sustainability

MDPI

Review

Barriers to Peer-to-Peer Energy Trading Networks: A Multi-Dimensional PESTLE Analysis

Zheyuan Sun [1], Sara Tavakoli [1], Kaveh Khalilpour [1,*], Alexey Voinov [2] and Jonathan Paul Marshall [3]

1 Faculty of Engineering & IT, University of Technology Sydney, Sydney, NSW 2007, Australia; lorasun111@gmail.com (Z.S.); s.tavakoli555@gmail.com (S.T.)
2 Faculty of Engineering Technology, University of Twente, 7500 AE Enschede, The Netherlands; aavoinov@gmail.com
3 Faculty of Art and Social Sciences, University of Technology Sydney, Sydney, NSW 2007, Australia; jonathan.marshall@uts.edu.au
* Correspondence: kaveh.khalilpour@uts.edu.au

Abstract: The growing adoption of distributed energy production technologies and the potential for energy underutilisation when the energy is produced by non-connected groups has raised interest in developing 'sharing economy' concepts in the electricity sector. We suggest that mechanisms, such as peer-to-peer (P2P) energy trading, will allow users to exchange their surplus energy for mutual benefits, stimulate the adoption of renewable energy, encourage communities to 'democratically' control their own energy supplies for local development, improve energy efficiency, and create many other benefits This approach is receiving increasing attention across the world, particularly in Germany, the Netherlands and Australia. Nevertheless, the actual development and implementation of these platforms are slow and mostly limited to trial activities. This study investigates the challenges and barriers facing P2P energy trading developments based on previous academic and industry studies. We provide a comprehensive multidimensional barrier analysis through a PESTLE approach to assess the barriers from a variety of perspectives, including the political (P), economic (E), social (S), technological (T), legal (L), and environmental (E) aspects. This approach clarifies the many intersecting problem fields for P2P trading in renewable energy, and the paper identifies a list of such barriers and discusses the prospects for addressing these issues. We also elaborate on the importance of incentive-based P2P market design.

Keywords: community energy; energy sharing; barrier analysis; tragedy of commons; free rider effect; incentive

check for updates

Citation: Sun, Z.; Tavakoli, S.; Khalilpour, K.; Voinov, A.; Marshall, J.P. Barriers to Peer-to-Peer Energy Trading Networks: A Multi-Dimensional PESTLE Analysis. *Sustainability* **2024**, *16*, 1517. https://doi.org/10.3390/su16041517

Academic Editor: Talal Yusaf

Received: 21 September 2023
Revised: 31 January 2024
Accepted: 5 February 2024
Published: 10 February 2024

1. Introduction

1.1. P2P Networks

Over recent decades, network management has progressed steadily. Several distribution methods, such as centralised, decentralised and fully distributed, have been investigated or implemented in response to the increased need for additional features such as scalability, security and flexibility in network management solutions. A peer-to-peer (P2P) network is a distributed self-organising network that does not need to have central nodes, and each node can act as either a server or a client at any given time [1]. Analogies to P2P networking have been shown in the history of evolution, when living beings benefit from the efficiency of collaboration with neighbours, or even internal parasites, for survival or performance improvement (symbiosis) [2]. Modern P2P, or the so-called "sharing economy" concept, goes back to the late 1990s, with the emergence of the internet and the consequent digital revolution [3]. The first large P2P scheme (which allowed users to share music files with each other) [4] was developed by Napster in 1999 and was quickly followed by the Gnutella protocol [5], resulting in a massive surge in internet traffic [6]. Both methods of sharing faced significant legal problems, from challenges by old industries and traditional modes of selling or commodification. P2P differs from traditional networks as every peer in the network has multiple roles, such as being a provider of data, collector of data, and maintainer of software. The fundamental objective of P2P technology is to share resources directly between 'peers'. By combining the resources of many autonomous nodes, P2P systems can provide a low-cost platform for distributed computing. Because of the properties and special mechanisms that are used in the network, a P2P network is more robust [7] than traditional networks. P2P traffic on the internet has now surpassed HTTP traffic and is utilised in a number of sectors. There have been several P2P applications in telecommunication [8], energy trading [9], financial services [10], and file sharing [11,12], among other areas. Because of its high sharing efficiency and, thus, high resource utilisation performance, it has become even more popular in recent years [13] and has diffused into our daily lives. Another emerging P2P framework arises in the context of renewable energy sharing or trading. This is the focus of this paper, which identifies some key barriers hindering the successful development or operation of such networks based on previous academic and industry studies. While there are several studies that have addressed barriers to P2P energy trading, there is no comprehensive study that has categorised barriers based on the PESTLE system ((P) political, (E) economic, (S) social, (T) technological, (L) legal, and (E) environmental). This perspective enables decision-makers to consider different factors that could affect their decisions in this field and helps researchers identify the effect of their proposed solutions on other aspects [14]. We discuss the prospects for addressing these issues and elaborate on the importance of incentive-based P2P market design. The findings of this study should assist decision-makers and businesspeople in overcoming the difficulties with P2P energy trading networks.

The rest of this paper is structured as follows. First, we provide a background to describe the state of the art in energy network decentralisation and the consequent P2P energy networks. We briefly investigate the global trend of P2P energy trading development. Then, using PESTLE analysis, we investigate the barriers to P2P energy platform development from six aspects and provide recommendations. Last, we discuss the potential of incentive-based solutions for improving the feasibility of such networks and follow with the conclusion.

1.2. Energy Network Decentralisation and P2P Energy Trading Emergence

Climate change is increasingly recognised as a civilisational threat arising from pollution and the destructive extraction of food and resources, which requires immediate global action. Traditional energy sources such as coal, oil, and natural gas are key sources of pollution [15]. Hence, using renewable resources such as wind and solar energy is often taken as a path to a better future. In recent years, distributed energy resources (DERs) have expanded rapidly because of their greater energy efficiency, lesser environmental impact, and wider range of energy sources [16,17]. DERs are typically composed of wind turbines and solar panels, which, in combination with an energy storage system, enable users to generate, store, and access energy onsite without reliance on centralised power plants. Renewable energy is not necessarily a DER as it can be centralised in large-scale wind and solar farms, but it has that potential, as solar, in particular, is cheap, environmentally friendly, modular, and hence easy to install locally in increments.

The rise in DERs is altering energy distribution networks and changing ways of producing and consuming, as well as changing the roles of energy consumers [18]. The connection and integration of various DERs to the energy grid have resulted in the emergence of new roles for grid and DER owners. Traditionally, the only role of end users in the electricity grid has been as a consumer. Transmission and distribution networks have been used to transport energy from large power plants to customers, involving only one-way transmission. With the development of DERs, end users can produce energy by themselves and transmit it back into the distribution network. Hence, the role of the end users has changed into becoming 'prosumers', and there can be a two-way information exchange and two-way energy flow between prosumers and other market agents [19]. There are other systems, such as virtual power plants (VPPs), which may look like P2P trading but are not. For instance, AGL, a large electricity company with more than 3.95 million customers in Australia [20], has released a VPP program based on its studies of DERs [21]. These VPP systems are intended to orchestrate the operation of the members' home energy system to benefit multiple stakeholders, including the homeowners (through reduced energy bills), the retail company (reduced peak purchase from the pool market), and the network and society (reducing peak demand). Unlike P2P trading, there is no interaction between members in the VPPs and system control is carried out either by a third-party company known as a distributed network service provider (DNSP) or the retailer (e.g., AGL in this example).

One immediate consequence of widespread DER uptake is underutilisation of the asset through curtailment of the surplus energy of the user (when the electricity generation is higher than the current load requirement and the remaining capacity of the installed storage systems). This curtailment is a problem for centralised systems as well, but costs can be absorbed by the supplying company. Individual prosumers are more likely to resent not being paid when they could be, in theory, and are likely to seek a solution for the unrealised income. This resource underutilisation problem is similar to that of unused rooms in a house (which the concept of Airbnb came to utilise) or underused cars in the family (from which Uber emerged) [22]. Hence, right from the early stages of DER uptake in some countries over the last decade, the need for sharing economy business solutions has been raised and investigated (e.g., as with Continental Power Exchange CPEX) [23]. In summary, the evolution of DERs and the principles of peer-to-peer networks have given rise to interest in the concept of P2P energy trading networks.

1.3. The Physical and Market Structure of P2P Trading Networks

In general, P2P energy trading involves both new technology and commercial energy transferring models on the demand side of power networks, allowing prosumers to freely select their energy trading parameters, such as the trading price per unit or amount of energy sharing, so as to enhance their overall energy performance, engagement with others, and economic benefits [24]. In a P2P energy trading network, there are no intermediate energy suppliers. People are encouraged to share their energy surplus directly with their local communities. The energy surplus will be sold at an export price, and the additional electricity demand can be encouraged by a cheaper-than-normal retail price [25]. P2P energy appears to have various advantages, including a decrease in power outages, an improvement in power system efficiency, an enhancement of local energy supplies, possible local application of those supplies, some independence from utility providers and a choice of multiple energy sources to go with user preferences [9,26]. In addition, P2P energy trading can also meet community requirements, such as reducing power bills [27], encouraging clean energy, and distributing surplus energy to those in need in a way decided by the community [28]. However, there is a possible problem for traditional energy suppliers as they can lose control over the markets and pricing, hence lose profit and start to work against the sharing system. Figure 1 illustrates the differences between a traditional centralised energy network and the emerging decentralised network with prosumers building demand-side P2P energy sharing networks.

Soto et al. [25] provided a general overview of P2P energy trading. They mention that the change of roles from consumer to prosumer enables prosumers to gain benefits. Azim et al. [29] have demonstrated that both small sellers and buyers can gain economic benefits in a typical day. Based on their simulation results, the authors demonstrate that "the more prosumers participate in P2P trading, the more they can gain financial benefits".

Tushar et al. [30,31] provided a detailed background discussion of P2P energy trading. They divided the P2P energy system into two elements: the virtual layer and the physical layer. The virtual layer offers participants a safe computerised link through which they may select the settings for their energy trading. The physical layer is the physical network that enables electricity to be moved from sellers to buyers. According to Tushar et al. [30], the key components in the *virtual layer* are information systems, market operations, pricing mechanisms, and energy management systems. In the *physical layer*, the key components are grid connection, metering, and communication infrastructure. In what we might call the *social and political layers*, regulations are another influential element, affecting the ease of action such as connection, payment and change.

