulatory exemptions and the increasing datafication of energy will provide a diverse range of opportunities for increasing energy governance experimentation and value creation at the peer and community level. In that case, the data aspect of electricity trading might become a more important market determinant than the actual energy traded. The value of data is already leading to the entrance of many non-State actors with expertise in data management and profit-making motivations. Further research on the role played by non-traditional data actors in the energy sector, and how they can help protect consumers taking an active role on the grid, will be necessary.

In the absence of a more fundamental change to energy system governance, and while P2P electricity trading is at a pre-competitive stage, this paper therefore suggests that policymakers and regulators should err on the side of caution, especially in relation to issues that are becoming increasingly apparent in sharing and platform economies. This is particularly crucial in relation to energy due to its essential services we all depend on. The regulatory sandbox is currently the best option to assess potential risks, while supporting innovation which can bring benefits to consumers and the sector.

Acknowledgments

This work was supported by the EPSRC grant EnergyREV (Energy Revolution Research Consortium) under grant number EP/S031863/1; UKRI Centre for Research into Energy Demand Solutions (grant number EP/R035288/1); and the UK Energy Research Centre (grant number EP/S029575/1).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Engineering and Physical Sciences Research Council [EP/S031863/1], [EP/R035288/1] and [EP/S029575/1].

ORCID

Michael J. Fell  <http://orcid.org/0000-0003-2764-7464>

References

- Ableitner, L., V. Tiefenbeck, A. Meeuw, A. Wörner, E. Fleisch, and F. Wortmann. 2020. User behavior in a real-world peer-to-peer electricity market. *Applied Energy* 270:115061. doi:[10.1016/j.apenergy.2020.115061](https://doi.org/10.1016/j.apenergy.2020.115061).
- Allen, H. J. 2019. Regulatory Sandboxes. *The George Washington Law Review* 87 (3):579.