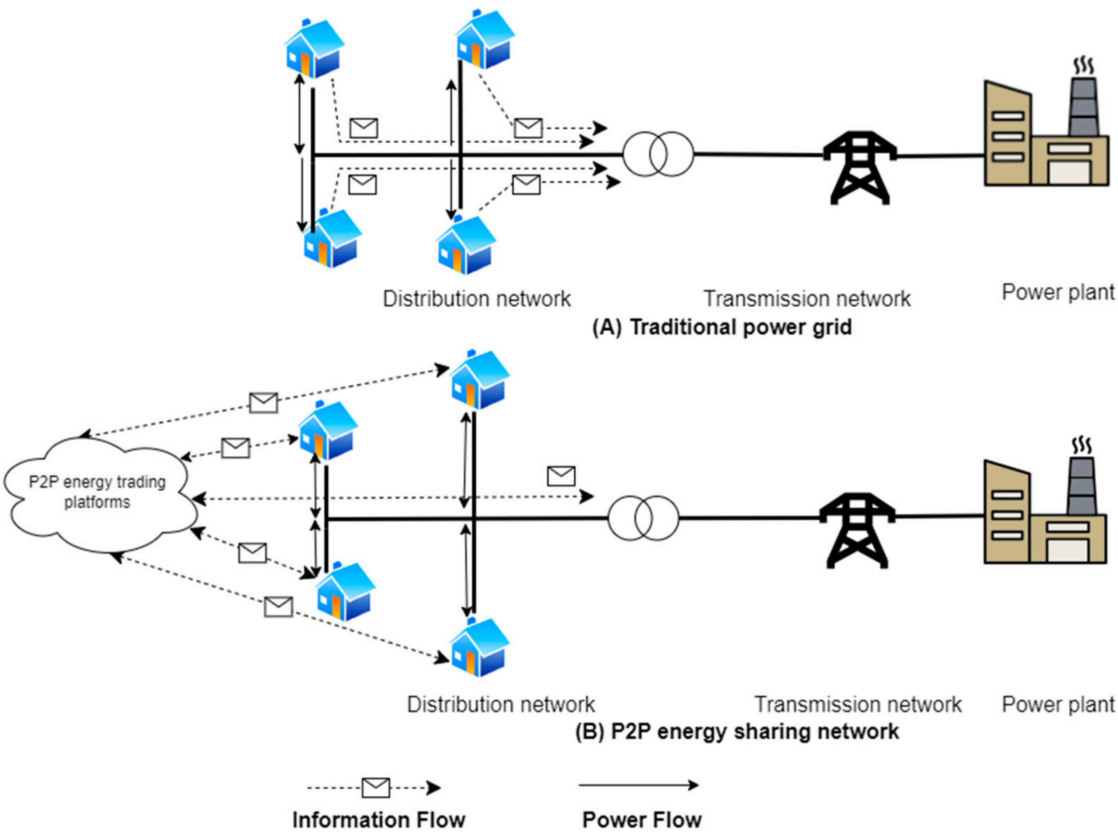

Figure 1. Demand-side electricity trade: (**A**) Traditional system, (**B**) P2P-enabled energy network.

The information system is the core of the virtual layer as it supports bidirectional communication between peers and helps them decide the energy parameters they will use, and it enables each market participant's usage to be monitored in real time [32]. The 'smart contract' (self-executing programs that have the capability to observe and modify the ledger based on rules defined by the user) is an example of such an information system. Han et al. [33] designed a smart contract model as a partial blockchain platform. The results show that their blockchain model implemented the whole trading process successfully as the smart contract strictly executes the trading and payment regulations, so the safety and fairness of electricity trading are greatly improved.

Market operations refer to the bidding strategies and market clearing methodologies that match real-time buying and selling orders. Muhsen et al. [34] reviewed different types of current bidding strategies as well as market clearing approaches from various business perspectives. Pricing mechanisms (also known as 'pricing schemes') can also help balance the demand and supply of energy [30]. A study by Lee et al. [35] has provided a theoretical analysis of pricing where the authors suggest a strategy for community microgrids in which individual prosumers with solar and storage can engage in a P2P system to trade with other residents (if the social and political layers including regulations allow them) and create dynamic power prices. An energy management system (EMS) is supposed to secure the energy supply of prosumers. Akter et al. [36] provided a hierarchical transactive energy management system for a residential microgrid. Using their generalised cost-benefit analysis framework, the authors concluded that prosumers and those residents without renewable energy sources and energy storage systems could benefit through their proposed energy management scheme. According to Khalilpour and Vassallo's study [22], cooperation-based pricing mechanisms in P2P markets improved the resilience of the network and provided the fairest financial incentives to all members.

Grid connection, metering, and communication infrastructure are the main elements in physical layers. The terms 'grid-connected' and 'grid-disconnected' (or 'off-grid') define the relationship of the user's premises with a circumferent electricity grid, if available. Other features in relation to grid connection are the flow directions of energy, which can be referred to as 'one-directional' or 'bidirectional'. One-directional connections allow either energy export or energy import, while bidirectional connections allow both. Azim et al. [37] conducted a thorough analysis of the physical layer to investigate how P2P trading may affect network energy losses. Since there may not always be a direct transfer of electricity from the same prosumer to the target customers, the study states that energy trading in the physical layers can be transferred in watts and negawatts (the amount of energy saved by lowering electricity demand or consumption for a certain period) [38].

1.4. The Global Trend of P2P Energy Trading Development

Changes in the structures and supply-demand relationships in local electricity grids have created novel trading markets and brought some side benefits to the local community. For instance, P2P systems have created job opportunities for specialists and strengthened the sense of attachment to the community as members are more connected to one another and trade with each other. Because of the environmental and economic benefits, power companies and commercial businesses have all demonstrated a growing interest in P2P energy sharing and have provided a variety of related initiatives with various goals and features. Some famous examples are Brooklyn Microgrid, which is a fully decentralised market adopting blockchain [39] in the USA [39]; Latrobe Valley Virtual microgrid [40], which has provided a local energy marketplace in Australia; Sonnen [41] in Germany, which is considering a virtual energy pool; Vandebron [42] in the Netherlands and Piclo [43] in the UK which are two online trading platforms. Academic research on this topic has also become global. Figure 2 shows a world map coloured according to the number of published academic papers on P2P energy trading on Scopus from 2017 to 2023 using P2P energy trading as a keyword [44].

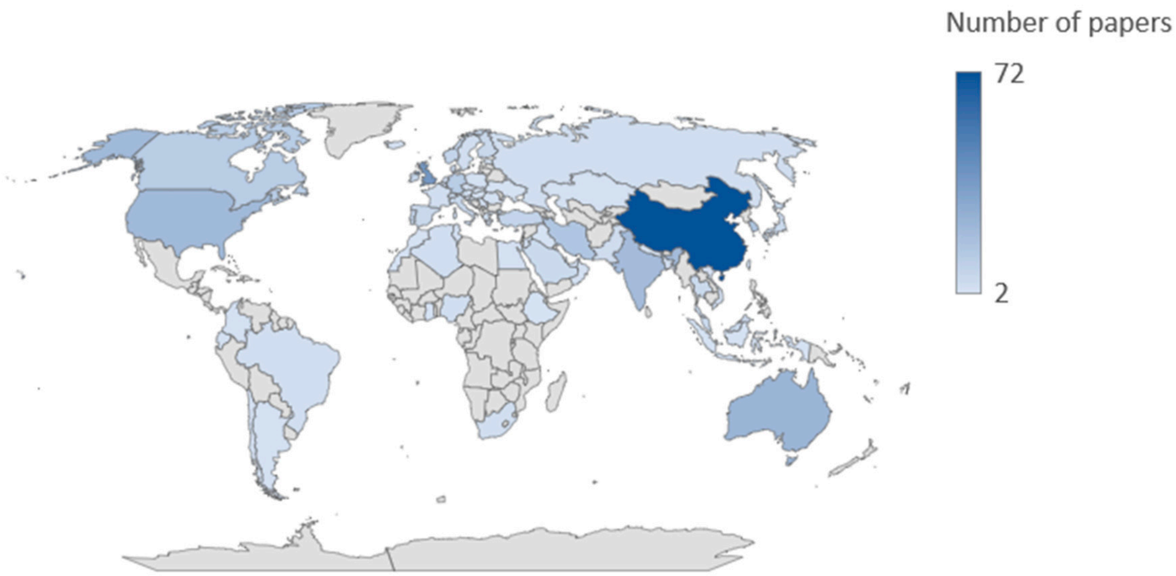

Figure 2. Distribution of academic papers, by country, on P2P energy trading from 2017 to 2023.

Most P2P energy trading projects focus on trading platforms to enable buyers, sellers, and prosumers to transact energy directly. Beyond the trading platforms, what these projects have in common are the main services they offer, such as billing, information exchange and metering. There are differences between these P2P energy trading projects. First, these projects have different scales. For instance, the Latrobe Valley virtual microgrid and the Brooklyn Microgrid focus on a local microgrid, whereas Piclo and Vandebron focus on the national level. Second, some projects have a central core, including Centrica's Cornwall Local Energy Market [45] and Sonnen's storage-based P2P trading [41]. Gunarathna et al. [46] summed up five main value propositions for global P2P energy trading projects, including trading platforms for renewable energy, community development and operations, energy utilisation optimisations, information services, and demand-side management. In addition, the projects' business models differ greatly from one another [47]. First and foremost, they originate from different kinds of corporate organisations. For example, Piclo is run by a renewable energy supplier called Good Energy, whereas Sonnen is operated by a battery manufacturer called sonnerBatterie, which possibly indicates the power of commercial stakeholders in design. In terms of customers, some projects specifically target certain kinds of consumers, such as large commercial clients, and some projects focus on local landholders. These projects can also generate income in different ways. Some research and development projects, such as Power Ledger [48], are funded by local governments. However, Vandebron has asked users and energy providers for a monthly subscription [42].

Despite growing interest, the development of P2P has been slower than expected. There are some challenges facing P2P energy trading networks and markets that need to be addressed, including network constraints, security issues and government policies [31]. Studies exist focusing on the challenges in P2P energy trading, such as [49,50]. However, most studies [47] only compare and examine the primary goals and characteristics of the cited P2P initiatives. Additionally, although there are several studies reviewing the challenges and solutions of P2P energy trading projects (e.g., [32,46], there is a lack of studies that provide a comprehensive multidimensional barrier analysis, as as provided here. Given the diversity of challenges, this study aims to identify the key barriers hindering the successful development or operation of global P2P energy trading projects using PESTLE analysis. The findings of this study are supposed to assist decision-makers and businesspeople in overcoming the difficulties in the P2P energy trading networks and structures from a multidimensional perspective.

2. PESTLE Analysis

A PESTLE analysis generally looks for the political (P) situation of the object and the struggles surrounding it; the economic (E) factors involved; the impact of socio-cultural (S) factors; the technological (T) barriers in the industry; regulation, policy, legal (L) situations; and environmental (E) concerns or disruptions. In reality, these factors are rarely completely distinct, and they can overlap with fuzzy boundaries (e.g., politics and economics can be particularly hard to separate). Nevertheless, the technique can still provide investors and policymakers with a multidimensional perspective which helps deal with complex systems, such as energy systems. PESTLE analysis helps improve strategic thinking and understanding of coexisting factors, including attitudes, consumer protection laws, and new technological trends, among others [51]. It inhibits analyses from depending on one or two factors which leads the analysis to detrimentally oversimplify the complexity of systems. Organisations, enterprises, and politicians may use PESTLE analysis as a perceptual tool to track the external factors that influence their operations. It aids businesses in optimising prospects for a given technological path and limits risks.

2.1. Energy Studies Using PESTLE Analysis

PESTLE has gained popularity in recent years across a variety of academic fields, including engineering for sustainable and renewable energy [52,53]. For instance, Zalengera et al. [54] reviewed the Malawi energy sector by considering the current energy policy, the available renewable energy resources, and challenges to developing energy infrastructure. They used PESTLE analysis to ensure the long-term acceptance and adoption of renewable energy technologies that can aid local communities in achieving the United Nations Millennium Development Goals (MDGs) and sustainable livelihoods. After addressing the issues in Malawi, the authors proposed a paradigm change that may offer long-term supportive mechanisms for Malawi's growth of renewable energy sources. Agyekum et al. [52] used a PESTLE approach to investigate Ghana's transition to renewable energy. With the help of 20 experts in Ghana's renewable energy industry, they made use of the 'Analytical Hierarchical Process' (AHP), a decision-making methodology to help individuals and organisations make complex decisions to rank the numerous criteria. The study claimed that the most important issues in Ghana were economic issues (capital cost), particularly for long-term projects. Thomas et al. [53] used this approach to investigate the obstacles affecting the installation of household solar systems in refugee camps in Rwanda. The research concludes that solar systems were feasible and highlighted crucial elements for project success, such as matching energy initiatives with current government policies. The suggestions had multiple aspects, including the market, policy, and financial aspects.

2.2. PESTLE Analysis for P2P Energy Trading

As P2P energy trading is a fast-moving field, it demands having a solid understanding of its limits. In this PESTLE approach, we define political factors as government interventions and local struggles, overuse, presence and so on. Economic factors include pricing, production, demand, supply, pollution, and shortages in the external environment. Social factors involve social, cultural and human issues. Technological factors include technological actions, 'machinery', capabilities and facilities. Legal factors mainly relate to the current law, regulation and discussions over P2P energy trading. Environmental factors include potential environmental concerns or risks. To analyse the challenges properly, we first identify various obstacles and the current issues about P2P energy trading and then discuss some future directions. We investigate academic and industry publications and provide a detailed analysis of the identified challenges. By filtering keywords such as "challenges", "risks", "issues", "obstacles", and "barriers" within "P2P energy" or "P2P energy trading", we collected the conclusions and viewpoints of relevant published articles from 2017 to 2023 on Scopus and Google scholar. Then, we recorded and combined common viewpoints to form a list of challenges for P2P energy trading. Finally, we categorise the collected arguments into related PESTLE sections. The bullet point lists of the challenges are provided in Figure 3, and details of each PESTLE element are discussed here, followed by recommendations.

2.2.1. Political

Policy has proven to be a key means for both renewable energy development and combatting climate change. Starting from the 1990s, some OECD (Organization for Economic Cooperation and Development) countries have attempted to innovate renewable energy policies and have introduced a series of policies for their energy sector [55]. Close to three decades of these endeavours have led to the current position where most countries have developed their own renewable energy target. For example, there is a national legislation called the Renewable Energy Target (RET) in Australia to ensure a certain percentage of electricity is supplied by renewables over a given timeframe [56]. The US government has also set target emission rules, which it calls The Clean Power Plan [57]. Although most P2P energy trading projects and studies seem to be implemented in European countries [58], the policy reforms regarding P2P energy trading are still not properly developed. The European Union (EU) countries aim to establish a liberalised EU internal electricity market. One problem is ensuring that renewable energy is not simply an add-on to fossil fuel energy or that fossil fuel emissions do not keep increasing under the disguise of reducing energy intensity measures. A liberalised market means that the prosumers have more choices as they are not bound to their local utility company [59]. However, the market may be more likely shaped by the needs of large players with greater riches and political connections. The new roles of consumer/prosumer brought by P2P energy trading are the first step in building a P2P energy trade framework with support from emerging intermediary companies, i.e., DNSPs (distribution network service providers).

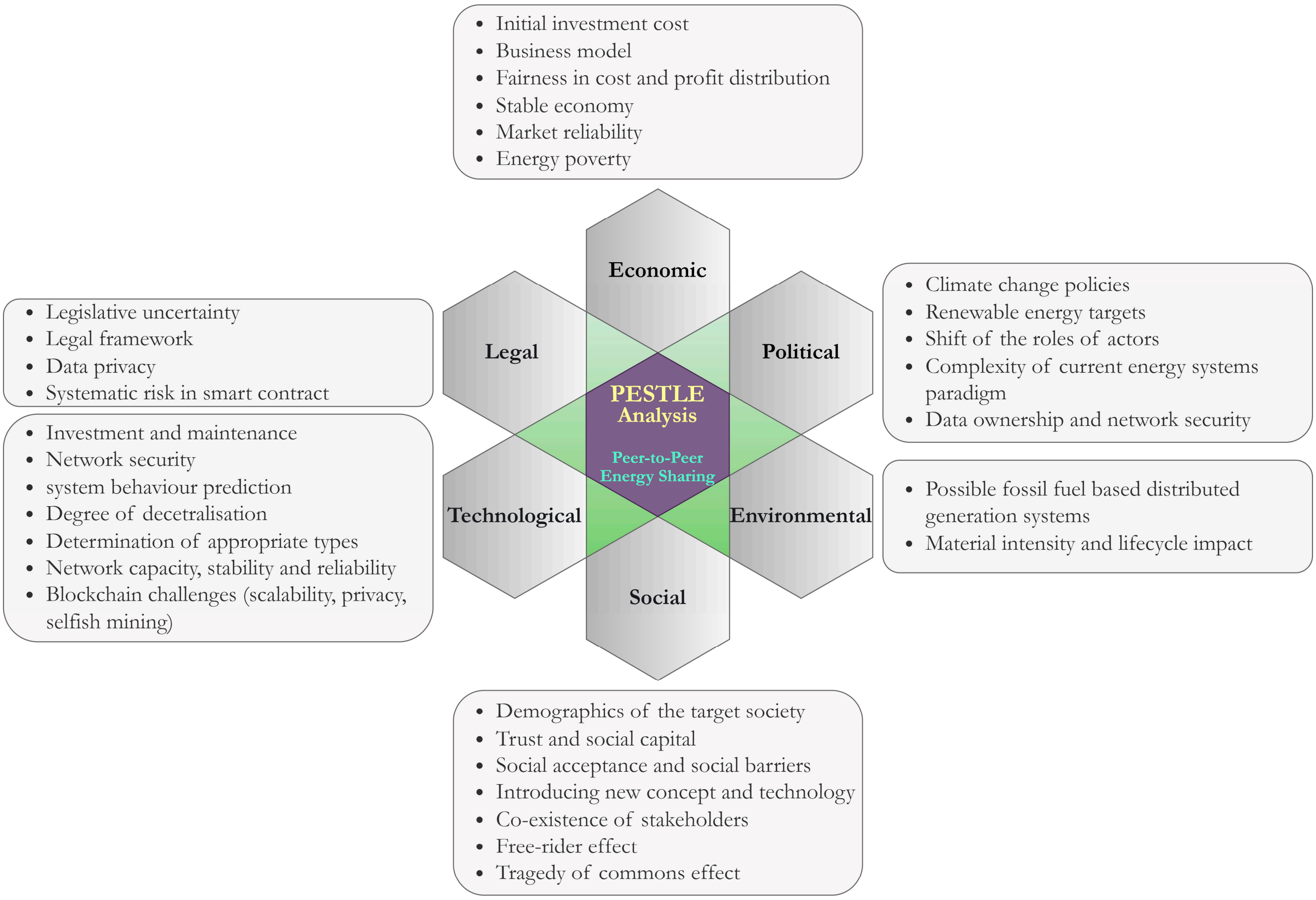

Figure 3. The key PESTLE challenges related to P2P energy trading.

Developing countries face more challenges than developed countries due to having limited access to electricity networks, particularly in distant or rural regions where many people live in poverty [34]. For instance, in Thailand, the biggest obstacle to the growth of P2P energy trading schemes has been identified as the absence of explicit policies, which leads to market and investor uncertainty [49]. Similarly, the world's largest developing country, China, is facing policy issues in the P2P energy trading sector. The current Chinese P2P regulations and policies cannot be adapted to China's business models [60]. In China, the government sets the target of energy consumption in their climate pledge (its "nationally determined contribution", or NDC). However, as P2P energy trading is a newly raised business model, the policies for P2P and DER are "lagging behind technological development" [61]. For developing countries with high levels of energy poverty, particularly at the edge of grid areas, P2P localised community networks might be easier to develop than a full-scale electricity network. They may also be more resilient under conditions of climate change, as people can still have energy when the grid breaks down. Hence, this factor may be considered more as an opportunity than as a weakness. These areas need courageous policy and regulation innovation at the current time.

Clear regulations and policies are important for P2P energy trading, as the regulations and policies determine the market design, fees and tariffs, market integration, and who has power in that market [62]. Most global energy policies are developed according to the traditional centralised energy system paradigm and are unfit for P2P energy trading [58]. Besides, the development of P2P and blockchain platforms leads to changing actors, roles, and power relations in the energy industry, which could lead to corporate resistance.

For example, users who had only a passive role of "consumer" would be able to sell electricity at a desired quantity and time, thanks to DER and P2P technologies, potentially changing grid organisation patterns and the social power of electricity companies. EU legislation has started to use the term "prosumer" in the renewable energy directive ahead of many other countries [63]. As a result, further study should be done on policies, regulations, laws, customer views, and company resistance [64]. Regulations for data security and cybersecurity are also important, as the energy grid is crucial for the national infrastructure [65,66]. However, energy regulators may lack available data for regulations as data is often collected and kept hidden by existing companies and platforms.

All the industry and academic evidence implies the urgency for governments and regulative authorities to formulate clear, comprehensive, stable, and effective policy directions for P2P energy trading markets and similar possible modes of future energy markets. One recommendation in this direction is the development of energy regulatory sandboxes to enable sketching a full picture of the effects of P2P electricity trading on all market components and stakeholders [67]. Regulations for electricity markets have grown up with the older systems and may be expected to express the technical, profit, and power relations built up through those systems. There is possibly a temptation to try and retain those power relations and profit, to keep the old controllers of electricity in business (with little competition), and to maintain their political dominance. Certainly, we can expect resistance from established companies to changes in regulations that might benefit competitors (including prosumers). For example, in Australia, Energy Companies appear to be asking for the right to charge customers exporting to the grid rather than pay them so as to try to reduce congestion [68].

2.2.2. Economic

P2P energy trading, when in place, has been demonstrated to offer economic benefits for individuals and to promote active participation in local energy markets [69,70]. Nevertheless, the trading platforms, ICT devices, technology investment, and communication networks require substantial investment during the beginning stage. The high capital expenditures and consequent high levelised cost of energy can cause a big barrier to the promotion of renewable energy technologies [54]. In addition, the maintenance fees, running costs, and grid fees need to be calculated to help sustain the P2P energy trading networks. These factors lead to a question: How will such expenses be distributed under the P2P energy-sharing pricing model?

When P2P markets are established, energy poverty, or energy injustice, among some users or areas with lower economic power may worsen [71]. The utility-provided electricity price will probably be higher than the P2P energy trading price. Still, most vulnerable populations live in low-income areas where people usually do not have the RE or storage systems, enabling them to establish a P2P energy trade system. There, the challenge would be how to incentivise or support disadvantaged peers to address their energy poverty [28]. Moreover, Wu et al. [72] have shown that the economic stability of a country is important for developing renewable energy. Unemployment and underemployment are increased by economic downturns and global credit crises, which limit investment and innovation in distributed energy technology, partly because of the choices made by energy companies and governments. Thus, a stable economic environment is important for P2P economics. In recent years, COVID-19 has created uncertainty regarding the development of renewable energy. Electricity prices dropped due to a lack of demand, undermining investor's hopes for high profits. COVID-19 has had a huge economic and health impact on every country in the world [73]. The COVID pandemic and the invasion of Ukraine have created new problems, producing high prices and energy shortages, which have led some countries to increase coal and gas supplies [74]. In the Brooklyn Microgrids [36], it was found there are three issues: (1) the market and pricing mechanisms are not adapted for allocation efficiency, (2) there is a lack of relevant regulations, and (3) current research in energy trading microgrids ignores the socio-economic aspect—hence the advantage of using the PESTLE system for analysis. The studies from Piclo show that pricing distribution calculations could be a future challenge [75].