- Andoni, M., V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, P. McCallum, and A. Peacock. 2019. Blockchain technology in the energy sector: a systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews* 100:143–74. doi:10.1016/j.rser.2018.10.014.
- Armstrong, H., C. Gorst, and J. Rae. 2019. *Renewing regulation: 'anticipatory regulation' in an age of disruption*. Accessed March 31, 2021. https://www.regulation.org.uk/library/2019-NESTA-renewing_regulation.pdf.
- BEIS. 2020. *The Ten Point Plan for a Green Industrial Revolution*.
- Belk, R. 2007. Why not share rather than own? *The ANNALS of the American Academy of Political and Social Science* 611 (1):126–40. doi:10.1177/0002716206298483.
- Böcker, L., and T. Meelen. 2017. Sharing for people, planet or profit? Analysing motivations for intended sharing economy participation. *Environmental Innovation and Societal Transitions* 23:28–39. doi:10.1016/j.eist.2016.09.004.
- Britton, J., A. M. Minas, A. C. Marques, and Z. Pourmirza. 2021. Exploring the potential of heat as a service in decarbonization: Evidence needs and research gaps. *Energy Sources, Part B: Economics, Planning and Policy* 16 (11–12):999–1015. doi:10.1080/15567249.2021.1873460.
- Brown, D., S. Hall, and M. E. Davis. 2019. Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK. *Energy Policy* 135:110984. doi:10.1016/j.enpol.2019.110984.
- Brown, D., S. Hall, and M. E. Davis. 2020. What is prosumerism for? Exploring the normative dimensions of decentralised energy transitions. *Energy Research and Social Science* 66:101475. doi:10.1016/j.erss.2020.101475.
- Burger, C., A. Froggatt, C. Mitchell, and J. Weinmann. 2020. *Decentralised energy: a global game changer*. London: Ubiquity Press.
- Butenko, A., and K. Cseres. 2015. The regulatory consumer: prosumer-driven local energy production initiatives. *Amsterdam Law School Research Paper* (31).
- Centrica. 2020. *The Future of Flexibility: How Local Energy Markets Can Support the UK's Net Zero Energy Challenge*.
- Chasin, F. M., M. von Hoffen, M. Matzner, and M. Matzner. 2018. Peer-to-peer sharing and collaborative consumption platforms: a taxonomy and a reproducible analysis. *Information Systems and E-Business Management* 16 (2):293–325. doi:10.1007/s10257-017-0357-8.
- Codagnone, C., F. Biagi, and F. Abadie. 2016. The passions and the interests: unpacking the “sharing economy.” *JRC Science for Policy Report*.
- Cohen, M., and A. Sundararajan. 2015. Self-regulation and innovation in the peer-to-peer sharing economy. *University of Chicago Law Review Online* 82 (1):116–133.
- Commission de régulation de l'énergie. 2020. Lettre d'information. Accessed April 26, 2020. <https://www.cre.fr/Lettres-d-information/la-cre-consulte-sur-le-dispositif-d-experimentation-de-technologies-et-de-services-innovants>.
- Cortez, N. 2014. Regulating disruptive innovation. *Berkeley Technology Law Journal* 29 175–228.
- Council of European Energy Regulators (CEER). 2019. *Regulatory aspects of self-consumption and energy communities*. Accessed March 31, 2021. <https://www.ceer.eu/documents/104400/-/-/8ee38e61-a802-bd6f-db27-4fb61aa6eb6a>.
- Cusumano, M. A. 2015. Technology strategy and management: how traditional firms must compete in the sharing economy. *Communications of the Association for Computing Machinery* 58 (1):32–34. doi:10.1145/2688487.
- De Almeida, L., V. Cappelli, N. Klausmann, and H. van Soest. 2021. Peer-to-peer trading and energy community in the electricity market : analysing the literature on law and regulation and looking ahead to future challenges. *Florence School of Regulation Working Paper*. Accessed March 31, 2021. <https://fsr.eui.eu/publications/?handle=1814/70457>.
- Del Estado, J. 2013. *Ley 24/2013, de 26 de Diciembre, Del Sector Eléctrico*. Accessed April 26, 2020. <https://www.boe.es/buscar/act.php?id=BOE-A-2013-13645>.
- Dnv, G. L. 2017. The Brooklyn microgrid- blockchain-enabled community power. Accessed April 29, 2020. <https://www.dnvgl.com/energy/publications/podcast/pc-the-brooklyn-microgrid.html>.
- EDF Energy. 2019. EDF energy empowers social housing residents to trade solar energy. Accessed April 29, 2020. <https://www.edfenergy.com/media-centre/news-releases/edf-energy-empowers-social-housing-residents-trade-solar-energy>.
- Energy Web Foundation. 2020. The D3A market model. Accessed April 29, 2020. <https://www.energyweb.org/reports/the-d3a-market-model/>.
- Exergy. 2018. *Business Whitepaper*. Accessed April 26, 2020. <https://exergy.energy/wp-content/uploads/2018/04/Exergy-BIZWhitepaper-v10.pdf>.
- Fenwick, M., W. A. Kaal, and E. P. M. Vermeulen. 2018. Regulation tomorrow: strategies for regulating new technologies. In *Perspectives in law, business and innovation*, 153–74. Berlin: Springer.
- Filipović, S., M. Radovanović, and N. Lior. 2019. What does the sharing economy mean for electric market transitions? A review with sustainability perspectives. *Energy Research and Social Science* 58:101258. doi:10.1016/j.erss.2019.101258.
- Financial Conduct Authority (FCA). 2017. *Regulatory sandbox lessons learned report*. Accessed March 31, 2021. <https://www.fca.org.uk/publications/research/regulatory-sandbox-lessons-learned-report>.
- Fuentes, R., L. C. Hunt, H. G. Lopez-Ruiz, and B. Manzano. 2019. From the “iPhone effect” to the “amazon” of energy. *Network Industries Quarterly* 21 (3):8–11.
- Glachant, J.-M. 2020. Peer-2-peer in the electricity sector: an academic compass in the making. *Policy Brief Florence School of Regulation*.