To address these challenges, a clear P2P energy-sharing pricing model is required, and the study of energy poverty and its effects on P2P energy trading is necessary. Imran Khan [76] produced a prosumerism program to help people suffering from energy poverty in Bangladesh. The proposed model uses a bottom-up approach to increase access to clean and affordable energy, ease of integration, and rural electrification without major expenses. Nicolas et al. propose an energy exchange framework to enhance the economic operation of microgrids by employing net present value (NPV) as a measuring tool [77]. Last but not least, a stable economic environment and a user-friendly renewable energy subsidy policy are needed. Again, it seems reasonable to expect resistance from grid owners and electricity suppliers using their political influence to affect the regulations, etc.

2.2.3. Social

A P2P trading network introduces a novel social relationship between peers, which has created a new realm for social science research [58]. The social factors in developing renewable energy can have multiple aspects, including demographics (age, educational background, and population growth), the question of who is likely to be able to participate or is prevented from participating and why, previous fractioning in the community, inequalities of wealth and property, social and work organisation, and cultural patterns and understandings [52]. Existing trading in P2P energy between consumers and prosumers is highly dependent on trust, social acceptance and social barriers [78]. Usually, a trusting and transparent society will have higher social acceptance of (and maintain the resilience of) the new technology, especially if it is introduced by community decisions. Similarly, trust, community participation and fair procedures in P2P energy trading networks will increase social acceptance of P2P energy trading. To increase trust, a transparent regulative framework and a transparent trading mechanism are required, as well as possible ground-up (local) design and build of the technology and its workings. Borges et al. [79] presented two recommendations to increase social acceptance: (1) designing two different modes of operation in P2P energy market solutions for i) less involved people and ii) semi-autonomous people separately, and (2) a trading platform which should be administered by an impartial community committee. Impartiality in a community may be difficult, as those who are more educated, those with more wealth, and more used to wielding power are likely to be the ones who get involved, and hence, this may become another barrier to full community participation.

In addition, as P2P networks are a new concept, it often takes developers a lot of time to explain the structural and logical backgrounds of P2P networks [49]. An Australian case study has argued that the social challenge of renewable energy development for local government includes how they value and observe social benefits at the community level [80]. These issues point out five key challenges involving local government: financial support, concern and involvement, recognising local benefits, the overall regulatory environment and conflict of interest (regulator vs/operator role) [80].

Ecker et al. [81] stated that the co-existence of stakeholders becomes an inevitable challenge as the DER concept requires cooperation and participation among stakeholders, and, as mentioned, communities can already have existing factions and disputes. The P2P energy trading platforms involve multiple stages, such as 'prosumption' and consumption, transactions, and large-scale development. Conflicting interests usually arise when different stakeholders are involved in the decision-making process—which is inevitable. Therefore, it is necessary to prepare and implement an effective mechanism to manage the relationships between stakeholders.

P2P networks, if designed improperly, may face several drawbacks, including the two common problems of Free-riding and the tragedy of the commons (Figure 4) [82]. It is believed that the self-interest of peers is one key challenge and the root of many problems in such networks. When peers only consider their own welfare, the whole system may collapse [83,84]. These issues are elaborated next.

Figure 4. Two key challenges of P2P networks resilience: free-riding and the tragedy of commons.

Free-riding effect: This is a major cause of concern in P2P networks, with some users always being in a "client" role, enjoying the service provided by others without enough effort to reciprocate. In other words, free-riders utilise network resources without proper contributions [9]. This may not be a problem if they are paying for the electricity rather than 'sharing' it. Based on Gnutella's research on a file-sharing P2P network [84], there are two types of free-riders: (1) peers who simply gain resources and do not contribute to others' efforts and (2) peers who share low-quality resources. According to Ma et al. [85], almost 70% of P2P users do not share any files with other P2P users. The free-riding challenge is also a major cause of concern in the context of energy trading. In the energy trading context, it might refer to the unfairness of receiving the subsidy or other benefits in the energy trading network. For instance, peers may share less energy resources (e.g., PV and battery) than they gain from peers, or they share energy in low-demand hours while receiving it in high-demand periods (e.g., late afternoons). Free-riding exists beyond P2P energy trading, in the structure of the main network, and in business generally, as CO_2 emissions and other pollution are free-riding on the health of others. With rooftop solar, people may claim that solar panel owners who are paid for the solar energy they generate are "free riding" on the grid, which results in an unfair cross-subsidy from non-solar owners to solar owners [86], although this can also be seen as a tactic to diminish competition with grid suppliers. In summary, when individuals pursue their own interests in the trading network, market designers are supposed to consider a suitable mechanism and a precautionary approach to address disruptive free-riding challenges. A good example is Vanderbron, which has lately begun to charge customers for excess energy consumption due to the higher volume of electricity that needs to be sent back to the grids [87]. This highlights the importance of intra-group regulation and governance. In this line, Kla [88] suggested developing an appropriate metric by employing various methodologies for regulating P2P energy programs.

The tragedy of commons effect: Another major issue with P2P networks is the "tragedy of the commons" [89]. Hardin demonstrated the tragedy of the commons in 1968 [90], although the original concept goes back to an essay by William Forster Lloyd in 1833 [91]. The tragedy of commons might happen when shared resources are excessively consumed until everyone loses access to them without communal action to prevent this from happening. As a publicly available resource, internet bandwidth is freely used by any and all P2P applications. P2P apps use around 70% of all available bandwidth on the internet backbone [92]. As a result, nodes that share information and resources will impair the total system performance, leading to the possibility of a tragedy of the commons as bandwidth gets consumed [93]. The tragedy of commons can happen in electricity networks too, for instance, if most members of the P2P energy trading community behave selfishly in utilising the network energy during peak times. According to the theory of the tragedy of the commons, the overall performance of P2P networks will suffer since shared resources without exclusive ownership would eventually run out (reduced or failed energy supply reliability). However, there are numerous successful examples of long-term commoning, some of which are reported in the book "Governing the Commons" [94] by Elinor Ostrom, who received the 2009 Nobel Memorial Prize in Economic Sciences for this line of research.

Hardin later modified his position to argue that the tragedy primarily affected those commons which were not well managed locally [95]. One possibility for remediating the tragedy of commons in a P2P energy network is peers' collective self-regulation (e.g., through demand shifting) and avoiding large supply-demand mismatches, which make the P2P network fail to provide reliable service [22]. Ostrom's work suggests that the tragedy could also be avoided if P2P community members cooperated and regulated their access to the common resource. A more likely and historically repeated tragedy of the commons is not that the common people will destroy themselves but that rich and powerful elites will take the commons from them and destroy P2P trading or local access to energy.

In brief, both the free-riding effect and the tragedy of commons are social issues connected with the lack of proper regulation and lack of local/peer governance. With good regulation in place, not only can these issues be avoided, but with the creation of a sense of community responsibility and participation, the resilience of the P2P network can be further enhanced and possibly democratised, which might again lead to further resistance by established energy companies. A further problem involves the instability of the economy. It is well known that the free market tends towards periods of boom, bust and bailout [96]. P2P trading systems must be designed to survive these cycles, and while small, should probably be treated as "too important to fail".

2.2.4. Technological

The technological challenges can be discussed from various aspects, including the virtual layer (market design and trading platforms), the physical layer, and enabling technologies such as blockchain.

Virtual layer—market design: There are three P2P designs based on the degree of decentralisation and network topology: (a) a full P2P market model, (b) a prosumer-to-grid model, and (c) organised prosumer groups [30,71]. The full P2P market has the highest degree of decentralisation, as prosumers in the network are directly connected to each other. The prosumers in the prosumer-to-grid model are linked to an electricity microgrid that is itself connected to a larger grid. Organised prosumer groups combine the full P2P market and the prosumer-to-grid model. There are several challenges for different market designs [71,97]. For the full P2P market, the main challenges are (1) investment and maintenance, (2) network security, and (3) system behaviour prediction by grid operators because of the lack of centralised control. The main challenges in the prosumer-to-grid model are (1) fairness between community members (pricing deals, etc.) and (2) Matching the preferred energy consumption for community members. In organised prosumer groups, the main challenge is data management. In addition, the question of the appropriate degree of decentralisation for specific conditions should also be considered [65]. The key pillars are pricing mechanisms, factors of market integration, and the social and economic acceptability of peer-to-peer power trading and its results.

Virtual layer—trading platform: As P2P energy trading projects involve multiple technologies and applications such as smart grids, blockchain, and market platforms, they also partially contain the challenges from these fields. The adoption of P2P energy trading networks is built on the development of smart grid technologies [8]. Several studies [30,47] have summarised the challenges and issues in smart grids from multiple perspectives, such as technologies, implementation, design, and data security. An energy trading platform is a platform for buying and selling energy. It provides for the storage of all information relevant to production, consumption, and contractual relationships between participants. There are two types of P2P energy trading platforms: centralised and decentralised. The main challenge for trading platforms is to determine the types of trading platforms appropriate for different applications and social situations. To determine which kind of platform should be used, a rigorous cost-benefit analysis must be performed, with the involvement of the local peer community, which can point out relevant local factors and concerns, as locals have to support the platform for it to be successful [98].

Physical layer: As the number of users increases in the trading network, based on Zia [99] et als. study, without taking into account the network's limitations, it could lead to numerous bus voltages exceeding the applied voltage limit of the network, which would influence the reliability and security of the network [58]. At the same time, capacity constraints are also a problem that cannot be ignored. Controlling how much each prosumer may export to the network or import from it at any particular period is one possible strategy for reducing this risk. The third significant challenge is that the P2P transactions might result in increased network-wide power losses for the power grid (because the power flow is not optimum), which should be considered beforehand, along with network stability and reliability [50]. Keeping the electrical network stable and reliable may need changes in local electrical infrastructure like new lines, reconfiguration or improved capacities. These changes cause new challenges: Who will pay for these improvements? Who is in charge of studies and, operation and maintenance? How should the operator's interests be included in the smart contracts?

Blockchain technology: Used in decentralised P2P networks, blockchain is a cutting-edge distributed ledger technology that can be used to provide a secure environment for decentralised transactions between multiple organisations [98]. This distributed ledger technology can be used to facilitate reliable, decentralised monetary transactions amongst a wide range of businesses [100]. Agyekum et al. [49] and Andoni et al. [98] have tried to discuss the challenges and opportunities in blockchain technology singling out scalability problems and privacy leakage. The challenges related to scalability are transaction storage, transaction process speed, and the low capacity of blocks. In privacy leakage, the major problem is transactional privacy, as the transactions and balances are public and can reveal peer's information.

According to Borges et al. [79], blockchain technology and smart contracts face the following challenges: (1) jurisdiction: blockchain is not subject to any authorities. (2) blockchain smart contracts are immutable if they are not intended for upgradeability. Therefore, litigation and disputes arising from the smart contract itself may be difficult to resolve. It is important to note that blockchain does notneed to operate like, its most famous example, Bitcoin. Some features of Bitcoin-like blockchains are not useful for P2P trading. Mining, as in Bitcoin, for example, is counter-productive, can consume large amounts of energy and does not have to be part of the system.

Future research into blockchain should be in the desired scalability, decentralisation, security and energy usage. More efficient and secure trading systems need to be developed.

2.2.5. Legal

One of the key current legal challenges in P2P networks, in general, is the legislative uncertainty around blockchain usage since blockchain technology utilises smart contracts to verify, document, and implement terms that have been negotiated by peers and companies [79,101]. As argued above, smart contracts should contain all the mandatory features that make traditional contracts legally enforceable.

The legal framework for renewable energy is also worth discussing, as it forms a major context for P2P trading. At present, some countries such as France, Germany, Netherlands, and the UK have better frameworks for collective prosumers in the construction of the legal frameworks for renewable energy. While other countries, such as Spain and Portugal, still do not allow collective self-consumption schemes [102]. Moreover, according to Diestelmeier [59], the current legal frameworks for P2P energy trading do not adapt to the shifting of the roles of actors in European countries because P2P energy trading network facilitates the coordination of multiple individuals in a decentralised pattern, eliminating the requirement from a central connecting entity. In some developing countries, such as Peru [103], the lack of an appropriate legal framework makes P2P trading even more problematic. According to Schneiders and Shipworth [104], problems like the legal recognition of prosumers, their personal data protection, and the validity of smart contracts have yet to be solved in the UK. They suggested that legal entities can help in providing legal frameworks for P2P energy trading smart contracts in countries using energy cooperative models, but it is unclear who is responsible for data privacy reinforcement.

Regarding data privacy, Chiarini and Compagnucci [105] focused on the General Data Protection Regulation (GDPR) that was adopted in the EU in 2016. GDPR works on addressing the challenges raised by the digital economy regarding the protection of personal data in the EU. The authors name six domains that blockchain trading compliance with GDPR, including accountability, right to rectification, right to erasure, the principle of purpose limitation, the principle of data minimisation and Hashing technique (which converts the key or string into another one) and pseudonymisation (which replaces the personal ID into an anonymous ID). They highlighted that there is a need to take a clear and shared position to overcome these challenges.

In addition to the above-mentioned challenges, Lee and Khan [106] add systematic risk due to possible errors in coding in smart contracts as another legal challenge. They mention that the code may include an error leading to incorrect billing, malfunction between transactions and loss of potential or purchased energy units, but it will run without showing errors. This problem may also make trading open to hacking and theft. They propose coalition-forming, ceiling and floor caps, and a regulatory system for smart contracts certification as solutions for the legal challenges of P2P energy trading.

2.2.6. Environmental

Renewable-based P2P energy trading systems are directly attempting to solve environmental climatic challenges. Therefore, it is required that they are beneficial for the environment. For example, it is vital that energy consumption in the trading system does not increase emissions or environmental destruction. Coutinho et al. [107] showed P2P energy trading can bring carbon emission savings. Nevertheless, there are some minor risks. For instance, potential environmental concerns can be raised if fossil-fuel-based distributed generation systems are used in the platform, which is likely to happen if trading involves taking energy from the grid. Though decentralised fossil fuel-based generation is still better than centralised (due to lower transmission losses), they may not be aligned with net-zero aspirations. On the other hand, renewable energy technologies, despite their numerous advantages, face challenges of material intensity. For instance, the PV installation rate implies that massive amounts of materials are used, which require recycling at the end of their life to reduce pollution [108]. So P2P trading needs to be conducted as part of a minimally damaging economic cycle, where sharing economy concepts can improve the utilisation factors and diminish the wastage of energy of such systems, and thus reduce the need for material. However, as the P2P energy trading market grows, more solar panels are being installed. This means that more solar panel PV waste will be made, and more recycling is needed and must be enabled. P2P trading systems should involve low-energy consumption platforms so as not to increase energy use. This is, however, not primarily a problem of P2P trading but of the manufacturers and extraction that enable P2P.

3. Smart Incentives as a Solution

The previous sections discussed the challenges facing the development of P2P energy trading markets and platforms. In addressing these challenges, incentive design is one of the solutions that has received high interest in the literature. Incentive design relates to almost all six PESTLE elements. P2P energy sharing is a kind of trade-based approach to incentivise prosumers to exchange their surplus energy and to minimise energy expenses. P2P incentive schemes can be divided into three categories: (1) trust-based incentive approaches [109], (2) auction-based incentive approaches [110], and (3) Game theory-based incentive approaches [1]. Hence, these mechanisms need to be discussed.

3.1. Trust-Based Incentive Solution

The application of blockchain has brought a trust crisis for P2P energy trading as its hierarchy assumes that every prosumer is honest. However, the assumption could fail if peers can benefit more from cheating as with free-riding behaviour or some other form [111]. A trust-based energy trading mechanism is supposed to tackle the possibility of collusion between energy buyers and sellers within a reputation-based score system. The trust-based energy trading mechanism is designed to overcome the privacy challenges of the blockchain. Chen et al. [111] derived a trust-based P2P energy trading framework by combining blockchain and optimisation. Yahaya et al. [112] proposed a two-layered blockchain-based P2P energy trading model. Generally, a trust-based energy trading model includes three sections: the incentive/punishment mechanism for energy trading, followed by a proposed consensus mechanism, and a pricing scheme. The core concept of incentive/punishment is to encourage users to contribute a greater amount of energy and to communicate truthfully with one another. It is proposed that trusted prosumers acquire social reward values from the trading mechanism. The consensus mechanism aims to reduce the trading process duration time and cut down on the number of rogue validators. The pricing scheme is designed to sort prosumer's preferences based on bidding prices.

3.2. Auction-Based Incentive Mechanisms

An auction-based incentive technique rewards participants in multiple areas, such as mobile crowdsensing (a paradigm in computing that uses common mobile devices to create collaborative sensor networks) [113] and cooperative communications [114]. A distributed action-based energy trading system is another incentive mechanism to ensure the fairness of trading services, the reliability of trading processes, and the security of information shared [101,102]. Thakur et al. [115] presented a blockchain-based double auction mechanism to formulate a centralised peer-to-peer auction where each participant can function as an auctioneer and multiple local double auctions are conducted concurrently and asynchronously. Kim et al. [110] designed a five-step energy trading process, including buyer requesting, winning bid determination, approach process, final seller determination, and final energy trading transaction. For example, firstly, a peer sends energy requests to other peers. Then, an algorithm will perform on a peer side for determining the winner of a double auction after receiving energy needs from its neighbours. Once a winner is identified, the transactions will be created by the trading mechanism.

3.3. Game Theory-Based Incentive Mechanisms

Game theory, as a field of contemporary mathematics, tries to investigate how individuals and groups with conflicting objectives use their own knowledge and resources to maximise socially defined benefits [116]. It is now widely adopted in energy trading sectors to model peers' behaviours [117] or formulate game-theoretical incentives [118]. By applying game theory in the P2P trading procedure, it is possible to pick the profitable transaction price throughout the transaction matching process. The game theory approach extends its benefits to prosumers, providing them with a decentralised energy management approach that thoroughly considers both maximising benefits and fairness throughout the entire trading process [119]. Liu et al. [117] proposed a game theory-based scheme including all the players and an equilibrium solution method to put it into practice to ensure that prosumers involved in the energy trading network are secure and gain maximised benefits. Wang et al. [120] also conducted a two-level hierarchical incentive mechanism based on game theory. The consensus mechanism is used in conjunction with Shapley value [119] to incentivise participants to follow the smart contract by calculating internal trade prices among peers in the network. Wang et al. [121] provided a game theory-based novel energy-sharing scheme that enables users to share their energy with others. It used game theory to decide a benefits allocation for users without users' bidding in order to incentivise users' participation.

3.4. Efficient Reputation System

Any market design and incentive model requires a reputation system, which is a tool designed to rate the peers in a P2P network using incentive mechanisms. However, some P2P network peers may want to manipulate the reputation systems to disrupt the network environment. As a result, it is thought that a good reputation system and P2P network should decrease the times peers cheat. The reputation system should probably be designed with the local users so it does not impose ways of behaving upon them, which may be unwanted.

In summary, smart market design, using key elements such as incentives, is an opportunity for policymakers, regulators, investors, and market operators to build a cooperative sandbox to study and identify the best mechanisms which satisfy the objectives and constraints of all stakeholders. This can unlock the barriers ahead of P2P trading and ensure a clean, reliable, fair, and affordable energy solution for society.

4. Conclusions and Future Work

This paper used PESTLE analysis as a tool to highlight the different challenges of P2P energy trading development from political (P), economic (E), social (S), technological (T), legal (L) and environmental (E) aspects. Section 2.2 analysed the common challenges and recommendations in P2P energy trading development to help all stakeholders identify weaknesses and address the difficulties in the successful implementation of P2P energy trading. A summary of the challenges and potential solutions is also presented in Table 1. This analysis can also help policymakers, governments, and companies gain a better understanding of the global P2P energy market. According to the PESTLE analysis, the challenges in developing P2P energy trading globally are divided into political, economic, social, technological, legal, and environmental aspects, none of which can be ignored.

Table 1. Summary of key challenges facing the P2P energy trading development and potential solutions.

Aspect	Challenge	Suggestions
Political	Climate change policies Renewable energy policies Shifts in the roles of actors Current energy system paradigm Data ownership and network security	Formulate experimental and provisional policies. Make sure that an energy regulatory sandbox is correctly built.
Economic	Initial investment cost Fairness in cost and profit distribution Stable economy Market reliability Energy poverty	Form an energy-sharing pricing model Study energy poverty in P2P energy Build a stable economic environment and a user-friendly renewable energy subsidy policy
Social	Demographics of the target society Trust, social acceptance and social barriers Introducing new concepts and technologies Existing disputes Co-existence of stakeholders Free-rider effect Tragedy of commons effect	Further research is required in suggested policies, governing laws, customer views, corporate interference and culture and organisation of electricity use. Design operation modes Manage trading platform Study stakeholder relationships Consultation with users and attempts to build local management. Increase awareness of 'commoning' practices.
Technological	Investment and maintenance Network security System behaviour prediction Degree of decentralisation Determination of appropriate types Network capacity, stability and reliability Blockchain challenges (scalability and privacy)	Virtual layer: study related mechanisms. Physical layer: study controlling strategy and consider power losses consider the energy consumption Blockchain: consider the desired transparency, scalability, decentralisation, security, and lack of gaming the systems.

Table 1. *Cont.*

Aspect	Challenge	Suggestions
Legal	Legislation uncertainty Legal framework Data privacy Systematic risk in smart contract	Promote legislative progress Regulations which allow smaller and local systems to work.
Environmental	Fossil-fuel based distributed generation systems Material intensity	Raise public awareness Conduct LCA assessment Enforce recyclability

In the political aspect, the main framing of P2P trading is climate change policies and renewable energy targets, together with potential changes in the balances of power and independence of local community energy and whether governments or other political actors are in favour of these or not. The main challenges are the established and 'hostile' regulations which were built to support old systems and old corporate powers. To gain a successful P2P energy system, we need to change these unclear and hostile renewable energy regulations and deal with shifting roles for actors and power relations, complex data ownership, and network security. To prevent tragedies of the commons, we need to ensure that P2P users have input into policy, regulation and participation in their own governance.