- Gollwitzer, L., D. Ockwell, B. Muok, A. Ely, and H. Ahlborg. 2018. Rethinking the sustainability and institutional governance of electricity access and mini-grids: electricity as a common pool resource. *Energy Research & Social Science* 39:152–61. doi:10.1016/j.erss.2017.10.033.
- Hackbarth, A., and S. Löbbe. 2020. Attitudes, preferences, and intentions of German households concerning participation in peer-to-peer electricity trading. *Energy Policy* 138:111238. doi:10.1016/j.enpol.2020.111238.
- Hall, S., D. Brown, M. Davis, M. Ehrtmann, and L. Holstenkamp. 2020. *Prosumers for the Energy Union: Mainstreaming Active Participation of Citizens in the Energy Transition*.
- Hall, S., and K. Roelich. 2016. Business model innovation in electricity supply markets: the role of complex value in the United Kingdom. *Energy Policy* 92:286–98. doi:10.1016/j.enpol.2016.02.019.
- Heldeweg, M. 2017. Normative alignment, institutional resilience and shifts in legal governance of the energy transition. *Sustainability* 9 (7):1273. doi:10.3390/su9071273.
- Institute for Public Policy Research. 2018. *A Distributed Energy Future for the UK- An Essay Collection*.
- Institute for Sustainable Futures. 2018. Social Access Solar Gardens: Market Research Phase 1 Report.
- International Energy Agency (IEA). 2017. *Digitalization and Energy*.
- International Labour Organization (ILO). 2006. *Freedom of association*. Accessed April 26, 2020. http://www.ilo.org/wcmsp5/groups/public/-ed_norm/-normes/documents/publication/wcms_090632.pdf.
- International Renewable Energy Agency (IRENA). 2020. *Peer-to-Peer Electricity Trading: Innovation Landscape Brief*.
- Judson, E., O. Fitch-Roy, T. Pownall, R. Bray, H. Poulter, I. Soutar, R. Lowes, P. M. Connor, J. Britton, B. Woodman, et al. 2020. The centre cannot (always) hold: examining pathways towards energy system de-Centralisation. *Renewable and Sustainable Energy Reviews* 118:109499. doi:10.1016/j.rser.2019.109499.
- Katz, V. 2015. Regulating the sharing economy. *Berkeley Technology Law Journal* 30 (4):1067.
- Kloppenburger, S., and M. Boekelo. 2019. Digital platforms and the future of energy provisioning: promises and perils for the next phase of the energy transition. *Energy Research and Social Science* 49:68–73. doi:10.1016/j.erss.2018.10.016.
- Kragh-Furbo, M., and G. Walker. 2018. Electricity as (Big) data: metering, spatiotemporal granularity and value. *Big Data & Society* 5 (1):205395171875725. doi:10.1177/2053951718757254.
- Kuzemko, C., M. Lockwood, C. Mitchell, and R. Hoggett. 2016. Governing for sustainable energy system change: politics, contexts and contingency. *Energy Research and Social Science* 12:96–105. doi:10.1016/j.erss.2015.12.022.
- Langley, P., and A. Leyshon. 2017. Platform capitalism: the intermediation and capitalization of digital economic circulation. *Finance and Society* 3 (1):11–31. doi:10.2218/finsoc.v3i1.1936.
- Legifrance. 2018. *Code de l'énergie - Article L315-2*. Accessed April 26, 2020. <https://www.legifrance.gouv.fr/affichCodeArticle.do?cidTexte=LEGITEXT000023983208&idArticle=LEGIARTI000032939887&dateTexte=&categorieLien=cid>.
- Legifrance. 2019. *Arrêté Du 21 Novembre 2019 Fixant Le Critère de Proximité Géographique de l'autoconsommation Collective Étendue*. Accessed April 26, 2020. <https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000039417566&dateTexte=&categorieLien=id>.
- Luthander, R., D. Lingfors, and J. Widén. 2017. Large-scale integration of photovoltaic power in a distribution grid using power curtailment and energy storage. *Solar Energy* 155:1319–25. doi:10.1016/j.solener.2017.07.083.
- Mengelkamp, E., T. Schönland, J. Huber, and C. Weinhardt. 2019. The value of local electricity - A choice experiment among German residential customers. *Energy Policy* 130:294–303. doi:10.1016/j.enpol.2019.04.008.
- Mitchell, C. 2008. *The political economy of sustainable energy*. London: Palgrave Macmillan.
- Moezzi, M., K. B. Janda, and S. Rotmann. 2017. Using stories, narratives, and storytelling in energy and climate change research. *Energy Research and Social Science* 31:1–10. doi:10.1016/j.erss.2017.06.034.
- Molina, P. S. 2019. Spain's new rules for self-consumption come into force. *PV Magazine*. Accessed April 26, 2020. <https://www.pv-magazine.com/2019/04/08/spains-new-rules-for-self-consumption-come-into-force/>.
- Montero, J. J., and M. Finger. 2017. Platformed! Network industries and the new digital paradigm. *Competition and Regulation in Network Industries* 18 (3–4):217–39. doi:10.1177/1783591718782310.
- Montero, J. J., and M. Finger. 2021. *The rise of the New Network industries: regulating digital platforms*. London: Routledge.
- Morstyn, T., N. Farrell, S. J. Darby, and D. McCulloch. 2018. Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nature Energy* 3 (2):94–101. doi:10.1038/s41560-017-0075-y.
- Nolden, C. 2019. Transaction cost analysis of digital innovation governance in the UK energy market. *Journal of Energy Markets* 12 (2):49–69.
- Nolden, C., J. Barnes, and J. Nicholls. 2020. Community energy business model evolution: a review of solar photovoltaic developments in England. *Renewable and Sustainable Energy Reviews* 122:109722. doi:10.1016/j.rser.2020.109722.
- Octopus Energy. 2021. *Meet energy local, a new UK energy venture keeping small-scale green generation within the community*. Accessed March 31, 2021. <https://octopus.energy/blog/energy-local/>.
- Ofgem. 2018. *Targeted charging review: minded to decision and draft impact assessment*. Accessed April 26, 2020. https://www.ofgem.gov.uk/system/files/docs/2018/11/targeted_charging_review_minded_to_decision_and_draft_impact_assessment.pdf.