In the economic aspect, current challenges involve dealing with the instabilities of economic processes and investment, the massive investment required to begin the P2P process (with potentially low profits), fairness in cost and profit distribution, energy poverty, and market reliability.

In the social aspect, demographics, trust, social acceptance and social barriers, introducing new concepts and technologies, dealing with free-riding problems if they exist, and possible tragedy of the common effects –which again may stem from existing power relations. Pre-existing and new stakeholder conflict and building higher levels of trust in trading seem to be key challenges, as are expanding the groups of people who can or will participate and removing barriers to participation. To prevent these problems, policymakers should consider such solutions as smart incentives, as discussed in Section 3, consulting with communities and users, encouraging local management of the P2P system and awareness of common practices.

The challenges of technology are various, including investments and maintenance, network security, system behaviour prediction, degree of decentralisation, network capacity, stability and reliability, and blockchain-related challenges. Technologies may also set up barriers to participation by not being easy to use or geared at particular social learnings. Designers are advised to consider these challenges when technology development projects are defined in the P2P energy trading area.

From a legal aspect, legislative uncertainty and legal frameworks in the renewable energy section should be considered. This could lead to legislation to make events have more clarity and fewer unintended consequences. Policymakers should consider legal aspects before implementing P2P energy trading. For example, passing laws and designing clear legal procedures for smart contracts and collective presumptions are needed, with the understanding that unforeseen events are normal, and the legislation is likely to need change as more is learnt about the process. Policymakers should remember that current laws are likely to be organised to favour large commercial operators, and it may be necessary to facilitate local and small-scale P2P trading.

The two major challenges in the environmental realm are the possible inclusion of fossil-fuel based distributed generation systems, which could lead to increased pollution, along with added energy generation for the P2P platform and material intensity challenge as materials such as solar panels require recycling at their end of life to reduce pollution. Environmental challenges should be closely studied to consider the effect of P2P energy trading implementation on the long-term environmental goals of the region.

Some suggestions are also provided to address these challenges. From the political perspective, it is suggested that the government, with the participation of users, should formulate clear, extensively considered, stable, and effective policy directions and create suitable national policy frameworks in accordance with this new mode of operation of future energy markets. These regulations and legislation must be considered experimental and provisional so they can be easily changed when encountering or generating unexpected problems. Policymakers should make sure that an energy regulatory sandbox is correctly built. Suggestions for the economic aspect include forming an energy-sharing pricing model and studying energy poverty in P2P energy while building a stable economic environment and a user-friendly renewable energy subsidy policy. The government should also set short-term policy goals to face the potential crisis.

From the social perspective, further research is needed on suggested policies, governing laws, customer views, possible corporate interference, and to discover the culture and organisation of electricity use. Designing operation modes, managing trading platforms, and studying stakeholder relationships are also crucial. Challenges in technology are various. In the virtual layer, studying related mechanisms will be significant. In the physical layer, studying controlling strategy and considering power losses are two recommendations. We also need to consider the energy consumption of various trading systems themselves. Future research directions in blockchain should consider the desired transparency, scalability, decentralisation, security, and lack of gaming systems.

Studies in legal and environmental aspects have shown that it is necessary to promote legislative progress and raise public awareness about environmental protection, as well as the kinds of contracts and mutual obligations required. Life cycle assessment (LCA) is a quantitative and systematic approach to analyse the environmental effects associated with products and services across the entire lifecycle and may be useful in this context. Applying LCA to distributed generation and storage systems can provide valuable insights into the long-term efficiency of such systems while considering their end-of-life recycling as well [122]. Given the growing social and business interests, with many ongoing trials, this paper highlights the urgency of increased studies as well as agile planning and regulations.

For future studies in this area, we recommend a system thinking study on P2P energy trading. Different aspects of P2P energy trading have effects on each other. For example, a change in legal or economic area may lead to changes in the technology area that will have environmental results with some time lag. These results can change society's perspective toward P2P energy trading. Hence, it is necessary to study the effects of the PESTLE aspects upon each other to prevent any conflict or new challenges raised by the change in an aspect without considering that change's effect on other aspects.

Author Contributions: Conceptualization, Z.S. and K.K.; methodology, Z.S.; software, S.T.; validation, K.K., S.T., A.V. and J.P.M.; formal analysis, Z.S. and S.T.; writing—original draft preparation, Z.S. and S.T.; writing—review and editing, K.K., A.V. and J.P.M.; supervision, K.K; All authors have read and agreed to the published version of the manuscript.

Funding: The participation of Jonathan Marshall was funded by an Australian Research Council Future Fellowship FT160100301 'Society and climate change: A social analysis of disruptive technology'.

Data Availability Statement: No new data were created.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Buragohain, C.; Agrawal, D.; Suri, S. A game theoretic framework for incentives in P2P systems. In Proceedings of the Third International Conference on Peer-to-Peer Computing (P2P2003) 0121562, Linköping, Sweden, 1–3 September 2003; pp. 48–56. [CrossRef]
2. Chapelle, G.; Servigne, P. *Mutual Aid: The Other Law of the Jungle*; John Wiley & Sons: Hoboken, NJ, USA, 2021.
3. Raymond, E.S. *The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*; O'Reilly Media Inc: Sebastopol, CA, USA, 2001.
4. Washbourne, L. A survey of P2P network security. *arXiv* **2015**, arXiv:1504.01358.

5. Howe, A. *Napster and Gnutella: A Comparison of Two Popular Peer-to-Peer Protocols*; Universidade de Victoria: Victoria, BC, Canada, 2000. Available online: http://members.tripod.com/ahowe_ca/pdf/napstergnutella.pdf (accessed on 19 November 2022).
6. Strahilevitz, L.J. Charismatic code, social norms, and the emergence of cooperation on the file-swapping networks. *Va. Law Rev.* **2003**, *89*, 505–596. [CrossRef]
7. Palomar, E.; Estevez-Tapiador, J.M.; Hernandez-Castro, J.C.; Ribagorda, A. Security in P2P networks: Survey and research directions. In *Emerging Directions in Embedded and Ubiquitous Computing*; LNCS; Springer: Berlin/Heidelberg, Germany, 2006; Volume 4097, pp. 183–192. [CrossRef]
8. Kellerer, W.; Kunzmann, G.; Schollmeier, R.; Zöls, S. Structured peer-to-peer systems for telecommunications and mobile environments. *AEU-Int. J. Electron. Commun.* **2006**, *60*, 25–29. [CrossRef]
9. Abdella, J.; Shuaib, K. Peer to peer distributed energy trading in smart grids: A survey. *Energies* **2018**, *11*, 1560. [CrossRef]
10. Moenninghoff, S.C.; Wieandt, A. The Future of Peer-to-Peer Finance. *Schmalenbachs Z. Für Betriebswirtschaftliche Forsch.* **2013**, *65*, 466–488. [CrossRef]
11. Golle, P.; Leyton-Brown, K.; Mironov, I.; Lillibridge, M. Incentives for sharing in peer-to-peer networks. In Proceedings of the 3rd ACM Conference on Electronic Commerce, Tampa, FL, USA, 14–17 October 2001; Volume 2232, pp. 75–87. [CrossRef]
12. Marshall, J.P.; Rimini, F. Paradoxes of Property: Piracy and Sharing in Information Capitalism The Incoherence of Property. In *A Reader on International Media Piracy*; Amsterdam University Press: Amsterdam, The Netherlands, 2015; pp. 1–27.
13. Asvanund, A.; Clay, K.; Krishnan, R.; Smith, M.D. An empirical analysis of network externalities in peer-to-peer music-sharing networks. *Inf. Syst. Res.* **2004**, *15*, 155–174. [CrossRef]
14. Perera, R. *The PESTLE Analysis*; Nerdynaut: Avissawella, Sri Lanka, 2017.
15. Azad, A.K.; Khan, M.M.K.; Ahasan, T.; Ahmed, S.F. Energy Scenario: Production, Consumption and Prospect of Renewable Energy in Australia. *J. Power Energy Eng.* **2014**, *2*, 19–25. [CrossRef]
16. Bilan, Y.; Rabe, M.; Widera, K. Distributed Energy Resources: Operational Benefits. *Energies* **2022**, *15*, 8864. [CrossRef]
17. Schwartz, L.; Wei, M.; Morrow, W.; Deason, J.; Schiller, S.R.; Leventis, G.; Smith, S.; Leow, W.L.; Levin, T.; Plotkin, S.; et al. *Electricity End Uses, Energy Efficiency, and Distributed Energy Resources Baseline*; Lawrence Berkeley National Laboratory: Berkeley, CA, USA, 2017; Volume 77.
18. Muqeet, H.A.; Ahmad, A.; Sajjad, I.A.; Liaqat, R.; Raza, A.; Iqbal, M.M. Benefits of Distributed Energy and Storage System in Prosumer Based Electricity Market. In Proceedings of the IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Genova, Italy, 11–14 June 2019; pp. 3–8. [CrossRef]
19. Qi, M.; Yang, H.; Wang, D.; Luo, Y.; Zhang, S.; Liao, S. Prosumers Peer-to-Peer Transaction Decision Considering Network Constraints. In Proceedings of the 2019 IEEE 3rd Conference on Energy Internet and Energy System Integration (EI2), Changsha, China, 8–10 November 2019; pp. 643–647. [CrossRef]
20. AGL Energy Limited. annual report 2020. 2020. Available online: https://www.agl.com.au/content/dam/digital/agl/documents/about-agl/investors/2020/2097212_annualreport.pdf (accessed on 28 November 2022).
21. ARENA. AGL Virtual Power Plant—Australian Renewable Energy Agency (ARENA). Available online: https://arena.gov.au/projects/agl-virtual-power-plant/ (accessed on 28 November 2022).
22. Khalilpour, K.R.; Vassallo, A. *Cooperative Community Energy Networks BT—Community Energy Networks with Storage: Modeling Frameworks for Distributed Generation*; Khalilpour, K.R., Vassallo, A., Eds.; Springer: Singapore, 2016; pp. 151–182. [CrossRef]
23. Tuch, D.; Weier, B.; John, S. Apparatus and Method for Trading Electric Energy. U.S. Patent 6115698A, 5 September 2000. Available online: https://patents.google.com/patent/US6115698A/en (accessed on 28 November 2022).
24. Tushar, W.; Chai, B.; Yuen, C.; Smith, D.B.; Wood, K.L.; Yang, Z.; Poor, H.V. Three-Party Energy Management with Distributed Energy Resources in Smart Grid. *IEEE Trans. Ind. Electron.* **2015**, *62*, 2487–2498. [CrossRef]
25. Soto, E.A.; Bosman, L.B.; Wollega, E.; Leon-salas, W.D. Peer-to-peer energy trading: A review of the literature. *Appl. Energy* **2021**, *283*, 116268. [CrossRef]
26. Zhou, Y.; Wu, J.; Song, G.; Long, C. Framework design and optimal bidding strategy for ancillary service provision from a peer-to-peer energy trading community. *Appl. Energy* **2020**, *278*, 115671. [CrossRef]
27. Australian Renewable Energy Agency. Peer-to-Peer Distributed Ledger Technology Assessment. In *Virtual Peer-to-Peer Energy Trading Using Distributed Ledger Technology: Comprehensive Project Assessment Report*; Australian Renewable Energy Agency: Sydney, Australia, 2017.
28. Klein, L.P.; Krivoglazova, A.; Matos, L.; Landeck, J.; De Azevedo, M. A novel peer-to-peer energy sharing business model for the Portuguese energy market. *Energies* **2019**, *13*, 125. [CrossRef]
29. Azim, M.I.; Pourmousavi, S.A.; Tushar, W.; Saha, T.K. Feasibility Study of Financial P2P Energy Trading in a Grid-tied Power Network. In Proceedings of the 2019 IEEE Power & Energy Society General Meeting (PESGM), Atlanta, GA, USA, 4–8 August 2019; Volume 2019, pp. 1157–1161. [CrossRef]
30. Tushar, W.; Saha, T.K.; Yuen, C.; Smith, D.; Poor, H.V. Peer-to-Peer Trading in Electricity Networks: An Overview. *IEEE Trans. Smart Grid* **2020**, *11*, 3185–3200. [CrossRef]
31. Tushar, W.; Yuen, C.; Saha, T.K.; Morstyn, T.; Chapman, A.C.; Jan, E.; Alam, M.; Hanif, S.; Poor, H.V. Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges. *Appl. Energy* **2021**, *282*, 116131. [CrossRef]

32. Wörner, A.; Ableitner, L.; Meeuw, A.; Wortmann, F.; Tiefenbeck, V. Peer-to-peer energy trading in the real world: Market design and evaluation of the user value proposition. In Proceedings of the 40th International Conference on Information Systems (ICIS 2019), Munich, Germany, 15–18 December 2019.
33. Han, D.; Zhang, C.; Ping, J.; Yan, Z. Smart contract architecture for decentralized energy trading and management based on blockchains. *Energy* **2020**, *199*, 117417. [CrossRef]
34. Muhsen, H.; Allahham, A.; Al-halhouli, A.; Al-mahmodi, M. Business Model of Peer-to-Peer Energy Trading: A Review of Literature. *Sustainability* **2022**, *14*, 1616. [CrossRef]
35. Lee, J.T.; Henriquez-Auba, R.; Poolla, B.K.; Callaway, D.S. Pricing and Energy Trading in Peer-to-Peer Zero Marginal-Cost Microgrids. *IEEE Trans. Smart Grid* **2022**, *13*, 702–714. [CrossRef]
36. Akter, M.N.; Mahmud, M.A.; Oo, A.M.T. A hierarchical transactive energy management system for energy sharing in residential microgrids. *Energies* **2017**, *10*, 2098. [CrossRef]
37. Azim, M.I.; Tushar, W.; Saha, T.K. Investigating the impact of P2P trading on power losses in grid-connected networks with prosumers. *Appl. Energy* **2020**, *263*, 114687. [CrossRef]
38. Lovins, A.B. Saving Gigabucks with Negawatts. 1985. Available online: https://www.osti.gov/biblio/5787710 (accessed on 29 November 2022).
39. Mengelkamp, E.; Gärttner, J.; Rock, K.; Kessler, S.; Orsini, L. Designing microgrid energy markets A case study: The Brooklyn Microgrid. *Appl. Energy* **2018**, *210*, 870–880. [CrossRef]
40. The Australian Renewable Energy Agency. *Latrobe Valley Microgrid Feasibility Assessment*; Australian Renewable Energy Agency: Sydney, Australia, 2021.
41. Sonnen. SonnenCommunity | Sonnen. Available online: https://sonnen.de/sonnencommunity/ (accessed on 28 November 2022).
42. Vandebron. Available online: https://vandebron.nl/ (accessed on 28 November 2022).
43. Piclo. Available online: https://www.piclo.energy/ (accessed on 28 November 2022).
44. Elsevier. Scopus. Available online: https://www.scopus.com/ (accessed on 20 December 2022).
45. Engerati. Centrica Trials Blockchain in Cornwall Local Energy Market. 2018. Available online: https://www.engerati.com/energy-retail/centrica-trials-blockchain-in-cornwall-local-energy-market/ (accessed on 28 November 2022).
46. Gunarathna, C.L.; Yang, R.J.; Jayasuriya, S.; Wang, K. Reviewing global peer-to-peer distributed renewable energy trading projects. *Energy Res. Soc. Sci.* **2022**, *89*, 102655. [CrossRef]
47. Park, C.; Yong, T. Comparative review and discussion on P2P electricity trading. *Energy Proc.* **2017**, *128*, 3–9. [CrossRef]
48. Power Ledger. Available online: https://www.powerledger.io/ (accessed on 28 November 2022).
49. Junlakarn, S.; Kokchang, P.; Audomvongseree, K. Drivers and Challenges of Peer-to-Peer Energy Trading Development in Thailand. *Energies* **2022**, *15*, 1229. [CrossRef]
50. Javed, H.; Irfan, M.; Shehzad, M.; Muqeet, H.A.; Akhter, J.; Dagar, V.; Guerrero, J.M. Recent Trends, Challenges, and Future Aspects of P2P Energy Trading Platforms in Electrical-Based Networks Considering Blockchain Technology: A Roadmap Toward Environmental Sustainability. *Front. Energy Res.* **2022**, *10*, 134. [CrossRef]
51. Simões, E.N. Competitive Intelligence Algorithm for PESTLE Analysis: A Decision Support System Application Module. Ph.D. Thesis, Universidade Nova de Lisboa, Lisbon, Portugal, 2019; p. 69. Available online: https://run.unl.pt/bitstream/10362/94985/1/TGI0290.pdf (accessed on 27 November 2022).
52. Agyekum, E.B.; Amjad, F.; Mohsin, M.; Ansah, M.N.S. A bird's eye view of Ghana's renewable energy sector environment: A Multi-Criteria Decision-Making approach. *Util. Policy* **2021**, *70*, 101219. [CrossRef]
53. Thomas, P.J.M.; Sandwell, P.; Williamson, S.J.; Harper, P.W. A PESTLE analysis of solar home systems in refugee camps in Rwanda. *Renew. Sustain. Energy Rev.* **2021**, *143*, 110872. [CrossRef]
54. Zalengera, C.; Blanchard, R.E.; Eames, P.C.; Juma, A.M.; Chitawo, M.L.; Gondwe, K.T. Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy. *Renew. Sustain. Energy Rev.* **2014**, *38*, 335–347. [CrossRef]
55. Baldwin, E.; Carley, S.; Nicholson-Crotty, S. Why do countries emulate each others' policies? A global study of renewable energy policy diffusion. *World Dev.* **2019**, *120*, 29–45. [CrossRef]
56. Renewable Energy Target. Available online: https://www.cleanenergycouncil.org.au/advocacy-initiatives/renewable-energy-target (accessed on 28 November 2021).
57. Clean Power Plan. Available online: https://archive.epa.gov/epa/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.html (accessed on 28 November 2021).
58. Zhou, Y.; Wu, J.; Long, C.; Ming, W. State-of-the-Art Analysis and Perspectives for Peer-to-Peer Energy Trading. *Engineering* **2020**, *6*, 739–753. [CrossRef]
59. Diestelmeier, L. Changing power: Shifting the role of electricity consumers with blockchain technology—Policy implications for EU electricity law. *Energy Policy* **2019**, *128*, 189–196. [CrossRef]
60. Wang, Y.; Tian, L.; Xia, J.; Zhang, W.; Zhang, K. Economic assessment of the peer-to-peer trading policy of distributed PV electricity: A case study in China. *Sustainability* **2020**, *12*, 5235. [CrossRef]
61. Zhu, S.; Song, M.; Lim, M.K.; Wang, J.; Zhao, J. The development of energy blockchain and its implications for China's energy sector. *Resour. Policy* **2020**, *66*, 101595. [CrossRef]
62. Mohsenian-rad, H.; Saha, T.; Poor, H.V.; Wood, K.L. Networks via Peer-to-Peer. *IEEE Signal Process. Mag.* **2018**, *35*, 90–111.