- Ofgem. 2018b. *Future supply market arrangements – response to our call for evidence*. Accessed April 26, 2020. https://www.ofgem.gov.uk/system/files/docs/2018/07/future_supply_market_arrangements_-_response_to_our_call_for_evidence_0.pdf.
- Ofgem. 2019. *Ofgem's Future Insights Paper 6 - Flexibility Platforms in Electricity Markets*.
- Ofgem. 2021. The innovation link. Accessed March 29, 2021. <https://www.ofgem.gov.uk/about-us/how-we-engage/innovation-link>.
- Oltermann, P. 2018. Berlin and Barcelona use sleuths to root out illegal holiday lets. *The Guardian*. Accessed April 26, 2020. <https://www.theguardian.com/world/2018/may/21/berlin-and-barcelona-use-sleuths-to-root-out-illegal-holiday-lets>.
- Parag, Y., and B. K. Sovacool. 2016. Electricity market design for the prosumer era. *Nature Energy* 1 (4):16032. doi:10.1038/nenergy.2016.32.
- Parente, R. C., J. M. G. Geleilate, and K. Rong. 2018. The sharing economy globalization phenomenon: a research agenda. *Journal of International Management* 24 (1):52–64. doi:10.1016/j.intman.2017.10.001.
- Plewnia, F. 2019. The energy system and the sharing economy: interfaces and overlaps and what to learn from them. *Energies* 12 (3):339. doi:10.3390/en12030339.
- Powerpeers. 2021. About powerpeers. Accessed April 1, 2021. <https://www.powerpeers.nl/about>.
- Richter, H., and P. R. Slowinski. 2019. The data sharing economy: on the emergence of new intermediaries. *IIC - international Review of Intellectual Property and Competition Law* 50 (1):4–29. doi:10.1007/s40319-018-00777-7.
- RVO. 2018. Experimenten Elektriciteitswet 2015-2018. Accessed April 26, 2020. <https://www.rvo.nl/subsidies-regelingen/experimenten-elektriciteitswet>.
- Sandys, L., J. Hardy, and R. Green. 2017. *Reshaping Regulation- Powering from the Future*.
- Schneiders, A., A. Gorbacheva, M. Fell, and D. Shipworth. 2021. “Disrupting markets with peer-to-peer energy trading,” chapter in book *Research Handbook on Energy and Society*. London: Edward Elgar.
- Shannon, L., and J. Prestidge. 2019. Is your energy really green? How some firms exploit cheap certificates. Accessed March 24, 2021. <https://www.thisismoney.co.uk/money/bills/article-6992675/The-green-energy-firms-exploiting-cheap-certificates-mean-charge-more.html>.
- Singh, A., A. T. Strating, N. A. Romero Herrera, D. Mahato, D. V. Keyson, and H. W. van Dijk. 2018. Exploring peer-to-peer returns in off-grid renewable energy systems in rural india: an anthropological perspective on local energy sharing and trading. *Energy Research and Social Science* 46:194–213. doi:10.1016/j.erss.2018.07.021.
- Smale, R., and S. Kloppenborg. 2020. Platforms in power: householder perspectives on the social, environmental and economic challenges of energy platforms. *Sustainability* 12 (2):692. doi:10.3390/su12020692.
- Solar Trade Association (STA). 2019. *Trading Sunlight: Prospects for Peer to Peer Energy Trading*.
- Srnicek, N. 2016. *Platform capitalism*. New York: Wiley.
- Stirling, A. 2007. Risk, precaution and science: towards a more constructive policy debate. *EMBO Reports* 8 (4):309–15. doi:10.1038/sj.embor.7400953.
- Sundararajan, A. 2016. *The sharing economy: the end of employment and the rise of crowd-based capitalism*. Cambridge: MIT Press.
- Szulecki, K. 2018. Conceptualizing energy democracy. *Environmental Politics* 27 (1):21–41. doi:10.1080/09644016.2017.1387294.
- Tsang, C.-Y. 2019. From industry sandbox to supervisory control box: rethinking the role of regulators in the era of FinTech. *University of Illinois Journal of Law, Technology & Policy* (355 355–404).
- UCL Energy Institute. 2018. *France and UK Are Well-Positioned to Learn from Each Other on Self-Consumption and Peer-to-Peer Energy Trading*.
- UCL Energy Institute. 2019. *Summary: Launch Event of GO-P2P*.
- United Nations. 2020. Sustainable Development Goal 7. Accessed April 26, 2020. <https://sustainabledevelopment.un.org/sdg7>.
- Vigurs, C., C. Maidment, M. J. Fell, and D. Shipworth. 2021. Customer privacy concerns as a barrier to sharing data about energy use in smart local energy systems: A rapid realist review. *Energies* 14 (5):128.5. doi:10.3390/en14051285.
- Wilkinson, S., K. Hojckova, C. Eon, G. M. Morrison, and B. Sandén. 2020. Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia. *Energy Research and Social Science* 66:101500. doi:10.1016/j.erss.2020.101500.
- Willis, R., C. Mitchell, R. Hoggett, J. Britton, H. Poulter, T. Pownall, and R. Lowes. 2019. *Getting Energy Governance Right: Lessons from IGov*.
- Wörner, A. M., L. Ableitner, A. Meeuw, F. Wortmann, and V. Tiefenbeck. 2019. Peer-to-peer energy trading in the real world: market design and evaluation of the user value proposition. 4th International Conference on Information Systems (ICIS 2019), Munich, Germany, December 15–18, 2019. 10.3929/ETHZ-B-000395174.
- Zetsche, D., R. Buckley, J. Barberis, and D. Arner. 2017. Regulating a revolution: from regulatory sandboxes to smart regulation. *Fordham Journal of Corporate & Financial Law* 23 (1):31–103.
- Zhang, C., J. Wu, C. Long, and M. Cheng. 2017. Review of existing peer-to-peer energy trading projects. *Energy Procedia* 105:2563–68. doi:10.1016/j.egypro.2017.03.737.
- Zhang, C., J. Wu, Y. Zhou, M. Cheng, and C. Long. 2018. Peer-to-peer energy trading in a microgrid. *Applied Energy* 220:1–12. doi:10.1016/j.apenergy.2018.03.010.