63. de Almeida, L.; Klausmann, N.; van Soest, H.; Cappelli, V. Peer-to-Peer Trading and Energy Community in the Electricity Market—Analysing the Literature on Law and Regulation and Looking Ahead to Future Challenges. Robert Schuman Centre for Advanced Studies Research Paper No. RSCAS, 35. *SSRN Electron. J.* **2021**. [CrossRef]
64. Heng, Y.B.; Ramachandaramurthy, V.K.; Verayiah, R.; Walker, S.L. Developing Peer-to-Peer (P2P) Energy Trading Model for Malaysia: A Review and Proposed Implementation. *IEEE Access* **2022**, *10*, 33183–33199. [CrossRef]
65. Schneiders, A.; Fell, M.J.; Nolden, C. Peer-to-peer electricity trading and the sharing economy: Social, markets and regulatory perspectives. *Energy Sources Part B Econ. Plan. Policy* **2022**, *17*, 2050849. [CrossRef]
66. Judge, M.A.; Khan, A.; Manzoor, A.; Khattak, H.A. Overview of smart grid implementation: Frameworks, impact, performance and challenges. *J. Energy Storage* **2022**, *49*, 104056. [CrossRef]
67. Ahl, A.; Yarime, M.; Tanaka, K.; Sagawa, D. Review of blockchain-based distributed energy: Implications for institutional development. *Renew. Sustain. Energy Rev.* **2019**, *107*, 200–211. [CrossRef]
68. Elams, M. "Sun Tax": Outcry over Plans to Charge Families for Feeding Their Excess Solar Power into the Grid. Australia. 2023. Available online: https://thenewdaily.com.au/finance/finance-news/2023/02/24/sun-tax-solar/ (accessed on 4 March 2023).
69. Langdon, R.J.; Yousefi, P.D.; Relton, C.L.; Suderman, M.J. Empowering Local Electricity Markets: A survey study from Switzerland, Norway, Spain and Germany. *Clin. Epigenetics* **2017**. [CrossRef]
70. Ableitner, L.; Tiefenbeck, V.; Meeuw, A.; Wörner, A.; Fleisch, E.; Wortmann, F. User behavior in a real-world peer-to-peer electricity market. *Appl. Energy* **2020**, *270*, 115061. [CrossRef]
71. Sousa, T.; Soares, T.; Pinson, P.; Moret, F.; Baroche, T.; Sorin, E. Peer-to-peer and community-based markets: A comprehensive review. *Renew. Sustain. Energy Rev.* **2019**, *104*, 367–378. [CrossRef]
72. Wu, W.; Quezada, G.; Schleiger, E.; Bratanova, A.; Graham, P.; Spak, B. *The Future of Peer To Peer Trading of Distributed*; CSIRO: Brisbane, Australia, 2019.
73. Hoang, A.T.; Nižetić, S.; Olcer, A.I.; Ong, H.C.; Chen, W.-H.; Chong, C.T.; Thomas, S.; Bandh, S.A.; Nguyen, X.P. Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications. *Energy Policy* **2021**, *154*, 112322. [CrossRef] [PubMed]
74. IEA Coal 2022. 2022. Available online: https://www.iea.org/reports/coal-2022 (accessed on 7 January 2023).
75. Mujeeb, A.; Hong, X.; Wang, P. Analysis of Peer-to-Peer (P2P) Electricity Market and Piclo's Local Matching Trading Platform in UK. In Proceedings of the 2019 IEEE 3rd Conference on Energy Internet and Energy System Integration (EI2), Changsha, China, 8–10 November 2019; pp. 619–624. [CrossRef]
76. Khan, I. Drivers, enablers, and barriers to prosumerism in Bangladesh: A sustainable solution to energy poverty? *Energy Res. Soc. Sci.* **2019**, *55*, 82–92. [CrossRef]
77. Spiliopoulos, N.; Sarantakos, I.; Nikkhah, S.; Gkizas, G.; Giaouris, D.; Taylor, P.; Rajarathnam, U.; Wade, N. Peer-to-peer energy trading for improving economic and resilient operation of microgrids. *Renew. Energy* **2022**, *199*, 517–535. [CrossRef]
78. Albayati, H.; Kim, S.K.; Rho, J.J. Accepting financial transactions using blockchain technology and cryptocurrency: A customer perspective approach. *Technol. Soc.* **2020**, *62*, 101320. [CrossRef]
79. Borges, C.E.; Kapassa, E.; Touloupou, M.; Macón, J.L.; Casado-Mansilla, D. Blockchain application in P2P energy markets: Social and legal aspects. *Conn. Sci.* **2022**, *34*, 1066–1088. [CrossRef]
80. Mey, F.; Diesendorf, M.; MacGill, I. Can local government play a greater role for community renewable energy? A case study from Australia. *Energy Res. Soc. Sci.* **2016**, *21*, 33–43. [CrossRef]
81. Ecker, F.; Spada, H.; Hahnel, U.J.J. Independence without control: Autarky outperforms autonomy benefits in the adoption of private energy storage systems. *Energy Policy* **2018**, *122*, 214–228. [CrossRef]
82. Feldman, M.; Lai, K.; Stoica, I.; Chuang, J. Robust incentive techniques for peer-to-peer networks. In Proceedings of the 5th ACM Conference on Electronic Commerce, New York, NY, USA, 17–20 May 2004; Volume 5, pp. 102–111. [CrossRef]
83. Kang, J.; Yu, R.; Huang, X.; Maharjan, S.; Zhang, Y.; Hossain, E. Enabling Localized Peer-to-Peer Electricity Trading among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains. *IEEE Trans. Ind. Informatics* **2017**, *13*, 3154–3164. [CrossRef]
84. Shneidman, J.; Parkes, D.C. Rationality and self-interest in peer to peer networks. In Proceedings of the Second International Workshop, IPTPS 2003, Berkeley, CA, USA, 21–22 February 2003; Volume 2735, pp. 139–148. [CrossRef]
85. Ma, R.T.B.; Lee, S.C.M.; Lui, J.C.S.; Yau, D.K.Y. A game theoretic approach to provide incentive and service differentiation in P2P networks. *Perform. Eval. Rev.* **2004**, *32*, 189–198. [CrossRef]
86. Trabish, H.K. NV Energy CEO: Solar Has Gotten a "Free Ride" on the Grid. 2013. Available online: https://www.greentechmedia.com/articles/read/a-conversation-with-edison-electric-institute-chair-michael-yackira (accessed on 17 January 2023).
87. Vandebron to Charge Customers Fees for Surplus Solar Power. Dutch News, 2023. Available online: https://www.dutchnews.nl/2023/08/vandebron-to-charge-customers-fees-for-surplus-solar-power/ (accessed on 10 October 2023).
88. Kla, A.B. Regulating the energy "free riders". *Bost. Univ. Law Rev.* **2020**, *100*, 581–649.
89. Greco, G.M.; Floridi, L. The tragedy of the digital commons. *Ethics Inf. Technol.* **2004**, *6*, 73–81. [CrossRef]
90. Wang, G.; Chao, Y.; Cao, Y.; Jiang, T.; Han, W.; Chen, Z. A comprehensive review of research works based on evolutionary game theory for sustainable energy development. *Energy Rep.* **2022**, *8*, 114–136. [CrossRef]
91. Lloyd, W.F. *Two Lectures on the Checks to Population: Delivered Before the University of Oxford, in Michaelmas Term 1832*; S. Collingewood: Collingwood, Australia, 1833. Available online: https://books.google.com.au/books?id=kQt9Kg-chXAC (accessed on 7 January 2023).

92. PeerApp. PeerApp White Paper Comparing P2P Solutions. March 2007. Available online: https://www.tlm.unavarra.es/pluginfile.php/24844/mod_assign/intro/A03-Comparing%20P2P%20Solutions.pdf (accessed on 10 December 2022).
93. Tang, Y.B.; Wang, H.M.; Dou, W. Trust based incentive in P2P network. In Proceedings of the IEEE International Conference on E-Commerce Technology for Dynamic E-Business, Beijing, China, 13–15 September 2004; pp. 302–305. [CrossRef]
94. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*; Cambridge University Press: Cambridge, UK, 1990. [CrossRef]
95. Hardin, G. Extensions of "the tragedy of the commons". *Science* **1998**, *280*, 682–683. [CrossRef]
96. Anderson, W.L. Boom Bust. Foundation for Economic Education. 1983. Available online: https://fee.org/articles/boom-bust/ (accessed on 7 January 2023).
97. Parag, Y.; Sovacool, B.K. Electricity market design for the prosumer era. *Nat. Energy* **2016**, *1*, 16032. [CrossRef]
98. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [CrossRef]
99. Zia, M.F.; Benbouzid, M.; Elbouchikhi, E.; Muyeen, S.M.; Techato, K.; Guerrero, J.M. Microgrid Transactive Energy: Review, Architectures, Distributed Ledger Technologies, and Market Analysis. *IEEE Access* **2020**, *8*, 19410–19432. [CrossRef]
100. Wang, H.; Zheng, Z.; Xie, S.; Dai, H.N.; Chen, X. Blockchain challenges and opportunities: A survey. *Int. J. Web Grid Serv.* **2018**, *14*, 352. [CrossRef]
101. Kirli, D.; Couraud, B.; Robu, V.; Salgado-Bravo, M.; Norbu, S.; Andoni, M.; Antonopoulos, I.; Negrete-Pincetic, M.; Flynn, D.; Kiprakis, A. Smart contracts in energy systems: A systematic review of fundamental approaches and implementations. *Renew. Sustain. Energy Rev.* **2022**, *158*, 112013. [CrossRef]
102. Inês, C.; Guilherme, P.L.; Esther, M.G.; Swantje, G.; Stephen, H.; Lars, H. Regulatory challenges and opportunities for collective renewable energy prosumers in the EU. *Energy Policy* **2020**, *138*, 111212. [CrossRef]
103. Campodónico, H.; Carrera, C. Energy transition and renewable energies: Challenges for Peru. *Energy Policy* **2022**, *171*, 113261. [CrossRef]
104. Schneiders, A.; Shipworth, D. Community energy groups: Can they shield consumers from the risks of using blockchain for peer-to-peer energy trading? *Energies* **2021**, *14*, 3569. [CrossRef]
105. Chiarini, A.; Compagnucci, L. Blockchain, Data Protection and P2P Energy Trading: A Review on Legal and Economic Challenges. *Sustainability* **2022**, *14*, 16305. [CrossRef]
106. Kitagawa, K.; Johnson-laird, A.; Loren, L.P.; Miller, J.S. *Intellectual Property Law: Cases & Materials*; Semaphore Press: Oregon City, OR, USA, 2012; Volume 1, pp. 1–10.
107. Coutinho, K.; Wongthongtham, P.; Abu-Salih, B.; Saleh, M.A.A.; Khairwal, N.K. Carbon emission and cost of blockchain mining in a case of peer-to-peer energy trading. *Front. Built Environ.* **2022**, *8*, 945944. [CrossRef]
108. Mahmoudi, S.; Huda, N.; Behnia, M. Photovoltaic waste assessment: Forecasting and screening of emerging waste in Australia. *Resour. Conserv. Recycl.* **2019**, *146*, 192–205. [CrossRef]
109. Hu, J.; Wu, Q.; Zhou, B. TTEM: An effective trust-based topology evolution mechanism for P2P networks. *J. Commun.* **2008**, *3*, 3–10. [CrossRef]
110. Kim, O.T.T.; Le, T.H.T.; Shin, M.J.; Nguyen, V.; Han, Z.; Hong, C.S. Distributed Auction-Based Incentive Mechanism for Energy Trading between Electric Vehicles and Mobile Charging Stations. *IEEE Access* **2022**, *10*, 56331–56347. [CrossRef]
111. Chen, S.; Shen, Z.; Zhang, L.; Yan, Z.; Li, C.; Zhang, N.; Wu, J. A trusted energy trading framework by marrying blockchain and optimization. *Adv. Appl. Energy* **2021**, *2*, 100029. [CrossRef]
112. Yahaya, A.S.; Javaid, N.; Almogren, A.; Ahmed, A.; Gulfam, S.M.; Radwan, A. A Two-Stage Privacy Preservation and Secure Peer-to-Peer Energy Trading Model Using Blockchain and Cloud-Based Aggregator. *IEEE Access* **2021**, *9*, 143121–143137. [CrossRef]
113. Ji, G.; Yao, Z.; Zhang, B.; Li, C. A Reverse Auction-Based Incentive Mechanism for Mobile Crowdsensing. *IEEE Internet Things J.* **2020**, *7*, 8238–8248. [CrossRef]
114. Huang, J.; Han, Z.; Chiang, M.; Poor, H.V. Auction-based resource allocation for cooperative communications. *IEEE J. Sel. Areas Commun.* **2008**, *26*, 1226–1237. [CrossRef]
115. Thakur, S.; Hayes, B.P.; Breslin, J.G. Distributed double auction for peer to peer energy trade using blockchains. In Proceedings of the 2018 5th International Symposium on Environment-Friendly Energies and Applications (EFEA), Rome, Italy, 24–26 September 2018. [CrossRef]
116. Gupta, R.; Gupta, J. Future generation communications with game strategies: A comprehensive survey. *Comput. Commun.* **2022**, *192*, 1–32. [CrossRef]
117. Liu, Z.; Zhang, X.; Lieu, J. Design of the incentive mechanism in electricity auction market based on the signaling game theory. *Energy* **2010**, *35*, 1813–1819. [CrossRef]
118. Chen, Y.; Li, Y.; Chen, Q.; Wang, X.; Li, T.; Tan, C. Energy trading scheme based on consortium blockchain and game theory. *Comput. Stand. Interfaces* **2023**, *84*, 103699. [CrossRef]
119. Long, C.; Zhou, Y.; Wu, J. A game theoretic approach for peer to peer energy trading. *Energy Proc.* **2019**, *159*, 454–459. [CrossRef]
120. Wang, Y.; Cao, Y.; Li, Y.; Jiang, L.; Long, Y.; Deng, Y.; Zhou, Y.; Nakanishi, Y. Modelling and analysis of a two-level incentive mechanism based peer-to-peer energy sharing community. *Int. J. Electr. Power Energy Syst.* **2021**, *133*, 107202. [CrossRef]

121. Wang, J.; Zhong, H.; Qin, J.; Tang, W.; Rajagopal, R.; Xia, Q.; Kang, C. Incentive mechanism for sharing distributed energy resources. *J. Mod. Power Syst. Clean Energy* **2019**, *7*, 837–850. [CrossRef]
122. Gandiglio, M.; Marocco, P.; Bianco, I.; Lovera, D.; Blengini, G.A.; Santarelli, M. Life cycle assessment of a renewable energy system with hydrogen-battery storage for a remote off-grid community. *Int. J. Hydrogen Energy* **2022**, *47*, 32822–32834. [CrossRef]